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1 Scope

1.1 Objective

The NTI AG / LinMot drives are designed to control linear and rotary motors. The drives are components that are built into electrical plants or machines and can only be operated as integral components of these plants or machines.

The existing drive series C1250 are completed by the series C1251-2S, which support functional safety features together with the appropriate 2S safety motors (based on 2S stators and 2S sliders).

1.2 Purpose of Document

The purpose of this document is to provide the necessary information about the safety products (drive series C1251-2S with the appropriate safety motors) for a safe and conformal use of them.

1.3 Applicable Documents

The listed documents provided input to this document. Other documents are not listed here. When referenced to this table, the text in the column Ref is used, e.g. /SMRS/ or /ISO13849-1/.

Ref	Doc-Identification	Document Title	Version/Release
/SMRS/	SMRS	SMRS, Safety Manual Requirement Specification	1.1
/IEC61508-2/	EN IEC 61508-2	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems	Ed. 2.0, April 2010
/IEC61508-3/	EN IEC 61508-3	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 3: Software requirements	Ed. 2.0, April 2010
/ISO13849-1/	EN ISO 13849-1:2015	Sicherheit von Maschinen - Sicherheitsbezogene Teile von Steuerungen - Teil 1: Allgemeine Gestaltungsleitsätze	June 2015

Table 1: Applicable Documents

1.4 Referenced Documents

These documents may contain further details of this document (information, which is outsourced from this document).

Ref	Doc-Identification	Document Title	Version
/MA_PROFIdrive/	PROFIdrive Manual	0185-1154-E_1V0_MA_PROFIdriveMI.pdf	1V0 or newer
/LinMotTalk/	LinMot-Talk Manual	0185-1059-E_6V17_MA_LinMotTalk.pdf	6V17 or newer
/MA_FSoE/	FSoE Manual	0185-1178-E_1V0_MA_EtherCAT-CiA402-MI.pdf	1V0 or newer

Table 2: Referenced Documents

2 Introduction / Preface

2.1 Legal Notices

2.1.1 Warning Concept

This manual contains notices you have to observe to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

 DANGER	**DANGER** indicates that death or severe personal injury will result if proper precautions are not taken.

 WARNING	**WARNING** indicates that death or severe personal injury may result if proper precautions are not taken.

 CAUTION	**CAUTION** indicates that minor personal injury can result if proper precautions are not taken.

 NOTICE	**NOTICE** indicates that property damage can result if proper precautions are not taken

If more than one degree of danger is present, the warning notice representing the highest degree of danger will be used.

2.1.2 Proper Use of LinMot Products

 CAUTION	**Use of LinMot-Products** LinMot products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by LinMot. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be complied with. The information in the relevant documentation must be observed.

2.1.3 Read the Documentation


CAUTION

Read the Documentation
Read the available documentation before installation and commissioning. Improper handling of the servo motor and linear actuator can cause harm to people or damage to property. The operator must therefore ensure that all persons entrusted to work on the actuator have read and understood the manual and that the safety notices in this safety guide are observed.

2.1.4 Qualified Personnel

The 2S safety system described in this documentation may be operated only by personnel qualified for the specific task (such as storage & transport, commissioning, operation, maintenance, repair, modification, decommissioning or disposal), in accordance with the relevant documentation, its warning notices and safety instructions.
Qualified personnel are those who, based on their training and experience, can identify risks and prevent potential hazards when working with these products/systems.

2.1.5 Intended Use

The products and equipment are designed and intended for specific purpose as described. Each product may only be used with equipment and under operating conditions described in relevant documentation. Users must be qualified to handle the devices and be aware of the hazards potentially associated with the process. Some processes may require the workplace be equipped with additional safety features (such as protective clothing, eyeglasses and gloves) or that precautions be otherwise taken to protect personnel and working environment. Generally, all country and industry-specific statutory or otherwise mandatory laws and regulations apply. Safety and warning instructions given in this document only apply to the product or equipment or devices and supplement the rules and regulations the operator stipulates at the workplace for the respective process. The user is solely responsible for applications, which go beyond the intended use described here and for each individual product or equipment or device, which are not described in instructions sets. Company does not accept any liability beyond the intended usage.
Furthermore, individual restrictions and product or equipment or device specifications in the offer description from the manufacturer also found in the delivery contract and such warranty terms also apply. Intended use also means that all specifications in these instructions must be followed. Any use beyond the intended use is considered to be misuse.

2.1.6 Prohibited Use

Commissioning the motor is prohibited if the machine, in which it was installed,

- does not meet the requirements of the EC Machinery Directive,
- does not comply with the EMC Directive,
- does not comply with the Low Voltage Directive.

2.1.7 Brands

All names identified by ® are registered trademarks of LinMot / NTI AG. The remaining trademarks in this publication may be trademarks whose use by third parties for their own purposes could violate the rights of the owner.

2.1.8 Non-Safety function

The non-safety functions are described in the LinMot-Talk manual and in the online manuals under https://linmot.com/download/.

2.1.9 Disclaimer

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

2.2 Preface

2.2.1 Technical Support Contacts

NTI AG – LinMot & MagSpring	
Bodenaeckerstrasse 2	
CH-8957 Spreitenbach	
Switzerland	
Technical Support:	+41 56 544 71 00
Email:	support@linmot.com
Support website	https://www.linmot.com/support

2.2.2 Target group

This documentation is intended for machine manufacturers, commissioning engineers, and service personnel who use the LinMot drive system.

2.2.3 Benefits

This manual provides all the information, procedures and operator actions required for the particular life cycles.

2.2.4 Standard scope

For reasons of clarity, this documentation does not contain all the detailed information on all the products and cannot take into consideration every conceivable setup.

3 Standards and Regulations

3.1 Aims

Manufacturers and operating companies of equipment, machines, and products are responsible for ensuring the required level of safety. This means that plants, machines, and other equipment must be designed to be as safe as possible in accordance with the current state of the art. For this purpose, companies describe in the various standards the current state of the art covering all aspects relevant to safety. If it can be justifiably assumed that all of the relevant standards are complied with, this ensures that state-of-the-art technology has been utilized and, in turn, a plant builder or a manufacturer of a machine or a piece of equipment has fulfilled his appropriate responsibility.

Safety systems are designed to minimize potential hazards for both people and the environment by means of suitable technical equipment, without restricting industrial production and the use of machines more than is necessary. The protection of man and environment must be assigned equal importance in all countries based on internationally harmonized rules and regulations. This is also intended to avoid competitive advantages or disadvantages due to different safety requirements in different countries.

There are different concepts and requirements in the various regions and countries of the world when it comes to ensuring the appropriate degree of safety. The legislation and the requirements of how and when proof is to be given and whether there is an adequate level of safety are just as different as the assignment of responsibilities.

The most important thing for manufacturers of machines and companies that set up plants and systems is that the legislation and regulations in the country where the machine or plant is being operated apply. For example, the control system for a machine that is to be used in the US must fulfill local US requirements even if the machine manufacturer (OEM) is based in the European Economic Area (EEA).

3.2 Functional Safety

Safety, from the perspective of the object to be protected, cannot be split-up. The causes of hazards and, in turn, the technical measures to avoid them can vary significantly. Therefore, a differentiation is made between different types of safety (e.g. by specifying the cause of possible hazards). "Functional safety" is involved if safety depends on the correct function.

To ensure the functional safety of a machine or plant, the safety-related parts of the protection and control devices must function correctly. In addition, the systems must behave in such a way that either the plant remains in a safe state or it is brought into a safe state if a fault occurs. In this case, it is necessary to use specially qualified technology that fulfills the requirements described in the associated standards. The requirements to implement functional safety are based on the following basic goals:

- Avoiding systematic faults
- Controlling random faults or failures

Benchmarks for establishing whether a sufficient level of functional safety has been achieved include the probability of hazardous failures, the fault tolerance, and the quality that is to be ensured by avoiding systematic faults. This is expressed in the standards using specific classification. In IEC/EN 61508, IEC/EN 62061 "Safety Integrity Level" (SIL) and /ISO13849-1/ "Category" and "Performance Level" (PL).

3.3 Considered Standards

The following standards and regulations have to be considered:

- EN ISO 3849-1-2: 2008, Safety of machinery - Safety-related parts of control systems - Part 2: Validation
- EN IEC 61508: 2010, parts 1 to 7, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
- EN 61800-5-2:2007, Adjustable speed electrical power drive systems - Part 5-2: Safety requirements - Functional
- PROFIsafe-Profile 3192 V261 Aug14
- PROFIsafe: Amend-Pdrive-on-Psafe 3272 V310 Feb19
- FSoE: ETG.5100 S V1.2.0 / Safety over EtherCAT Protocol specification, 11.03.2011 / V1.2.0
- FSoE: ETG.5120 / Safety over EtherCAT Protocoll Enhancements, 13.07.2020 / V1.3.0
- FSoE: ETG.6100 / Safety over EtherCAT Safety Drive Profile, 13.07.2020 / V1.3.0

3.4 Country specific Regulations

Additional to the regulations listed above to comply with, additional country specific regulations can be relevant. It is necessary to check for the specific application and place of action, which local regulations have to be fulfilled.

4 Fundamental Safety Instructions

4.1 General Safety Instructions

 DANGER	**Danger to life if the safety instructions and residual risks are not observed** If the safety instructions and residual risks in the associated documentation are not observed, accidents involving severe injuries or death can occur. • Observe the safety instructions given in the documentation. Consider the residual risks for the risk evaluation.

 WARNING	**Malfunctions of the machine because of incorrect or changed parameter settings** because of incorrect or changed parameterization, machines can malfunction, which in turn can lead to injuries or death. • Protect the parameterization (parameter assignments) against unauthorized access. • Handle possible malfunctions by taking suitable measures, e.g. emergency stop or emergency off

4.2 Liability

NTI AG (as manufacturer of LinMot linear motors and MagSpring products) excludes all liability for damages and expenses caused by incorrect use of the products. This also applies to false applications, which are caused by NTI AG's own data and notes, for example in the course of sales, support or application activities. It is the sole responsibility of the user to check the information and information provided by NTI AG regarding their safety-relevant correctness. In addition, the entire responsibility for safety-related product functionality lies exclusively with the user. Product warranties are void if products are used with stators, sliders, servo drives or cables not manufactured by NTI AG unless such use was specifically approved by NTI AG.
NTI AG’s warranty is limited to repair or replacement as stated in our standard warranty policy as described in our "terms and conditions" previously supplied to the purchaser of our equipment (please request copy of same if not otherwise available). Further reference is made to our general terms and conditions.

Application examples are not binding and do not claim to be complete regarding configuration, equipment or any eventuality which may arise. Application examples do not represent specific customer solutions, they are only intended to provide support for typical tasks.

As the user you yourself are responsible for ensuring that the products described are operated correctly. Application examples do not relieve you of your responsibility for safe handling when using, installing, operating and maintaining the equipment.

4.3 Industrial Security

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the Internet if such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

 WARNING	The Drive shall not be connected to the internet The drive shall not be directly connected to the Internet. The drive could be connected to an internal network. The machine operator shall analyze whether further security requirements are applicable to this internal network and its connection to other networks. Note: there is SL0 (= no security mechanisms applied) used inside the drive.

 WARNING	**Unsafe operating states resulting from software manipulation** Software manipulations (e.g. viruses, trojans, malware or worms) can cause unsafe operating states in your system that may lead to death, serious injury, and property damage. • Keep the software up to date. • Incorporate the automation and drive components into a holistic, state-of-the-art industrial security concept for the installation or machine. • Make sure that you include all installed products into the holistic industrial security concept. • Protect files stored on exchangeable storage media from malicious software by with suitable protection measures, e.g. virus scanners. • Protect the drive against unauthorized changes by activating the "know-how protection" drive function.

5 General Safety Notes LinMot Products

5.1 Products and Life Cycles

The following safety notes must be generally regarded to guarantee safety during all life cycles. The products covered are:

- Drives
- Motors (Slider and Stator)
- Cables

The life cycles are:

- Storage & Transport
- Machine Integration (Commissioning)
- Operation
- Maintenance & Repair
- Modification
- Decommissioning & Disposal

The safety notes address the different danger source, the relevant products and life cycles are indicated for each safety note.

5.2 Overview Life Cycle, Safety Notes and Products

The following table gives an overview over the safety notes, applicable life cycles and the products. The items are described in the following chapters separately. Specific safety instructions and warnings are also placed. Check nearby chapters, where safety products or safety functions are described.

Safety Note	Storage & Transport	Machine Integration	Operation	Maintenance & Repair	Modifi-cation	Decommis-sioning & Disposal	Slider	Stator	Drive	Cable
Strong Magnetic Field	x	x	x	x	x	x	x	-	-	-
High Temperatures	x	x	x	x	x	x	x	x	x	x
High Voltage	-	x	x	x	-	-	x	x	x	-
Mechanical Parts and Motion	-	x	x	x	-	-	x	x	x	-
Shock and Vibration	x	x	x	x	-	-	x	x	x	-
Dirt, IP	x	x	x	x	x	x	x	x	x	x
Corrosion	-	-	x	x	-	-	x	x		
Hazardous Materials	-	-	-	-	-	x	x	x	x	x
Lifetime, Maintenance, Wearing Out	-	x	x	x	-	-	x	x	-	x
EMC	-	-	-	-	-	-	-	-	-	x

Table 3 Life Cycle and Safety Notes

5.3 Safety Notes

This chapter contains the general safety notes.

DANGER

Danger to life if the safety instructions and residual risks are not observed
If the safety instructions and residual risks in the associated hardware documentation are not observed, accidents involving severe injuries or death can occur.

- Observe the safety instructions given in the hardware documentation.
- Consider the residual risks for the risk evaluation

WARNING

Malfunctions of the machine because of incorrect or changed parameter settings
If the safety instructions and residual risks in the associated hardware documentation are not observed, accidents involving severe injuries or death can occur.

- Observe the safety instructions given in the hardware documentation.
- Consider the residual risks for the risk evaluation

WARNING

Strong Magnetic Field
The slider consists of strong permanent magnets. High forces can occur when other magnetic material is attracted. Danger of severe injuries!
Products:

- Sliders

Life Cycles:

- all

Safety measures:

- Keep slider in original packaging when not mounted.
- Use protective gloves when handling.
- Protect slider in application if magnetic dust is present

WARNING

High Temperatures
Avoid the system from high temperatures and beware from hot parts.
Products:

- Sliders
- Stators
- Cables
- Drives

Life Cycles:

- all

Safety measures:

- Avoid high temperature exposure for the sliders and stators
- Note, that stator / slider can become warm when working.
- Make correct dimensioning and mounting of cables.
- If necessary, install cooling (stators and drives)
- Do not isolate cables

DANGER

High Voltage
As the drive and motors are electrical parts, make sure to implement the protection from electric shock.
Products:

- Drives
- Sliders

Life Cycles:

- Machine Integration
- Operation
- Maintenance & Repair

Safety measures:

- All components must be well grounded.
- See installation guides of drives and motors

DANGER

Mechanical Parts and Motion
Moved parts or sharp mechanical edges can be a danger.
Products:

- Drives
- Stators
- Sliders

Life Cycles:

- Machine Integration
- Operation
- Maintenance & Repair

Safety measures:

- The movement of the motor can be very dynamic. Keep distance or place a protection.
- Loose mounting may cause unintended motion.
- Realize correct mounting of motors (stator, slider) according to installation guides (grounding, tightening torque, …)
- Be aware of sharp edges or corners on drive, motor or mechanics. Protect by distance or place a protection.
- Weight of slider: the slider is quite heavy and due to the strong magnets; it can generate high magnetic forces.
- Note the minimal bending radius for cables.
- If cables are moved, use high flex cables.
- When water cooling is used, avoid leakage

WARNING

Shock and Vibration
Electronics, magnets and mechanics can be damaged by high shock or vibrations. This may lead to loss of function and can also cause dangers.
Products:

- Sliders
- Stators
- Drives

Life Cycles:

- Transport
- Machine Integration
- Operation
- Maintenance & Repair

Safety measures:

- Consider the limits defined in the installation guides


WARNING

Dirt, IP
A housing must be adequate for the environment. Dirt, dust or liquids may cause a danger, because of electric shock or other scenarios.
Products:

- Sliders
- Stators
- Drives
- Cables

Life Cycles:

- All (except for disposal)

Safety measures:

- Protect parts generally from dirt
- Consider information given in the installation guide about dirt and IP rating.
- The drive shall be mounted in a cabinet with an ingress protection of at least IP54


WARNING

Corrosion
Corrosion can damage mechanical attachments or change other material characteristics. This can cause a danger.
Products:

- Sliders
- Stators

Life Cycles:

- Operation
- Maintenance & Repair

Safety measures:

- Protect parts generally from corrosion
- Consider information given in the installation guide about environment.
- Use only allowed cleaning chemicals (see also installation guides):
    - LU06-250, Art. No. 0150-2394 (Klüberfood NH1 4-002 Spray)
    - or methylated spirits
    - or alcohol

WARNING

Hazardous materials
The type and functionality of the products need implementations, which are based on some hazardous components. If handled correctly, no danger for persons and environment can occur.
Products:

- Sliders
- Stators
- Cables
- Drives

Life Cycles:

- Decommissioning

Safety measures:

- Drives, stators and cables contain the typical electronics parts. Decommissioning and disposal must be done environmentally friendly.
- The sliders contain neodymium magnets. Make sure the magnets are disposed environmentally friendly. Sliders can also be sent back to LinMot which will recycle the goods.

WARNING

Lifetime, Maintenance, Wearing Out
As a machine or installation is in charge and gets older, some regular maintenance is necessary to exchange worn out parts and check if the safety is still guaranteed.
Products:

- Stators
- Sliders
- Cables

Life Cycles:

- Machine Integration
- Operation
- Maintenance & Repair

Safety measures:

- Check for correct mounting when commissioning, so the bearing is not loaded.
- A maintenance cycle must be defined for each machine, at least once a year.
- Items to be checked: Sliders, stators, bearings, mounting, cables, cooling (air and water)


WARNING

EMC
EMC must be regarded for avoiding disturbances with other equipment.
Products:

- Cables (cabling)

Life Cycles:

- Machine Integration
- Operation

Safety measures:

- Make wiring, shielding and grounding according to the installation guides.
- Comply with maximal cable length, cable type and cross section defined in installation guides


CAUTION

Modification Protection
Components, which are broken or worn out, must be replaced instead of repaired.


WARNING

Logic Supply

- The logic supply of the LinMot drive must be supplied with 24 VDC by an SELV/PELV power supply unit with an output voltage limit U_{max} of 36 VDC. Failure to observe this can result in a loss of safety.
- Use another power supply for the motor.


CAUTION

Hazard Analysis
A hazard analysis of the application must be performed prior to the use of the safety functions of the product in that application. The hazard analysis must be done by qualified personnel.

5.4 Fundamental Safety Instructions

NOTICE

Risk minimization by using safety
Safety can be used to minimize the level of risk associated with machines and plants.
Machines and plants can only be operated safely when the machine manufacturer:

- Precisely knows and observes this technical user documentation, including the documented limitations, safety information and residual risks.
- Carefully constructs and configures the machine/plant. A careful and thorough acceptance test must then be performed by qualified personnel and the results documented.
- Implements and validates all the measures required in accordance with the machine/plant risk analysis by means of the programmed and configured safety functions or by other means.
- The use of safety functions does not replace the machine/plant risk assessment carried out by the machine manufacturer as required by the EC machinery directive.
  In addition to using safety functions, further risk reduction measures must be implemented.

DANGER

Danger to life as a result of undesirable motor movement when automatically restarting
The Emergency Stop function must bring the machine to a standstill according to Stop Category 0 or 1 (STO or SS1) (EN 60204-1).
It is not permissible that the motor automatically restarts after an emergency stop, as this represents danger to life as a result of the associated undesirable motor motion.
When individual safety functions are deactivated, an automatic restart is permitted under certain circumstances depending on the risk analysis (except when emergency stop is reset). An automatic start is permitted when a protective door is closed, for example.

- For the cases listed above, ensure that an automatic restart is absolutely not possible.

DANGER

Danger to life as a result of undesirable motor motion when the system powers up and the drives are activated after changing or replacing hardware and/or software
After hardware and/or software components have been modified or replaced, it is only permissible for the system to run up and the drives to be activated with the protective devices closed. Personnel shall not be present within the danger zone.

- It may be necessary to carry out a partial or complete acceptance test or a simplified functional test after having made certain changes or replacements.
- Before personnel may re-enter the hazardous area, all of the drives should be tested to ensure that they exhibit stable control behavior by briefly moving them in both the plus and minus directions (+/-).
- When switching on carefully observed the following:
  The Safety Integrated Functions are only available and can only be selected after the system has completely powered up.

WARNING

Parameterization of the encoder system

Encoder faults are detected using different hardware and software monitoring functions.

- It is not permissible to disable these monitoring functions.
- Set the encoder configuration correctly.

WARNING

Converter operation despite active messages

With activated safety functions, there are a number of system messages that still permit the drive to be traversed. In these cases, you must ensure that the causes of the messages are corrected immediately. These messages include, among others, the following:

- Brake Test Time Ov: The brake test time interval has been elapsed. A brake test must be performed as soon as possible.

5.5 Residual Risk

DANGER

Danger due to short, limited movements
If two power transistors simultaneously fail in the power unit (one in the upper and one in the lower inverter bridge), then this can cause a brief, limited movement.
The maximum movement can be:

- Synchronous rotary motors: Max. movement = 180° / no. of pole pairs
- Synchronous linear motors: Max. movement = pole width.
  - P01-23x: 10mm
  - P01-37x: 20mm
  - P01-48x: 30mm

WARNING

Residual risk for a single-encoder system
Within a single-encoder system:
a) A single electrical fault in the encoder
b) A break of the encoder shaft (or loose encoder shaft coupling), or a loose encoder housing will cause the encoder signals to remain static (that is, they no longer follow a movement while still returning a correct level), and prevent fault detection while the drive is in stop state (for example, drive in SOS state).
Generally, the drive is held by the active closed-loop control. Especially for applications with suspended load, from a closed-loop control perspective, it is conceivable that drives such as these move without this being detected.
The risk of an electrical fault in the encoder as described under a) is only present for few encoder types employing a specific principal of operation.

- All of the faults described above must be included in the risk analysis of the machine manufacturer. Additional safety measures have to be taken for drives with suspended/vertical or pulling loads - e.g. in order to exclude faults under a):
  - Use of an encoder with analog signal generation.
  - Use of a two-encoder system.
- Failsafe detection of slip on the encoder shaft - or a broken encoder shaft connection. You can implement failsafe detection of slip on the encoder shaft or a broken motor encoder shaft by checking the plausibility of the acquired safety-relevant actual value with respect to the expected setpoint. If the actual value does not lie within a configurable tolerance bandwidth around the setpoint within a defined time, then it can be assumed that there is either slip - or that there is a broken connection between the encoder and the motor. You must ensure this monitoring functionality in the safety user program according to SIL 2 or PL d.
- For excluding the fault under b):
  - Perform an FMEA regarding encoder shaft breakage (or slip of the encoder shaft coupling) as well as loose encoder housings and use a fault exclusion process according to IEC 61800-5-2, or
  - Implementation of a two-encoder system (the encoders must not be mounted on the same shaft).

6 LinMot Safety Products

LinMot provides a safety system, which consists of drives and linear motors. A linear motor consists of a stator and a slider. All components, which belong to the safety system, have the suffix “2S”. The following chapters give a list of the supported safety products and their compatibility. The next figure shows a C1251-2S drive with the peripheral components.

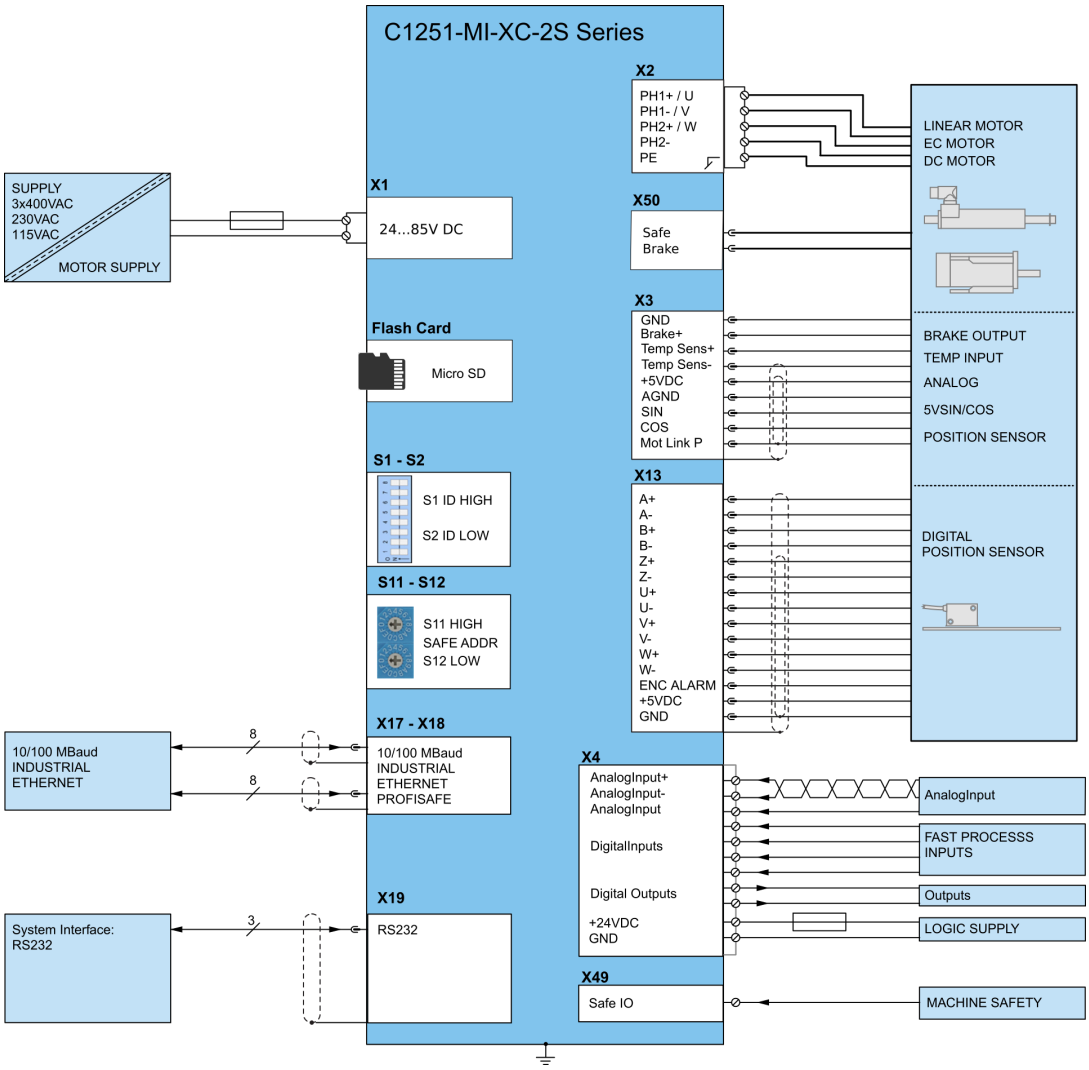


Figure 1: LinMot-System

6.1 Drives

The following drives support the functional safety:

Type	Article Number	Description	Version
C1251-MI-XC-2S-0E-000	0150-2933	Multi Interface (72V/25A/FS)	V2RB and higher
C1251-MI-XC-2S-0E-C00	0150-4185	Multi Interface (72V/25A/FS) Calibrated Measuring Amplifier	V2RB and higher
C1251-MI-XC-2S-0E-XXX	0150-XXXX	Multi Interface (72V/25A/FS), Customer specific	V2RB and higher

Table 4: Supported drives

Remark: The version string e.g. "V2RB" consists of Version 2 "V2" and Revision B "RB". V2RB may be followed by a single digit, this represents the sub-revision (e.g. "B2RB3"). All sub-revisions are functional and software compatible.

All drives support the motors listed under 6.2 - Motors.

The software version which are released for the safety applications are listed under 9.2 - FW Installation.

The key for the drive nomenclature is given by the following table:

Variations of							Description
Base type	C1251						72 VDC drive for P01 Motors
Interface		-MI					Multi Interface. With the same hardware different interfaces are supported. All available interfaces can be loaded by the customer. *Remark: With the non-safe interfaces, the safety functions are only controlled via safe digital I/Os*.
Power class			-XC				72 VDC, 25 A peak
Safety-Functions				-2S			With safety module SM02
Safety-Encoder					-0E		No encoder module assembled (only LinMot encoders are supported)
Extension						-xxx	The extension may consist of any three characters. It describes not safety related customer specific versions (for example configuration). • -000 means default • -C00 means calibrated measuring amplifier (same HW and FW functionality, only the non-safe analog inputs are calibrated and adjusted • -xxx: The customer-specific versions differ only from the configurations, which must be validated by the customer.

Table 5: Drive nomenclature

The installation guides for the drives are provided with the product or are available on the LinMot Webpage and must be carefully implemented.

6.1.1 Supported Safety Functions

The Drive supports the following safety functions according to EN 61800-5-2:

- STO: Safe Torque Off
- SBC: Safe Brake Control
- SS1: Safe Stop 1
- SOS: Safe Operating Stop
- SS2: Safe Stop 2
- SLS: Safe Limited Speed

A detailed description for these safety functions can be found in chapter 7 - Safety Functions.

6.1.2 Safety relevant Drive Installation Instructions

This chapter focuses on the safety relevant topics, which must be regarded, when the drive is installed. There is additional information in the drive's installation guide.

6.1.2.1 Physical Dimensions, Mounting, Environment

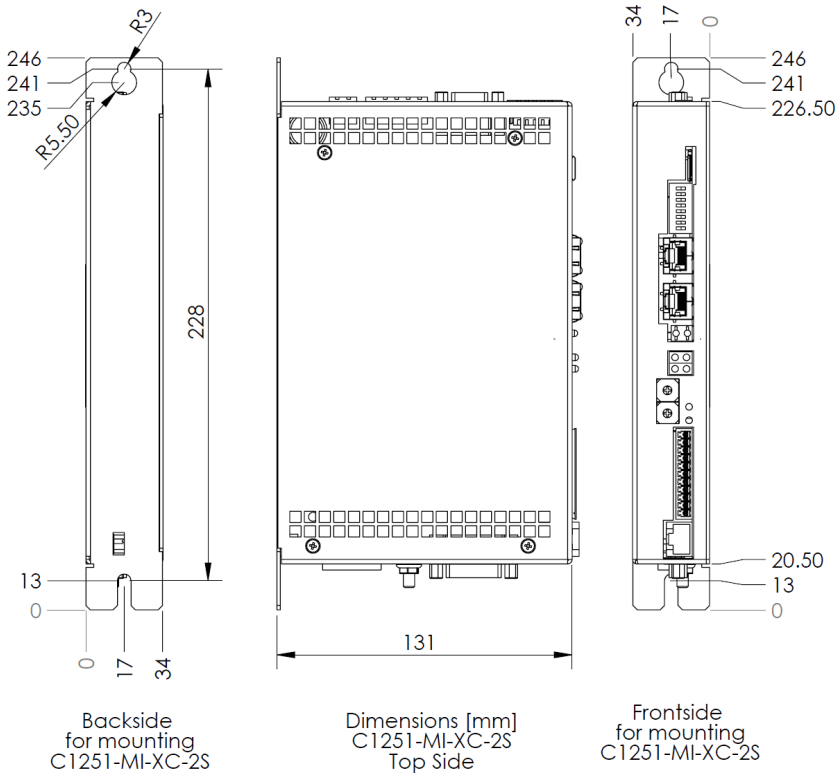


Figure 2: Drive Physical Dimension

C1251 Series single axis drive	Unit	C1251-MI-XC-2S-0E-xxx
Width	mm (in)	34 (1.4)
Height	mm (in)	206 (8.11)
Height with fixings	mm (in)	246 (9.69)
Depth	mm (in)	131 (5.16)
Weight	g (lb)	1100 (2.42)
Mounting Screws Mounting Distance	mm (in)	2 x M5 228 (8.98)
Case, Degree of Protection	IP	20 mount in cabinet with at least IP54
Storage Temperature	°C	-25 to 40
Transport Temperature	°C	-25 to 70
Operating Temperature	°C	5 to 40
Relative humidity	% r.H.	10 to 85 (non-condensing)
Pollution	IEC/EN 60664-1	Pollution degree 2
Shock resistance (22 ms)	m/s^2	40, tested with 50
Vibration resistance (10 - 150 Hz)	m/s^2	1, tested with 10
Max. Case Temperature	°C	70
Max. Power Dissipation	W	30
Mounting place		In the control cabinet
Mounting position		vertical
Distance between Drives	mm (in)	20 (0.8) horizontal / 50 (2) vertical

Table 6: Drive physical dimension, mounting and environment

6.1.2.2 Supply and Grounding

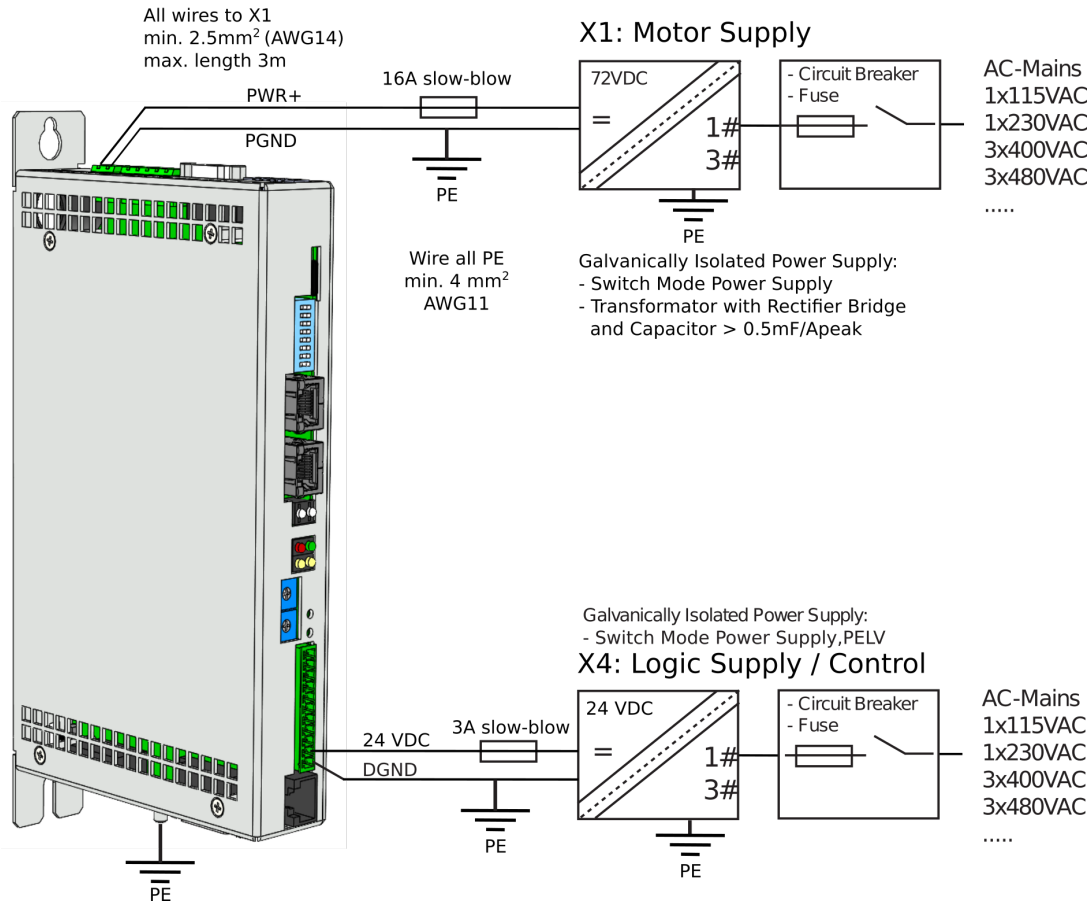


Figure 3: Supply and Grounding

6.1.2.2.1 Signal Power Supply

The logic supply needs a regulated power supply of a nominal voltage of 24 VDC. The voltage must be between 22 and 26 VDC.

Current to be provided from the supply:

CAUTION	**Fuse Protection for 24 VDC Supply** The 24 VDC supply for the control circuit must be protected with an external fuse (3A slow blow).

WARNING	**Signal Power Supply** The logic supply of the LinMot drive must be supplied with 24 VDC by an SELV/PELV power supply unit with an output voltage limit U_{max} of 36 VDC. Failure to observe this can result in a loss of safety. Use another power supply for the motor.

WARNING	**Do not connect or disconnect power supply while DC voltage is present!** Do not disconnect system components until all LinMot drive LEDs have turned off. (Capacitors in the power supply may not fully discharge for several minutes after input voltage has been disconnected). Failure to observe these precautions may result in severe damage to electronic components in LinMot motors and/or drives.

WARNING

Do not switch Power Supply DC Voltage!
All power supply switching and E-Stop breaks should be done to the AC supply voltage of the power supply. Failure to observe these precautions may result in severe damage to the drive.

6.1.2.2.2 Motor Power Supply

The calculation of the needed power for the Motor supply is depending on the application and the used motor.

The nominal supply voltage is 72 VDC.

The possible range is from 24 VDC to 85 VDC.

NOTICE

Use compatible Power Supplies
The motor supply can rise up to 95 VDC when braking. This means that everything connected to that power supply needs a voltage rating of 100 VDC. (Additional capacitors, etc.)
Due to high braking voltage and sudden load variations of linear motor applications, only compatible power supplies can be used. See chapter 6.1.3 - Drive Ordering Information.

CAUTION

Circuit Braker for Power Supply
The power supply for the motor must be protected with an external Circuit Breaker: 15 A / min. 100 VDC / C-Trip / 5 kA rms SCCR.

6.1.2.2.3 Regeneration

If the power supply rises too high when breaking, connect an additional capacitor to the motor power supply.

It is recommended to use a capacitor >= 10’000 µF (install capacitor close to the drive supply!).

6.1.2.3 Connectors and Wiring

The following subchapters provide important information about the correct wiring of the different connectors.

6.1.2.3.1 PE: Protective Earth

PE	Protective Earth
PE	• Use min. 4 mm^2 (AWG11) • Tightening torque: 2 Nm (18 lbin)

Table 7: PE Connector: Protective Earth

6.1.2.3.2 X1: Motor Supply

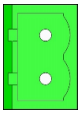
X1	Motor Supply
	PWR+ PGND
Connector has to be ordered separately: see chapter 6.1.3)	**Motor Supply: 72 VDC nominal, 24 VDC to 85 VDC** **Note:** • Absolute max. Rating: 72 VDC + 20 %. • External Circuit Breaker: 15 A / min. 100 VDC / C-Trip / 5 kA rms SCCR • If motor supply voltage exceeds 90 VDC, the drive will go into error state. **Mating connector (Art. No.: 0150-3525):** • Use 60/75 °C copper conductors only. • Conductor Cross-Section: 2.5 mm^2 (AWG14) max. Length 3 m • Stripping length: 7 mm • Screw thread: M3 • Tightening torque: 0.5 - 0.6 N

Table 8: X1 Connector: Motor Supply

6.1.2.3.3 X2/X3: Motor Connection

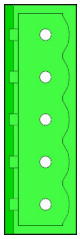
X2	Motor Phases		
	Ph 1+ U Ph 1- V Ph 2+ W Ph 2- X PE	**LinMot Motor:** Motor Phase 1+ red Motor Phase 1- pink Motor Phase 2+ blue Motor Phase 2- grey Shield	**3-phase EC-Motor:** Motor Phase U red Motor Phase V pink Motor Phase W blue Motor Phase X grey Shield
Connector has to be ordered separately: see chapter 6.1.3)	**Mating connector (Art. Nr. 0150-3526):** • Use 60/75 °C copper conductors only • Conductor Cross-Section: 0.5 - 2.5 mm2 (depends on Motor current) / AWG 21 -14 • Stripping length: 7 mm • Screw thread: M3 • Tightening torque: 0.5 – 0.6 N		

Table 11: X2 Connector: Motor Phases

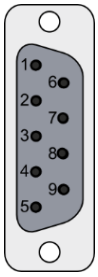
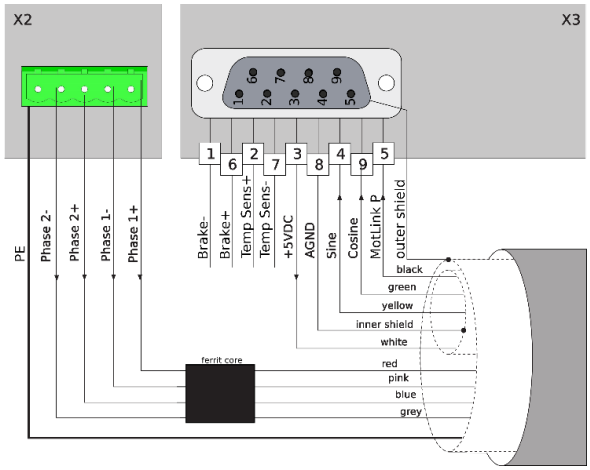
X3	Motor Phases		
	1 6 2 7 3 8 4 9 5 case	**LinMot Motor:** Non-Safe Brake - Non-Safe Brake+ Temp Sens+ Temp Sens- +5VDC AGND Sensor Sine Sensor Cosine Mot Link P Shield	**EC Motor:** Non-Safe Brake - Non-Safe Brake+ Temp Sens+ Temp Sens- +5 VDC AGND Sensor Sine / Hall Switch U Sensor Cosine / Hall Switch V Hall Switch W Shield
DSUB-9 (f)	**Note:** • Use +5 V (X3.3) and AGND (X3.8) only for motor internal hall sensor supply (max. 100 mA). • The motor cable length must not exceed 30 m. • Brake+: 24 V / max. 500 mA, Peak 1.4 A (will shut down if exceeded) the other terminal must be wired to Brake- (X3.1) **Locking Screws:** Tightening torque 0.4 Nm **Caution:** • Do NOT connect AGND (X3.8) to GND or earth! **Temperature Sensor:** • A resistive temperature sensor (PT1000, KTY) can be connected between Temp Sens+ (X3.2) and Temp Sens- (X3.7) **Important Notes:** • Use Y-style motor cables only (for example K15-Y/C)! A W-style cable has a different shielding, so it cannot be modified to a Y-style cable! • The motor cable length must not exceed 30 m		
			

Table 9: X3 Connector: Motor Sensor / Non Safe Brake

6.1.2.3.4 X4: Logic Supply / IO Connection

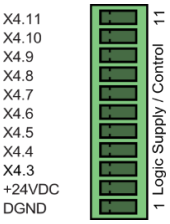
X4	Logic Supply / IO Connection		
	11	Diff An In-	Configurable +/- 10 V differential analog Input (with X4.10)
	10	Diff An In+	Configurable +/- 10 V differential analog Input (with X4.11)
	9	An In	Configurable single ended 0-10 V analog Input
	8	Dig In	Configurable digital Input
	7	Dig In	Configurable digital Input
	6	Dig In	Configurable digital Input
	5	Dig In	Configurable digital Input
	4	Dig Out	Configurable digital Output
	3	Dig Out	Configurable digital Output
	2	+24 VDC	Logic Supply 22 to 26 VDC
	1	DGND	Ground
Spring cage connector (has to be ordered separately: see chapter 6.1.3)	**Digital Inputs:** (X4.5 ... X4.8): 24 V / 5 mA (Low Level: –0.5 to 5 VDC, High Level: 15 to 30 VDC) **Digital Outputs:** (X4.3 & X4.4): 24 V / max. 500 mA, Peak 1.4 A (will shut down if exceeded) **Analog inputs:** 12 bit A/D converted • X4.9: Single ended analog input to GND, 0 to 10 V, Input Resistance: 51 kΩ to GND • X4.10/X4.11: Differential analog input, +/- 10 V. Common mode range: +/- 5 VDC to GND, Input Resistance 11.4 kΩ for each signal to GND. **Mating Connector (Art. Nr. 0150-3447):** • Use 60/75 °C copper conductors only. • Conductor cross-section max. 1.5 mm^2 • Stripping length: 11.5 mm **Important notes:** • The 24 VDC logic supply for the control circuit (X4.2) must be protected with an external fuse (3 A slow blow) and it should be SELV/PELV with an output voltage limit U_{max} of 36 VDC.		

Table 10: X4 Connector: Logic Supply / IO Connection

6.1.2.3.5 X17 – X18: Real Time Ethernet 10/100 Mbit/s

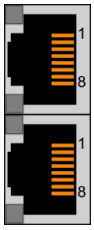
X17 – X18	Real Time Ethernet 10/100 Mbit/s	
	X17 RT ETH In X18 RT ETH Out	Specification depends on RT Bus. Please refer to according to documentation.
RJ-45	Warning: Do not connect the real time bus directly to the internet!	

Table 11: X17/X18 Real Time Ethernet 10/100 Mbit/s

6.1.2.3.6 X19: System

X19	System	
	1	(Do not connect)
	2	(Do not connect)
	3	RS232 RX
	4	RSGND
	5	RSGND
	6	RS232 TX
	7	(Do not connect)
	8	(Do not connect)
	case	Shield
RJ-45	Use isolated USB-RS232 converter (article number 0150-2473) for configuration over RS232	

Table 12: X19: System

6.1.2.3.7 X49: Safe Digital IO

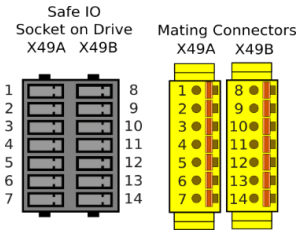
X49	Safe Digital IO	
		**X49A**
	1	SafeDigIn 1A- (safe digital input 1 channel A negative)
	2	SafeDigIn 1B- (safe digital input 1 channel B negative)
	3	SafeDigIn 2A- (safe digital input 2 channel A negative)
	4	SafeDigIn 2B- (safe digital input 2 channel B negative)
	5	DGND
	6	DigInAck- (non-safe acknowledge input negative)
	7	SafeDigOut A (safe digital output channel A)
		X49B
	8	SafeDigIn 1A+ (safe digital input 1 channel A positive)
	9	SafeDigIn 1B+ (safe digital input 1 channel B positive)
	10	SafeDigIn 2A+ (safe digital input 2 channel A positive)
	11	SafeDigIn 2B+ (safe digital input 2 channel B positive)
	12	GND
	13	DigInAck+ (non-safe acknowledge input positive)
	14	SafeDigOut B (safe digital output channel B)
Spring cage connectors (have to be ordered separately: see chapter 6.1.3)	• Detail specification for safe digital inputs see 7.12 - Safe Digital Inputs • Detail specification for acknowledge input see 7.13 - Acknowledge Input • Detail specification for safe digital output see 7.14 - Safe Digital Output **Mating connector (Art. Nr. 0150-4390 – two pieces necessary):** • Use 60/75 °C copper conductors only • Conductor cross section solid 0.2 mm² … 1.5 mm² • Conductor cross section flexible 0.2 mm² … 1.5 mm² • Conductor cross section AWG 24 … 16 • Conductor cross section flexible, with ferrule without plastic sleeve 0.25 mm² … 1.5 mm² • Conductor cross section flexible, with ferrule with plastic sleeve 0.25 mm² … 0.75 mm² • Stripping length: 10 mm	

Table 1213: X49 Connector: Safe Digital IO

6.1.2.3.8 X50 Safe Brake

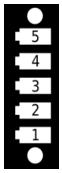
X50	Safe Brake	
	5 4 3 2 1	Do not connect Do not connect PE Safe Brake- Safe Brake+
Spring cage connectors (have to be ordered separately: see chapter 6.1.3)	• Use brake, which is engaged when not powered. • Use 24 V brake or valve. • Maximal current: 0.8 A • At 24 V a minimal current of 10 mA must flow • The brake must be active (braking), when the current is equal or below 10mA. • Brake must be tolerant for test pulses in high state of 1ms every 900 ms. **Mating connector (Art. Nr. 0150-4392):** • Conductor cross section: 0.2 mm² ... 1.5 mm² • Stripping length 6 mm • Clamping screw: M 2 • Screwdriver blade: 0.4 x 2.5 (DIN 5264) • Plugging cycles: 25 • Tightening torque (wire connection): 0.2 Nm ... 0.25 Nm • Tightening torque (screw flange): 0.15 Nm ... 0.2 Nm • Use 60/75 °C copper conductors only)	

Table 14: X50 Connector. Safe Brake

6.1.3 Drive Ordering Information

Drive	Description	Article Number
C1251-MI-XC-2S-0E-000	C1251 with MI interface (72 V / 25 A)	0150-2933
C1251-MI-XC-2S-0E-C00	C1251 with MI interface, Calibrated Measuring Amplifier (72 V / 25 A)	0150-4185
Accessories		
DC01-C1251-2S/X1/X4/X49/X50	**Drive Connector Set for C1251-2S**	**0150-4391**
DC01-C1X00/X1	Drive Connector for PWR 72 VDC Input	0150-3525
DC01-C1X00/X2	Drive Connector Motor Phases	0150-3526
DC01-Signal/X4	Drive Connector 24 VDC & Logic	0150-3447
DC01-Safety/X49	Drive Connector 2S Safety (2 pcs. necessary)	0150-4390
DC01-X50 Safe Brake	Drive Connector Safe Brake	0150-4392
Isolated USB-RS232 converter	**Isolated USB RS232 converter with cable**	**0150-2473**
Isolated USB-serial converter	Isolated USB RS232/422/485 converter	0150-3120
FC10-000	Flash Card for Safety Drives	0150-2936
Compatible Power Supplies		
S01-72/1000	Power Supply 72 V / 1000 W, 3x340-550 VAC	0150-1872
S01-72/500	Power Supply 72 V / 500 W, 1x120/230 VAC	0150-1874
S01-24/500	Power Supply 24 V / 500 W, 1x120/230 VAC	0150-2480
S01-48/300	Power Supply 48 V / 300 W, 1x120/230 VAC	0150-1941
S01-48/600	Power Supply 48 V / 600 W, 1x120/230 VAC	0150-1946
T01-72/420-Multi	Trafo-Supply 72 V / 420 VA, 3x230/400/480 VAC	0150-1869
T01-72/900-Multi	Trafo-Supply 900 VA, 3x230/400/480 VAC	0150-1870
T01-72/1500-Multi	Trafo-Supply 1500 VA, 3x230/400/480 VAC	0150-1871
T01-72/420 -1ph	Trafo-Supply 420 VA, 1x208/220/230/240 VAC	0150-1859
Power Supply Accessories		
Capacitor 10'000 uF / 100 V	Capacitor with mounting material	0150-3075

Table 15: Drive Ordering Information

Bold items are strongly recommended accessories!

 NOTICE	**Ordering of Connectors** The connectors must be ordered separately and are not included with the drive!
 CAUTION	**Configuration over RS232** Use isolated USB RS232 converter for configuration!

6.2 Motors

This chapter focuses on the safety relevant topics, which must be regarded, when the motor is installed. There is additional information in the motor's installation guide.

A motor consists of a stator and a slider.

Figure 4: Motor (Stator and Slider)

The following list shows the available stator types and the compatible slider families.

Stator Type Article Number	Version PnP Version	Slider Families	Description	Flange Article Number
PS01-23x80F-HP-R-2S 0150-21259	B and higher V3S5 and higher	PL01-12x…-HP…-2S PL02-12x…-HP…-2S	Stator HP, IP67 with connector M17/9(m) - Safety	PF02-23x90 0150-2146
PS01-23x160H-HP-R-2S 0150-21254	C and higher V3S5 and higher	PL01-12x…-HP…-2S PL02-12x…-HP…-2S	Stator HP, IP67 with connector M17/9(m) - Safety	PF02-23x170 0150-2117
PS01-37x120F-HP-C-2S 0150-21251	C and higher V3S5 and higher	PL01-20x…-HP…-2S PL02-20x…-HP…-2S	Stator HP, IP67 with connector M23/9(m) - Safety	PF02-37x140 0150-2105
PS01-48x150G-HP-C-2S 0150-22992	A and higher V3S5 and higher	PL01-28x…-HP -2S PL02-28x…-HP -2S	Stator HP, IP67 with connector M23/9(m) - Safety	PF01-48x136 0150-4072
PS01-48x240F-C-2S 0150-21220	B and higher V3S5 and higher	PL01-28x… -2S PL02-28x… -2S	Stator, IP67 with connector M23/9(m) - Safety	PF01-48x226 0150-2108
PS01-48x240F-HP-C-2S 0150-22991	A and higher V3S5 and higher	PL01-28x…-HP -2S PL02-28x…-HP -2S	Stator HP, IP67 with connector M23/9(m) - Safety	PF01-48x226 0150-2108

Table 16: Supported motors and ordering information

The safety sliders 2S have article numbers in the range 0150-20000 to 0150-29999. The article number for the safety sliders is based on the non-safety slider type. E.g. standard type PL01-20x400/340-HP has article number 0150-1508 and the corresponding 2S type is PL01-20x400/340-HP-2S with article number 0150-21508.

The installation guides for the motors are provided with the product or are available on the LinMot Webpage and must be carefully implemented.

All motors are supported by the listed C1251 drives under 6.1 - Drives

6.2.1 Environmental Conditions for Motors

The following table lists the information about the allowed environmental conditions for the safety motors. This includes safety stators and safety sliders according to table in 6.2 - Motors.

Item	Unit	Values
Case, Degree of Protection	IP	>= 54
Storage Temperature	°C	-25 to 40
Transport Temperature	°C	-25 to 70
Max. Ambient Temperature	°C	0 to 80
Relative Humidity	% r.H.	10 to 85 (non-condensing)
Shock resistance (6 ms)	m/s^2	200, tested with 250
Vibration resistance (10 - 150 Hz)	m/s^2	5, tested with 50
Max. Case Temperature	°C	90 non-HP motor 120 HP motor

Table 17: Environmental conditions for motors

6.2.2 Stators

6.2.2.1 Stator Nomenclature

Variations of								Description
Base type	PS01							Stator for P01 motors (72VDC)
Diameter		-YY						YY = Diameter of the back-iron tube [mm]: -23 = 23 mm diameter -37 = 37 mm diameter -48 = 48 mm diameter
Active coil length			xYYY					“x” is a separator YYY = active coil length [mm]: x80 = 80 mm coil length x120 = 120 mm coil length X150 = 150 mm coil length x160 = 160 mm coil length x240 = 240 mm coil length
Winding type				Y				Y = Winding type F = F winding type G = G winding type H = H winding type
Bobbin material					-HP			Bobbin material: empty = standard material (POM based) -HP = HP material (PEEK based)
Connector						-X		Connector: -R = R-Connector (Intercontec M17) -C = C-Connector (Intercontec M23)
Functional Safety							-2S	-2S = 2S-Safety encoder integrated

Table 18: PS01 Stator nomenclature

6.2.3 Sliders

The slider is a magnetic rod, which is moved in the stator.

6.2.3.1 Slider Nomenclature

Variations of							Description
Base type	PL0						Slider for slotless motors
Coating		Y					Y = Coating of the slider 1 = standard coating 2 = heavy duty coating
Diameter		-YY					-YY = Diameter of the slider [mm]: -12 = 12 mm diameter (for PS01-23) -20 = 20 mm diameter (for PS01-37) -28 = 28 mm diameter (for PS01-48)
Mechanical length			xYYY				“x” is a separator YYY = Total slider length [mm], for example x680 has the length of 680 mm
Magnetic length				/YYY			/YYY = length of magnetic pile [mm] / Multiple of pole length
Performance type					-YY		Type of magnets and iron: empty = standard for PL01-28x -HP = HP type (high performance)-
Functional Safety						-2S	-2S = slider for 2S systems

Table 19: PL0x Slider nomenclature

Remark: The PL02 sliders, with heavy duty coating, will be manufactured on request. The sliders are technically the same as the PL01 types, except for the coating.

The operation range must be covered by the slider and the configuration must be done correctly.

CAUTION

Slider Selection
The slider must be selected with the correct size for the application to avoid a broken motor slider. Do not use visible broken sliders.
2S safety sliders have article numbers between 0150-20000 and 0150-29999.

CAUTION

Safe Stroke
At the end of the magnetic pile, the magnetic field is distorted, due to physical facts. In this range the position and speed evaluation are less adequate. Therefore, it is advisable to use just a reduced stroke, compared with the data sheet.
Recommended stroke reduction on both sides for the different sliders:

- PL0x-12x... : 5 mm
- PL0x-20x... : 10 mm
- PL0x-28x... : 15 mm

6.2.3.1.1 Motor cable

CAUTION

Do not connect or disconnect motor when there is power on the servo drive.
Use only double-shielded original LinMot cable. Cables from other sources must be checked precisely before commissioning.
Incorrect connections can destroy the drive and stator.

CAUTION

Connectors and cables
The stator is connected to protective earth via the motor cable. The screw connections of the C and R connectors must be tightened up to the stop.
Three types of cables are available for linear motors. The cable attached to the stator is not a high flex cable. For moving cable applications, please use the special LinMot KS high flex (suitable for cable tracks) or KR robot cable. See table below.

	Standard cable		**High-Flex cable**		**Robot cable**	
Cable Type *)	K05-04/05	K15-04/05	KS05-04/05	KS10-04/05	KR05-04/05	KR10-04/05
Minimum bending radius for fixed installation	25 mm (1 in)	50 mm (2 in)	30 mm (1.2 in)	50 mm (2 in)	40 mm (1.6 in)	50 mm (2 in)
Minimum bending radius when moving	Not suitable for applications with moving motor cable		60 mm (2.4 in) No torsion	100 mm (4 in) No torsion	80 mm (3.2 in) Max. Torsion: ±270° / 0.5 m	100 mm (4 in) Max. Torsion: ±270° / 0.5 m
Approval	-	UL / CSA 300 V	UL / CSA 300 V		UL / CSA 300 V	
Material wire insulation	TPE-U		TPE-E		TPE-E	
Material cable sheath	PUR		PUR		PUR	
Oil resistance	very good acc. DIN VDE 0282 Part 10 + HD 22.10		very good acc. DIN VDE 0282 Part 10 + HD 22.10		very good acc. DIN VDE 0282 Part 10 + HD 22.10	
Chemical resistance (to acids, alkalis, solvents, hydraulic fluid)	good		good		good	

Table 20: Cable list

*) For longer cables than 8 m use cable version 1V1.

6.2.3.1.2 Rotatability of motor connectors

The motor connectors R and C can be rotated in both directions. See illustration below.

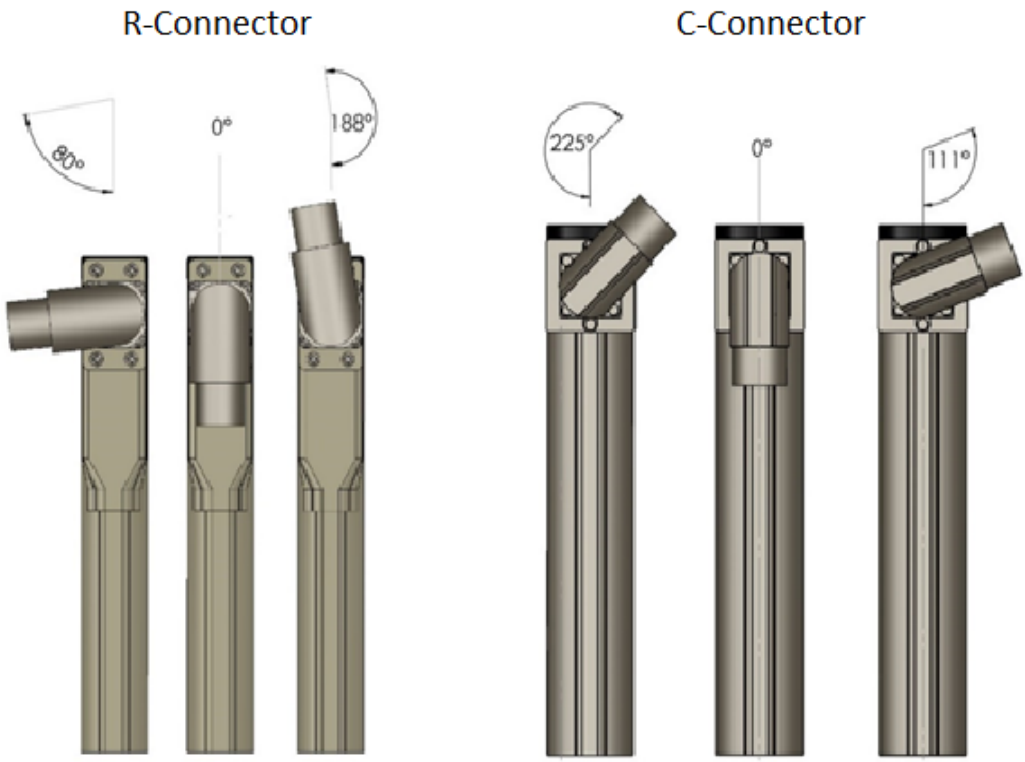


Figure 5: Rotatability of Motor Connectors

7 Safety Functions

7.1 Safety Functions Overview and Compatibility

The following table gives an overview of the available safety functions. Please be aware, that for some safety functions a safe encoder is necessary.

Function	Description	Use with non-safe Encoder	Use with safe Encoder	Documentation Chapter
STO	Safe Torque Off	yes	yes	7.16 - Safe Torque Off (STO)
SBC	Safe Brake Control	yes	yes	7.17 - Safe Brake Control (SBC)
SBT	Safe Brake Test	yes	yes	7.18 - Safe Brake Test (SBT)
SS1	Safe Stop 1	yes	yes	7.19 - Safe Stop 1 (SS1)
SOS	Safe Operational Stop	no	yes	7.20 - Safe Operating Stop (SOS)
SS2	Safe Stop 2	no	yes	7.21 - Safe Stop 2 (SS2)
SLS	Safe Limited Speed (4 levels implemented)	no	yes	7.22 - Safe Limited Speed (SLS)

Table 21: List of safety functions and combination with safe/non-safe encoders

Remarks:

- If no safe encoder is used, the safe IOs cannot be configured for safety functions requiring a safe encoder. A configuration error will be generated.
- If no safe encoder is used and over the safe fieldbus a safety function is activated which requires a safe encoder, the command will be ignored.
- SBT also works with non-safe encoders. In this case the non-safe position is checked.
- All safety functions can be used in parallel.
- The safety functions can be activated from safe digital inputs and safe fieldbus in parallel.

7.2 General Safety Information

The following subchapters contain general information for the safety functions, such as characteristics, boundaries, constraints etc.

7.2.1 Boundary of the Safety Compliant System

The safety parts in the 2S system contain the following:

- Safety related parts in the drive, such as
  - safe digital inputs
  - safe digital output
  - safe bus ID
  - safe position encoder
  - safe PROFIdrive
  - Safety over EtherCAT (FSoE)
  - circuit for STO
  - circuit for SBC
- Safety firmware on the safety Module SM
- Safety related parts in the motor encoder electronics

7.2.2 Constraints of the use of the Safety Compliant System

The following constraints have to be regarded:

Safe Encoder:

- A safe position encoder must be used for the safety function SOS, SS2, SLS and SBT.
- The safety functions STO, SS1 and SBC can also be used with a non-safe position encoder.

Safe Brake:

- The safe brake is not part of the safety compliant system.
- The brake has to be designed in the application regarding the application specific requirements.

7.2.3 Safety Characteristics for all Safety Functions

The complete safety system (containing the drive and the motor) with all its functions has the safety characteristics listed in the following tables. The PFHd and MTTFd values are fulfilled even when all safety functions are used in parallel.
Remark: Only the safe brake control (SBC) is considered. As the brake itself is evaluated application specific, it has to be included to the safety characteristics in the complete system.

Item	Value	Description / Comment
SIL	2	Safety Integrity Level
SFF	>= 60%	Safe Failure Fraction
PFHd	< 100 FIT	Probability of dangerous Failure per Hour
High demand mode		The system fulfills the high demand or continuous mode.
1oo2 architecture		The safety architecture realized in the drive is 1 out of 2.
Type B subsystem		The safety subsystem is of type B. (According to IEC 61508-2:2010 chapter 7.4.4.1.2 and 7.4.4.1.3)
Mission Time	20 years *)	Mission time for all safety functions, except the brake.
Proof Test Interval	20 years *)	Proof test interval for all safety functions, except the brake.

Table 22 : Characteristics of safety functions according to IEC 61508

**) Remark: These numbers are valid for all safety functions, except the brake. The brake test is the proof test for the brake and the proof test interval has to be configured accordingly.*

Item	Value	Description / Comment
Cat	3	Category
PL	d	Performance Level
DC_{agv}	>= 60%	Diagnosis Coverage
MTTFd	>= 100 years	Mean Time to Dangerous Failure
CCF	> 65	Fulfilled, according to ISO 13849-1:2015, table F.1

Table 23: Characteristics of safety functions according to /ISO13849-1/

7.2.4 Failure Modes

The failure model used assumes 50% of all failures are safe failures and 50% are dangerous failures. A more detailed investigation of the failure models is expected show more safe failures than the 50% assumed. Therefor this is a worst-case assumption causing an increased safety margin.

7.2.5 Implemented Measures against Systematic Errors

For the safety compliant system, for development and design, the following measures have been taken to prevent from systematic errors:

- implementation of tables under EN 61508-2 Appendix B
- implementation of tables under EN 61508-3 Appendix A

7.2.6 Used Technologies and architecture

For the implementation of the safety related functions the following technologies are used.

- HW design is based on C1250, which is proven in use
- two channel architecture for safety related functions
- cross monitoring of the two channels, realized in HW and SW
- fault exclusion for single channel parts

The safety related block diagram of the implementation is:

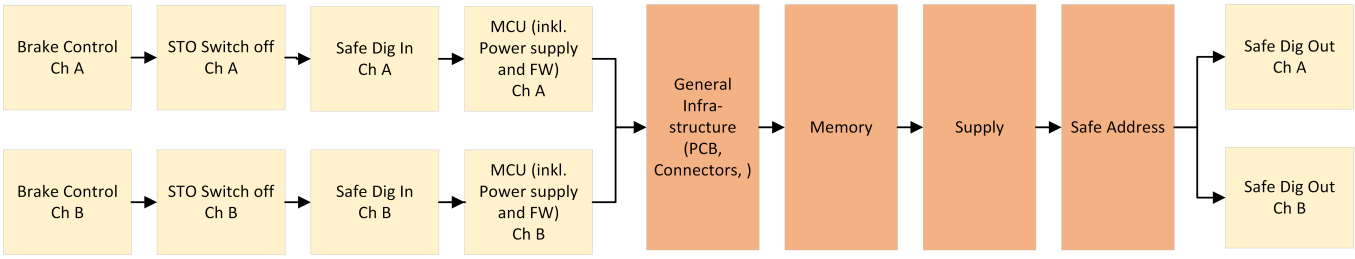


Figure 6: Safety related block diagram

Where a dual channel architecture is implemented the hardware fault tolerance (HFT) is 1:

- Brake Control
- STO Switch off
- Safe Dig In
- MCU (incl. Power Supply and FW)
- STO Switch off
- Safe Dig Out

Where a single channel architecture is implemented the HFT is 0.

- General Infrastructure (PCB, Connectors ...)
- Memory
- Supply
- Safe Address

There are risk reduction measures implemented for single channel architecture parts, see chapter 7.2.4 - Failure Modes.

7.2.7 Regarded Safety Related Errors taken Measures

The following table lists safety related errors, possible error causes and the measures or advice for the handling.

Fault	Measures, Discussion
Safe position encoder • general fault • Safe encoder stuck at • Safe encoder missing	The safe position encoder is permanently checked by orbit and cross monitoring.
Motor Temperature from safe stator • No Communication • Communication frozen	• Motor temperature is cyclically read. • Checksum and life signal are checked.
Safe Digital Inputs • Inconsistent values • Stuck At	• The two input channels are checked for consistency. • **Not detected:** Stuck at must be detected on the output module, e.g. with test pulse
Safe Digital Outputs • Inconsistency • Stuck at	• The output is permanently feedbacked to detect inconsistencies. • Stuck at high is detected.
Safe Field Bus • Disconnected • Bus Timing • Inconsistent data	• Bus cycle time is watched. • Bus cycle time is watched. • Bus is realized as black channel until the safety module. Data are CRC protected.
Safety Parameter Configuration • Parameter out of range • Inconsistency • Wrong encoder type configured	• All parameters are range checked. • Inconsistent parameter combinations are reported as failure. E.g. non-safe encoder selected in combination with SLS selection over safe digital inputs. • At startup the electronic data sheet from the stator is read and checked with the configured type.
Brake Driver • Hardware fault (cannot turn off brake current)	• Dual channel architecture. There are two switches in series to switch off the brake current. The drive checks periodically if the brake driver can switch off the current.
STO • Hardware fault, cannot turn off the power state	• Dual channel architecture. The PWM pulse transmission for the power state can be switched off on high and low side separately.

The table is continued on the next page.

Fault	Measures, Discussion
Memory • Program memory • RAM • EEPROM (parameter storage)	• The program code is CRC protected. On startup CRC is checked. • On startup and periodically RAM test is performed. • The safety parameters are CRC protected. On startup CRC is checked.
Power Supply • Low voltage • Over voltage	• All supply voltages (external and internal) are watched, either by reset component or by ADC conversion. A low level voltage is detected, missing voltages will keep the hardware in the safe state. • For the input supply voltages PELV supplies must be used.
Slider • Wrong slider length mounted • Non-safety slider mounted	**Not detected**: The slider length and type have to be checked with the acceptance tests.
Short Circuit • between PWR and signal • Signals on PCB	• **Fault exclusion**: The isolation between the PWR and signal circuits are HV tested. The cables are double isolated. • Each PCB is electrically tested in the production and the design rules are set the way the fault can be excluded.

Table 24: Regarded safety related errors and taken measures

7.2.8 Periodic Proof Tests

The following table shows the periodic proof tests, which are either automatically performed or have to be done manually.

Test	Automatically on Startup	Automatically periodically	Instructions for user
CPU	yes	yes, < 500 ms	
RAM	yes	yes, < 500 ms	
Parameter CRC	yes	yes, <500 ms	
Parameter Consistency	yes	no	
Safety program CRC	yes	yes, < 500 ms	
Safe Brake Control	no	yes, every 900 ms	Brake Output test pulses every 900ms for 1ms
STO circuit	no	yes every 1000 ms	STO switch change every 1000ms
Safe Dig In	no	yes, discrepancy time: 50 ms	Stuck at must be detected on the output module, e.g. with test pulse
Safe Dig Out		yes, Test pulses in high state every 1100 ms, discrepancy time: 50 ms	Input must be capable for test pulses. See also 7.14 - Safe Digital Output.
Fieldbus CRC	no	yes every bus cycle	
Brake Test	no	no, the drive signalizes if SBT Request Interval has expired.	The SBT Request Interval (UPID 47DAh) must be configured according to the applicational requirements. When the SBT Request Interval has expired (Safety Fn State Brake Tst time Ov UPID 1A21h becomes active) the SBT Request must be activated for starting the SBT sequence. See chapter 7.18 - Safe Brake Test (SBT)
Maintenance of System	no	no	A periodic maintenance of the machine has to be planned. See chapter 11.2 - Maintenance.

Table 25: Periodic proof tests

7.2.9 Error Reaction Times

The following table provides the maximal error reaction times of the system:

Item	Description	Time
I/O Discrepancy	The safe digital inputs and output are checked for consistency. If a discrepancy is present between the two channels, which stays longer than the indicated time, an error will be generated (Safe Input Fault or Safe Output Fault).	50 ms
Safe Encoder Discrepancy	The two MCU on the safety module check periodically the evaluated position. If a discrepancy occurs the "Encoder fault" error is generated and the drive activates STO.	10 ms
Safe Encoder Signal Error	If the sine and cosine signals are not consistent (invalid combination) the "Encoder fault" error is generated and the drive activates STO.	5 ms
Safe Brake Control Error	The safe brake control is checked periodically with test pulses. In case of an error "Brake output fault" is generated and the drive activates SS1.	5 s

Table 26: Error reaction times

7.2.10 System Reaction Times

The following table provides the maximal reaction system reaction times:

Item	Description	Time
Safety Function Reaction Time Digital IO	The reaction time from the safety function request via safe digital input to the feedback on the safe digital output. Note: for some safety functions there may be additional delay times to be regarded.	30 ms
Safety Function Reaction Time over Bus	The reaction time from the safe bus control word request to the feedback on the safe bus status word. Note: for some safety functions there may be additional delay times to be regarded.	20 ms
Safety Function Reaction Time Bus IO combined	The reaction time from request to feedback when one signal is via safe digital I/O and the other via safe bus. Note: for some safety functions there may be additional delay times to be regarded.	30 ms
Acknowledge Edge Distance	The minimal edge distance on the acknowledge signal.	12 ms
SOS Position Error	When the position deviation exceeds the position tolerance (UPID 47E2h), the configured error reaction is done. The position evaluation is done every millisecond.	5 ms
SLS Speed Error	If the speed, watched in SLS exceeds the limit an error is generated. The speed evaluation depends on the parameter speed computation time (UPID 47A3h) and for generating the fault reaction additional 5 ms must be calculated.	5 ms + Speed Computation Time
Brake Activation	The activation time of the brake mainly depends on the valve and the brake itself. The time between activation (via safe digital input or bus) and the switching of the brake output, maximal 20 ms will pass. For the configuration of 47D5h “SBC STO_Delay” consider the switching characteristics of the value and brake.	20 ms + physical brake delay

Table 27: System reaction times

7.2.11 Predictable User Errors

The following list shows predictable user errors an the measures taken:

User Error	Measures, Description
Wrong firmware loaded to drive.	As described in 9.2 - FW Installation, only approved firmware versions are allowed to use. The correct firmware installation must be checked by comparing the CRC.
Inconsistent Configuration	When writing the safety configuration to the drive, a consistency check is done. Especially the combination of safe encoder type and configured safety functions, based on a safe position encoder, are checked. In case of an inconsistency the error "Send data failed: Parameter Error" is generated.
Parameter Out of Range	All parameters are checked for the allowed range. In case of a range violation, LinMot-Talk will block and the safety software on the drive checks the ranges as well. In case of an error, the message "Send data failed: Parameter error" is generated.
Motor or Encoder not correctly connected	The safe position encoder is permanently checked by orbit and cross monitoring.
No safety Encoder connected	The communication to the motor is permanently running. The motor temperature is cyclically read and the checksum and life signal are checked.
Slider missing	The orbit monitoring will generate an error, due to wrong encoder signals.
Slider mounted in wrong direction	LinMot-Talk provides a motor wizard for the motor configuration. It guides the user graphically step by step through the configuration.
No safety slider	Compatibility listed in 6.2 - Motors
Wiring fault on Safe Dig In	Consistency check is done on drive. Stuck at must be detected on the output module. See also 7.2.8 - Periodic Proof Tests
Wiring fault on Safe Dig Out	Checked periodically with test pulses. See also 7.14 - Safe Digital Output
Brake not connected	SBC checks by measuring the current if the brake is connected.
Brake test with too small current	The user must check during SBT verification, that the demand current for the requested force is driven. See 7.18.4 - Verification and Validation
SBT with no brake configured	If the SBT is started when no brake (neither safe nor non-safe) is configured, the drive will report a brake test failure.

Table 28: Predictable User Errors and Measures

7.3 Data Types

The data types used for parameters and variables are the following:

Type	Min Value	Max Value	Description / Comment
Bool	0	1	Boolean value, can be 0: false or 1: true
UInt8	0	255	Unsigned integer 8 bit
Sint8	-128	127	Signed integer 8 bit
Enum8	0	255	Enumerator 8 bit. To each value a dedicated state or caption can be mapped.
UInt16	0	65535	Unsigned integer 16 bit
SInt16	-32768	32767	Signed integer 16 bit
Enum16	0	65535	Enumerator 16 bit. To each value a dedicated state or caption can be mapped.
UInt32	0	$2^{32} - 1$	Unsigned integer 32 bit
SInt32	-2^{31}	$2^{31} - 1$	Signed integer 32 bit
String	-	-	A sequence of characters. The maximal size is dependent on the parameter. The string is terminated with a zero byte.

Table 29: Data types for parameters and variables

7.4 Access and Visibility to Parameters and Variables

The parameters on the drive are configured via the LinMot-Talk configuration software. With this tool also variables can be monitored. Dependent on the login ID, different access levels can be reached.

- User: With the login "user" the basic functionality and the most common variables are accessible. The default password is empty.
- Service: With the login "service" additional parameters and variables can be accessed. The default password is empty.

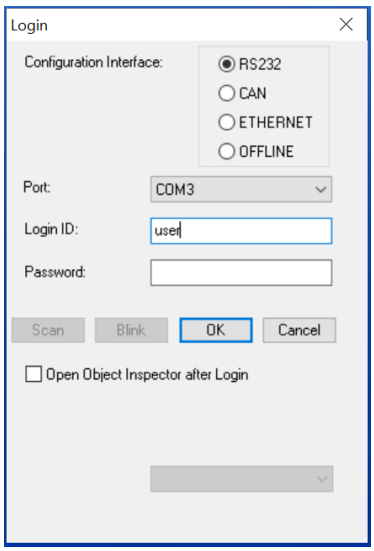


Figure 7: LinMot-Talk Login Mask

In /LinMotTalk/ a detailed description of the LinMot-Talk configuration software is given. All parameters and variables listed in this document can be accessed at least with the login "Service".

7.5 Safety Parameters Overview

All parameters, used for the configuration of the different safety functions, are displayed in the LinMot-Talk in the parameter section. There is a branch “Safety” which is colored yellow.

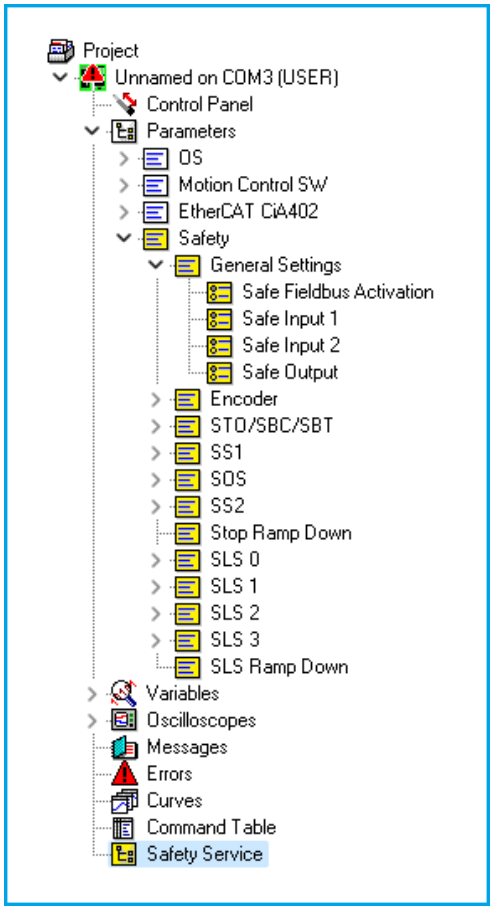


Figure 8: Safety parameters overview

7.6 Configure Safety Parameters

To configure the safety parameters, there are the following steps necessary:

- Setting the parameters
- Validate the parameters is done in the following steps:
  - Login
  - Verify Groups
  - Read ASCII Report
  - Print ASCII Report
  - Validate Parameters

All the steps above are described in the next chapters.

7.6.1 Setting the Safety Parameters

The parameters can be set the same way as the non-safety parameters. E.g. setting the FS Config Name:

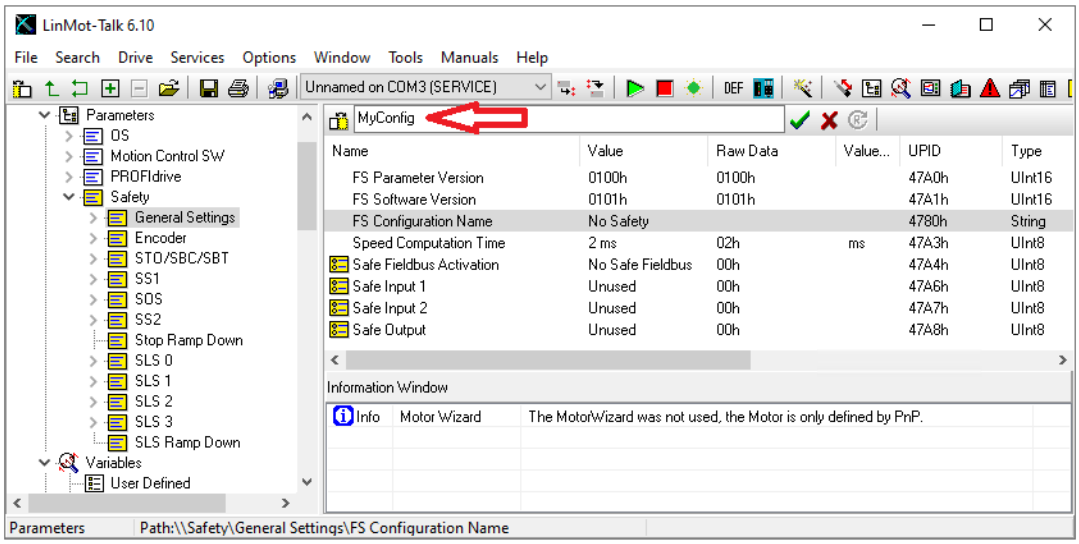


Figure 9: Changing safety parameters

Select the parameter and type in the new value, then press Enter or click on the check. And the value is changed:

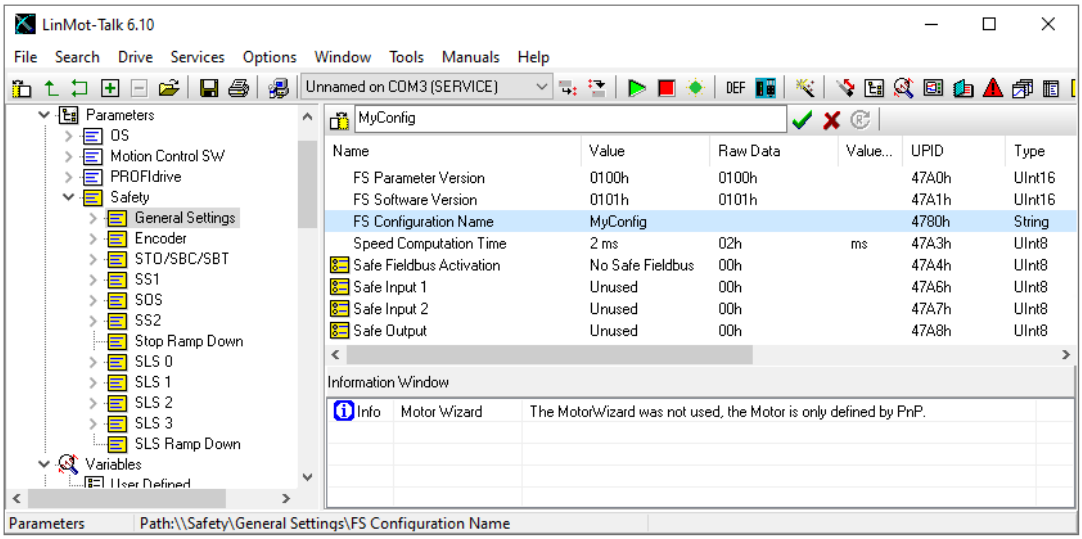


Figure 10: Changed safety parameter

Note: The value is not yet stored on the drive until the validation is completely run.

7.6.2 Validate the Safety Parameters

When a safety parameter has changed, the symbol for the Safety Service has changed, it shows an exclamation mark (1).

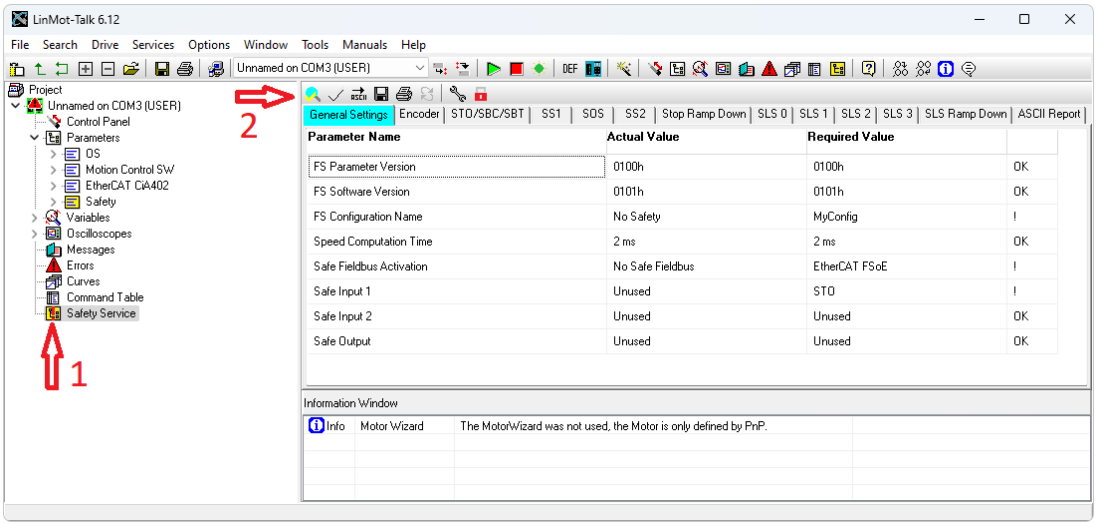


Figure 11: Start Safety Service

Click on start validation (2)  to continue and the login mask will appear.

7.6.2.1 Login

When started the parameter validation, the first step is to do a login:

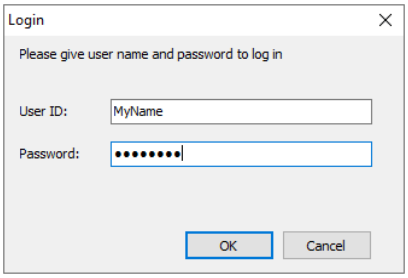


Figure 12: Login for safety parameter validation

- User ID: Type in the user ID, the string must have at least 3 characters.
- Password:
  - The default password is “DoChange”. The default password is active, when the firmware is freshly installed, or the parameters have been defaulted from LinMot-Talk or over the ID switches S1/S2
  - The password can be changed by clicking the Icon  .

A timeout of 5 minutes is active, when logged in. In case of inactivity for more than 5 minutes, an automatic logout will be performed.

The validation process can be stopped any time and restarted by clicking the start validation  .

A timeout of 5 minutes is active, when logged in. In case of inactivity for more than 5 minutes, an automatic logout will be performed.

7.6.2.2 Verify Groups

When the login is correct, the “Verify Par Group” button becomes active  . The parameter group shown is marked yellow and must now be verified. When everything is ok, the verify button can be clicked, the group will be marked green, and the next group will be shown and marked yellow.

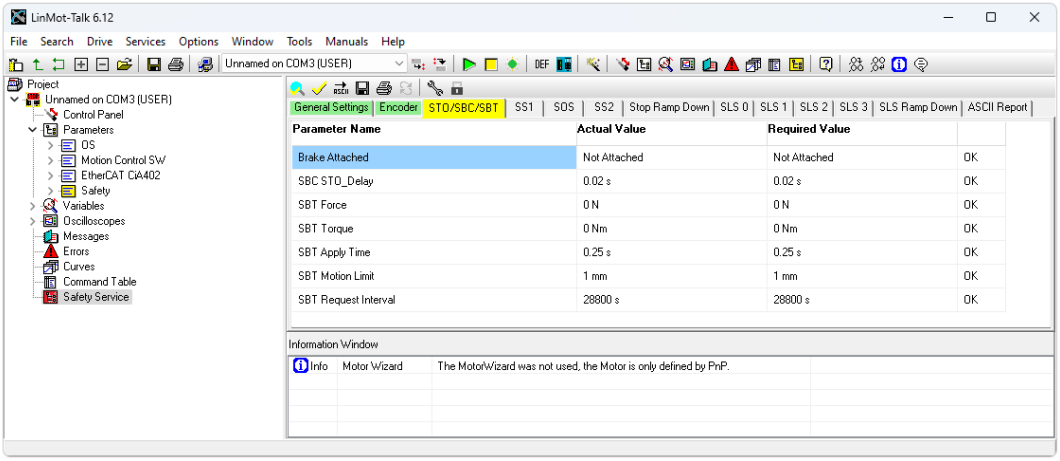


Figure 13: Verify safety parameter groups

7.6.2.3 Read ASCII Report

When all groups are verified, the ASCII report must be generated. The ASCII report is generated by the safety module and is a text file. It shows all safety parameter settings in clear text. To generate the ASCII report press  .

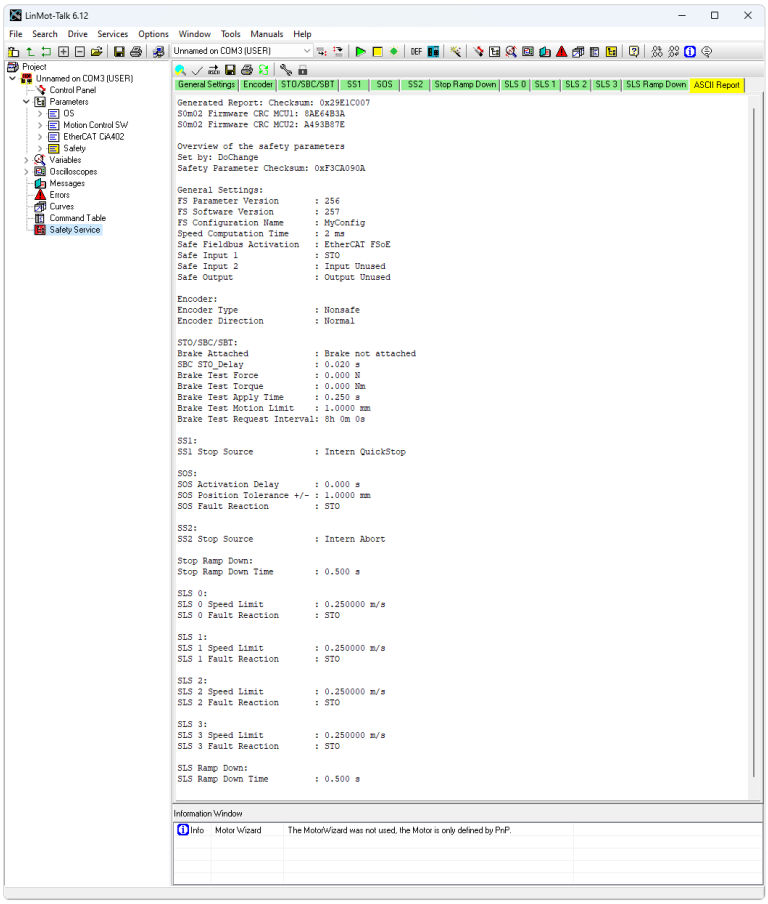


Figure 14: ASCII Report

7.6.2.4 Print ASCII Report

The ASCII report must be printed and put together to the machine documentation. Printing can be done to a PDF file.
Click to the printing button .

7.6.2.5 Validate Parameters

At the end, the parameters can be validated by clicking the button .
The password must be retyped.

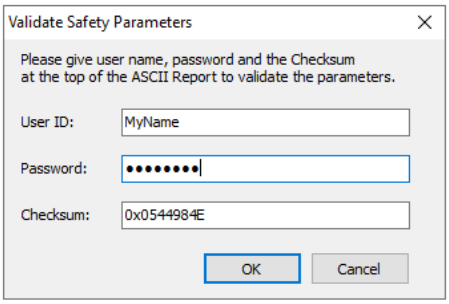


Figure 15: Validate Parameters

The checksum shown is calculated over the ASCII report.
The following window will finish the validation with the feedback if it was done correctly or not.

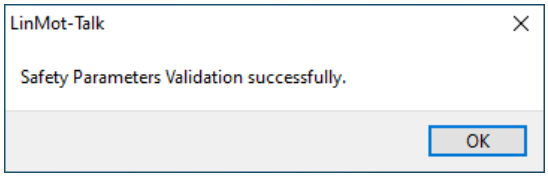


Figure 16: Status message on validation end

7.6.2.6 Safety Parameter Checksum

The safety parameter checksum shown at the end of the validation corresponds with the content of the variable “Parameter CRC”, UPID 0305h. This value must be used for validating a configuration loaded from the flash card. See chapter 7.7 - Flash Card (FC).

7.7 Flash Card (FC)

A micro SD card can be used in socket M1 “Memory Card”. The flash card must be a type provided by LinMot. Other flash cards are not supported. The following flash card is available for the C1251-2S drives.

Accessories	Description	Article Number
FC10-000	Flash Card for Safety Drives	0150-2936

Table 30: Flash Card List

The FC is used for drive exchange in the field, without the use of LinMot-Talk. The FC is used to save and reload drive configurations. The configurations are CRC protected.
The access to the flash card by unauthorized persons must be limited by the end user.
The FC commands are activated by the ID switches S1/S2 and the safe address switches S11/S12. The next tables give an overview. The detailed behavior is described in the following subchapters.

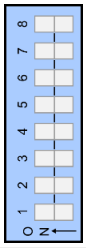
S1/S2 Positions	Commands
	S1 (5..8): Bus ID High (0 … Fh). Bit 5 is the LSB, bit 8 the MSB. S2 (1..4): Bus ID Low (0 … Fh). Bit 1 is the LSB, bit 4 the MSB.
FFh	Default all parameters: Sequence: FFh --> Reboot --> 00h --> Default all parameters (safe and non-safe) --> Reboot (user action)
FEh	Set IP configuration mode to DHCP. Not used for C1251-2S drives.
FDh	Saves the complete configuration to the FC. There are written two files, one for the non-safety configuration, the other for the safety configuration. The file name for the non-safety configuration is generated from the parameter 03E8h «Drive Name»: “Config_” + 03E8h + “.pvl” The file name for the safety configuration is generated from the parameter 4780h, «FS Config Name»: “SafetyConfig_” + 4780h+ “.lsc” Sequence: FDh --> Reboot --> 11h --> Save the complete configuration
FCh	Load non-safety configuration from the FC. The file “Config_*.pvl”is loaded (see command FDh). *Remark: Only one file must be on the FC, otherwise the selection is not clearly.* Sequence: FCh --> Reboot --> 22h --> load non-safety configuration
F0h - FBh	Reserved for future function

Table 31: Commands called by ID switches S1/S2

S11/S12 Positions	Commands
	Safe Address S11: High Nibble S12: Low Nibble
FFh	Load and validate the complete configuration from the FC. For the safety configuration, the file “SafetyConfig_*.lsc” is loaded. For the non-safety configuration, the file “Config_*.pvl” is loaded. *Remark: Only one file of each must be on the FC, otherwise the selection is not clearly.* Sequence: FFh --> Reboot --> FEh --> Load complete configuration --> Validate safety configuration

Table 32: Commands called by the safe address switches S11/S12

7.7.1 Default all parameters

All parameters (safe and non-safe parameters) can be set to their default values by the following sequence:

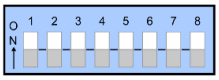
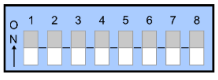
Steps		Description
1		Set ID switches S1/S2 to FFh.
2		Power cycle the drive.
3		Error and warn LEDs will blink alternating, ca 4 Hz.
4		Set ID switches S1/S2 to 00h.
5		Wait until Warn and EN LEDs blink together with ca. 2 Hz.
6		Power cycle the drive.

Table 33: Default all parameters

7.7.2 Save all parameters to FC with LinMot-Talk

All parameters can be saved by the drive itself to the inserted FC.
Preconditions:

- A valid FC must be inserted in the socked M1.
- The drive must be powered up or rebooted with the inserted M1.

Saving the parameters is started with the command --> Drive --> Safe Config to SD-Card.
Then follow the instructions. In case of a missing or invalid flash card, the appropriate message will be displayed.

7.7.3 Save all parameters to FC via ID Switches

All parameters can be saved by the drive itself to the inserted FC.

Preconditions:

- A valid FC must be inserted in the socked M1.
- The drive must be powered up or rebooted with the inserted M1.
- If no FC is inserted, the drive ignores the command and starts up normally.

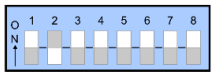
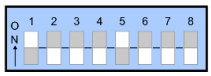
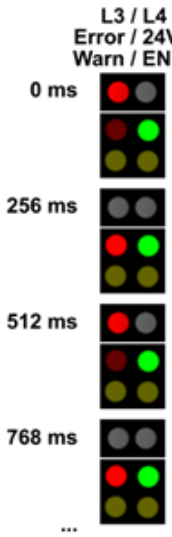
Steps		Description
1		Set ID switches S1/S2 to FDh.
2		Power cycle the drive.
3		Wait until LEDs L3 and L4 blink together red and green with ca. 4 Hz. If the drive starts up normally, no flash card is detected.
4		Set ID switches S1/S2 to 11h.
5a	No Error	The blinking stops. The drive safes the configuration and boots automatically. Wait until the drive has booted completely.
5b	Error 	In case of an error, the L3 and Error LEDs are alternating blinking at ca. 2 Hz. Possible errors: • The flash card is not compatible (no LinMot-Card, wrong type, …) • The flash card is not writable. • The flash Card is removed during operation. Required actions: • Check the error cause. • Reboot the drive.

Table 34: Safe all parameters to FC

7.7.4 Load non-safety parameters from the FC

All non-safe parameters are loaded to the drive.

Preconditions:

- A valid FC must be inserted in the socket M1.
- A valid configuration must be present on the FC.
- The drive must be powered up or rebooted with the inserted M1.
- If no FC is inserted, the drive ignores the command and starts up normally.

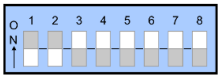
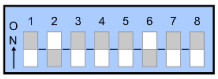
Steps		Description
1		Set ID switches S1/S2 to FCh.
2		Power cycle the drive.
3		Wait until LEDs L3 and L4 blink together red and green with ca. 4 Hz. If the drive starts up normally, no flash card is detected.
4		Set ID switches S1/S2 to 22h.
5a	No error	The blinking stops. The drive safes the configuration and boots automatically. Wait until the drive has booted completely.
5b	Error 	In case of an error, the L3 and Error LEDs are alternating blinking at ca. 2 Hz. Possible errors: • The flash card is not compatible (no LinMot-Card, wrong type, …). • The flash card is not writable. • The flash Card is removed during operation. • Configuration file is not readable. • Configuration is not compatible (HW and FW version). Required action: • Reboot or power cycle the drive • Check the error cause

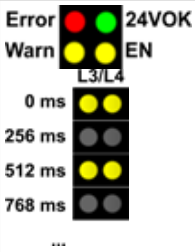
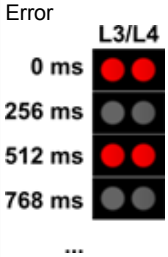
Table 35: Load non-safe parameters from the FC

7.7.5 Load and validate all Parameters from the FC

All parameters (safety and non-safety) are loaded and validated by this command.

Preconditions:

- A valid FC must be inserted in the socked M1.
- A valid configuration must be present on the FC.

Steps		Description
1		Set safe address switches S11/S12 to FFh
2		Power cycle the drive.
3		24VOK, Error, Warn and EN LEDs are always on during this sequence. Wait until LEDs L3 and L4 blink together yellow with ca. 2 Hz.
4		Set safe address switches S11/S12 to FEh.
5a	Command Acknowledge L3  L4	Wait until the L3/L4 LEDs show this state. Continue with step 6.
5b	Error 	In case of an error L3/L4 LEDs are blinking red together at ca. 2 Hz. Possible errors: • Flash Card not present. • Flash Card is not compatible (no LinMot-Card, wrong type, wrong formatting, …). • Configuration file is corrupt. • Configuration is not compatible (HW and FW version). • Configuration is not consistent (corrupt data). Required action: • Reboot or power cycle the drive. • Check the error cause.
6		Set S11 to 0 after setting S12. Set S12 to 1st nibble (least significant, e.g. 1A981C2**6**h) of Safety Parameter Checksum.
7	L3  L4	Wait until the L3/L4 LEDs show this state.

The table is continued on the next page.

Steps		Description
8		Set S11 to 1 after setting S12. Set S12 to 2nd CRC nibble (second least significant, e.g. 1A981C**2**6h)
9	L3  L4	Wait until the L3/L4 LEDs show this state.
10		Set S11 to 2 after setting S12. Set S12 to 3rd CRC nibble (e.g. 1A981**C**26h)
11	L3  L4	Wait until the L3/L4 LEDs show this state.
12		Set S11 to 3 after setting S12. Set S12 to 4th CRC nibble (e.g. 1A98**1**C26h)
13	L3  L4	Wait until the L3/L4 LEDs show this state.
14		Set S11 to 4 after setting S12. Set S12 to 5thCRC nibble (e.g. 1A9**8**1C26h)
15	L3  L4	Wait until the L3/L4 LEDs show this state.
16		Set S11 to 5 after setting S12. Set S12 to 6thCRC nibble (e.g. 1A**9**81C26h)
17	L3  L4	Wait until the L3/L4 LEDs show this state.
18		Set S11 to 6 after setting S12. Set S12 to 7thCRC nibble (e.g. 1**A**981C26h)
19	L3  L4	Wait until the L3/L4 LEDs show this state.
20		Set S11 to 7 after setting S12. Set S12 to the 8th CRC nibble (e.g. **1**A981C26h)

The table is continued on the next page.

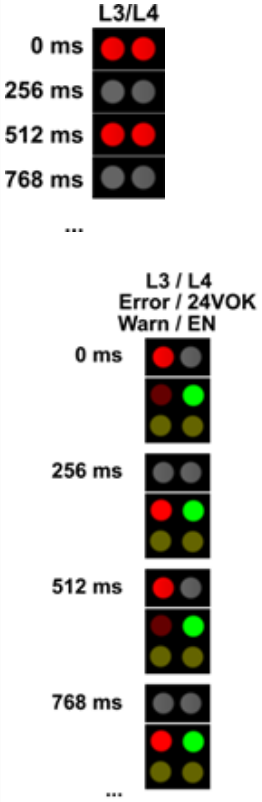
Steps		Description
21a	No Error	The drive loads the safety parameters and boots automatically. Wait until the drive has booted completely.
21b	Error 	L3/L4 LEDs are blinking red together at ca. 2 Hz. Possible errors: • The CRC is wrong. Recommended action: • Check the used CRC. • Reboot or powercycle and retry. L3 and Error LEDs are alternating blinking at ca. 2 Hz. This happens, when an error occurs when loading the non safety parameters. Possible errors: • The flash card is not compatible (no LinMot-Card, wrong type, …) • The flash card is not writable. • The flash Card is removed during operation. • Configuration file is not readable. • Configuration is not compatible (HW and FW version). Required action: • Reboot or power cycle the drive. • Check the error cause.

Table 36: Load complete parameters from the FC and validate the safety parameter

7.8 Safety Variables and Monitoring

The drive provides a list of variables for monitoring the safety states. All variables can be accessed via UPIDs and are shown in LinMot-Talk under \Variables\

7.8.1 Safety Variables on Safety Module

The variables related to the safety module are located under \Variables\OS Safety Module\:

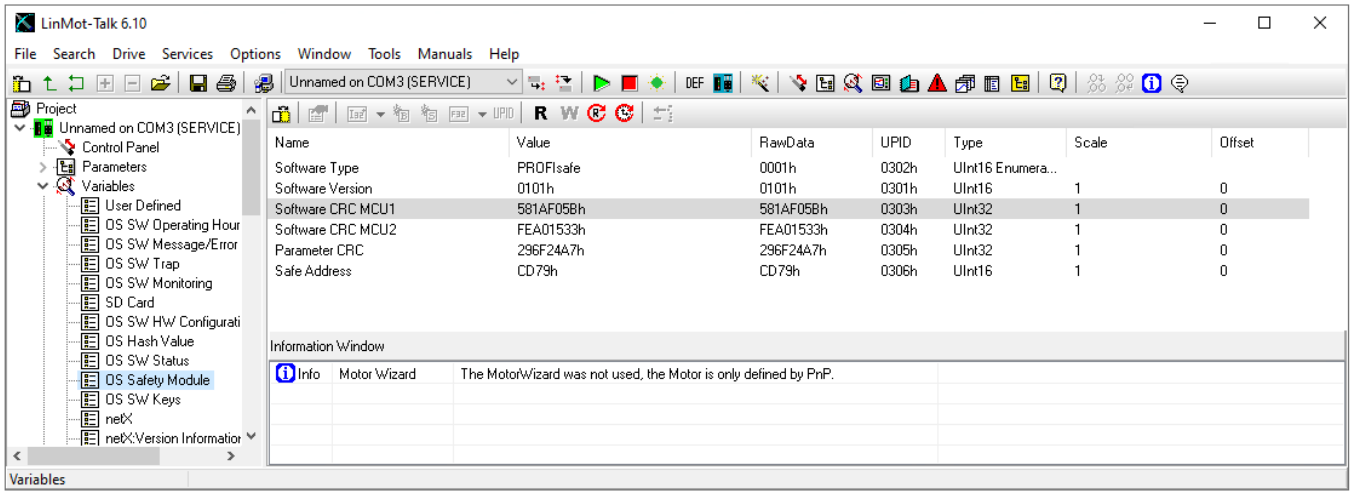


Figure 17: Safety Module Variables

Name	UPID Type	Value / Bit	Comments
Software Type	0302h Enum16	0001h	The installed firmware on the safety module is PROFIsafe. This firmware supports the PROFIsafe interface and the safety functions over the safe digital I/Os.
		0002h	The installed firmware on the safety module is EtherCAT FSoE. This firmware supports the FSoE interface and the safety functions over the safe digital I/Os.
Software Version	0301h UInt16	-	This parameter displays the software version installed on the safety module. The software version consists of two bytes which stand for the major and minor version. High Byte: major version Low Byte: minor version
Software CRC MCU1	0303h UInt32	-	This value shows the CRC over the MCU1 firmware.
Software CRC MCU2	0304h UInt32	-	This value shows the CRC over the MCU2 firmware.
Parameter CRC	0305h UInt32	-	This value shows the CRC over the values of the safety parameters. This CRC must be used when the configuration is loaded from the flash card.
Safe Address	0306h UInt16	-	This value shows the position of the safe address switches S11/S12 read at startup in the low byte. In the high byte the value is fixed, dependent of the selected safe fieldbus: • CDh in case of PROFIsafe • 4Ch in Case of FSoE

Table 37: Safety Module Variables

7.8.2 Functional Safety Variables

All variables related to the functional safety are located under \Variables\Functional Safety\

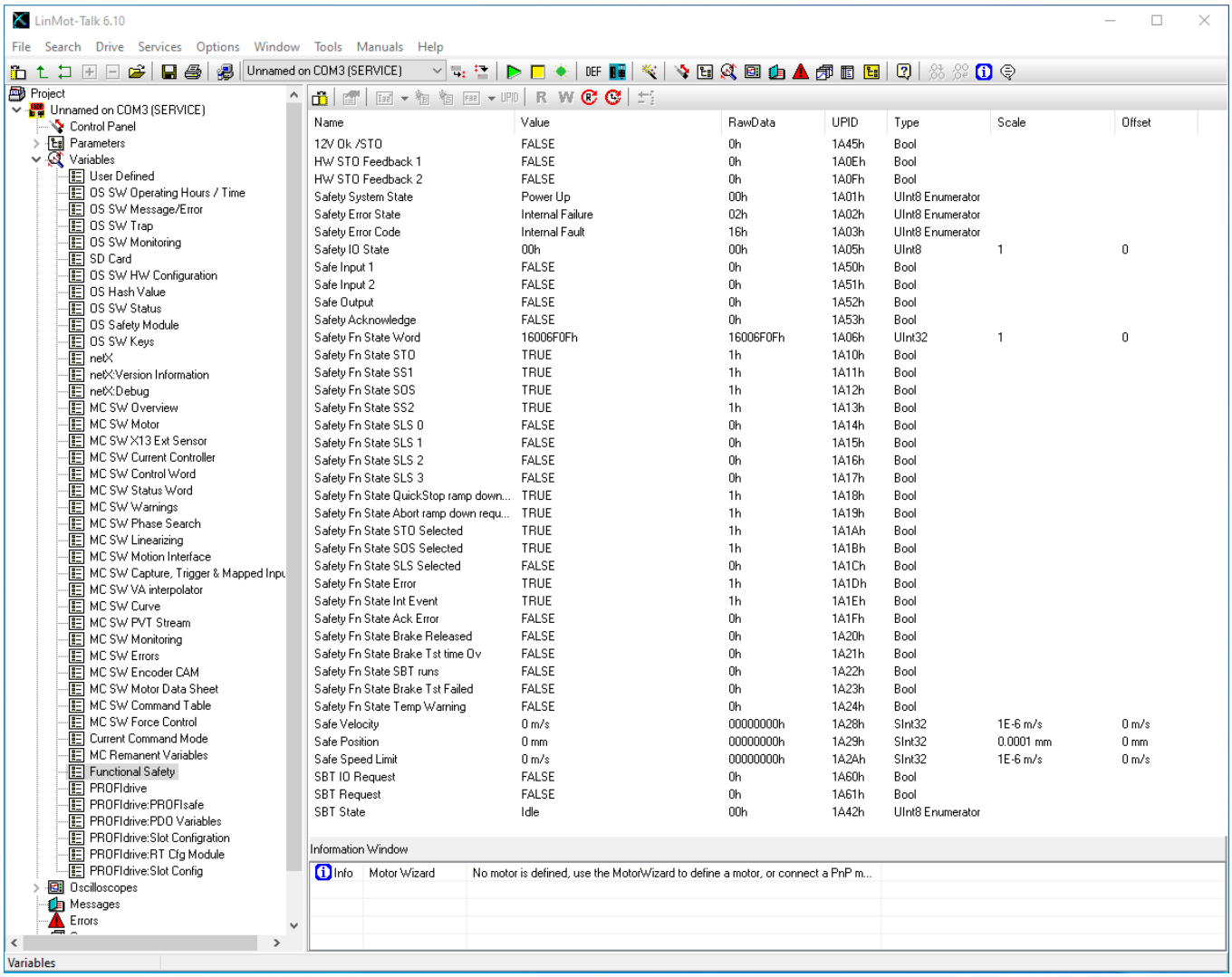


Figure 18: Safety Variables and States

7.8.2.1 HW Feedbacks

The STO is realized by two channels, which both must be active to enable the power stage (to leave the STO state). Both enables are monitored, the monitoring signals are HW STO feedback 1 and HW STO feedback 2.

Name	UPID Type	Value / Bit	Significance	Comments
12V Ok / STO	1A45h Bool	-	12 V Ok	This signal shows if the internal +12 V supply is ok (TRUE). It is mapped to the STO control word bit. The 12 V is generated out of the motor supply voltage.
HW STO Feedback 1	1A0Eh Bool	-	STO 1 feedback active	Set if the feedback of the STO 1 enable is active. The power stage is only active when both enables are active. Cleared if the power stage enable 1 is inactive.
HW STO Feedback 2	1A0Fh Bool	-	STO 2 feedback active	Set if the feedback of the STO 1 enable is active. The power stage is only active when both enables are active. Cleared if the power stage enable 2 is inactive.

Table 38: HW STO Feedback Signals

7.8.2.2 Safety System State

Name	UPID Type	Value / Bit	Significance	Comments
Safety System State	1A01h Enum8	00h	Power Up	The safety module is not started.
		01h	Start Up	The safety module is starting up. This will be present, while the connection to the safe fieldbus starts up.
		02h	Configuration needed	A new configuration is required. The configuration of the safety module may be broken.
		03h	Operation	The safety module is working normally. In this state, STO or the brake may be active.
		04h	Operation No Safety Active	The safety module is working normally, but no safety encoder is active.
		05h	Safe Brake Test	A brake test is processing. The test will be triggered by the drive processor.
		06h	Loading FS Par from FLASH Card	The safety module loads the parameter set from the flash card.
		07h-FFh	Invalid	Unused combinations.

Table 39: Safety System States

7.8.2.3 Safety Error State

Name	UPID Type	Value / Bit	Significance	Comments
Safety Error State	1A02h Enum8	00h	No Failure	No failure is detected
		01h	IO-Failure	The safety module has detected a failure that may be acknowledged. During this state STO and the brake will be active.
		02h	Internal Failure	Some severe failure occurred. The safety module does not release operation until it is power cycled.
		03h-FFh	Invalid	All other combinations of this 8bit variable are invalid.

Table 40: Safety Error States

7.8.2.4 Safety Error Codes

Name	UPID Type	Value / Bit	Significance	Comments
Safety Error Code	1A03h Enum8	00h	No Error	No error is present.
		01h	Safe Input Fault	An error on the safe inputs is detected. Possible faults: wiring, discrepancy between the two channels, disturbances, etc. Recommended action: check wiring, check configuration, contact support.
		02h	Safe Output Fault	An error on the safe digital output is detected. The internal diagnosis produces test pulses and checks the levels. Possible faults: Test pulses failed, wrong levels Recommended actions: check wiring, check configuration, contact support.
		03h	STO Output Fault	An error on the STO output is detected. The diagnosis is done internally. Recommended actions: Report error to provider, send drive back for repair or exchange it.
		04h	Ack Input Fault	An Error on the acknowledge input has been detected. The acknowledge input must only be switched when requested. Compare with UPID 1A19h, Drive Fn State Int Event. Recommended action: Check behavior of acknowledge control logic.
		05h	Encoder Communication Fault	The communication to the motor encoder has failed. Possible faults: Wiring, disturbances, cable Recommended actions: Check wiring to motor, contact support.
		06h	Encoder Fault	The motor position encoder has evaluation has generated an error. The signals are checked for consistency. Recommended actions: Check wiring, check configuration, contact support.
		07h	Power Supply Fault	An internal check referring the power supply has detected an error. Recommended actions: Report error to provider, send drive back for repair or exchange it.
		08h	Safe Fieldbus Fault	An error on the safe fieldbus has been detected. Possible faults: Communication without configuration, error in communication Recommended actions: Check firmware, wiring, configuration, PLC configuration. Contact support.
		09h	Error RAM Defective	A RAM fault has been detected. Recommended actions: Report error to provider, send drive back for repair or exchange it.
		0Ah	Safety FW CRC Wrong	The CRC of the firmware on the safety module is wrong. Recommended actions: Reinstall the complete firmware on the drive. Contact support.
		0Bh	CPU Fault	An error on the CPU has been detected. This is an internal error. Recommended actions: Report error provider, send drive back for repair or exchange it.
		0Ch	Stack Fault	An error with the stack has been detected. Recommended actions: Report error provider, send drive back for repair or exchange it.
		0Dh	Safety Parameter Invalid	The configuration of the safety parameters is not valid. Recommended actions: Check configuration, make validation. Contact support

The table is continued on the next page.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Error Code	1A03h Enum8	0Eh	Validation Failed	An error during the validation has been occurred. Recommended actions: Try again! Contact support
		0Fh	Authentication Failed	An error in authentication has occurred. Probably doesn't match the password Recommended actions: Use the correct password, default the configuration, reconfigure
		10h	Forbidden Safe Address	A forbidden value for the safe address is used. FFh is not allowed. Recommended action: Use a valid safe address
		11h	Safe Fieldbus Config Mismatch	A configuration error concerning the safe fieldbus is detected. Probably there is an active fieldbus communication without a valid configuration. Recommended action: check configuration
		12h	Brake Output Fault	The internal diagnosis for the brake output has detected a fault. Recommended actions: check configuration, check cabling, check brake, contact support
		13h	Temperature Error	The internal drive temperature has raised too high. Recommended actions: Check cooling (cabinet, fan, …), check application.
		14h	Timing Fault	An internal timing problem has been detected. Recommended actions: Report error to provider.
		15h	Internal Discrepancy	An internal discrepancy between the two monitoring channels has been detected. Recommended actions: Report error to provider.
		16h	Internal Fault	A nonspecific internal fault has been detected. Recommended actions: Report error to provider.
		17h	IO fault	A nonspecific IO fault has been detected. Recommended actions: Report error to provider.
		18h	FS Task less Calc Time	The safety task needs too much calculation time. Contact LinMot support.
		19h	FS Task Period Time too high	The safety task period time error. Contact LinMot support

Table 41: Safety Board Error Codes States

7.8.2.5 Safety IO States

The safety IO states give information about the evaluation and monitoring of safe digital IO signals, wired to X49a/b.

Name	UPID Type	Value / Bit	Significance	Comments
Safety IO State	1A05h UInt8	Bit 0	Safe Input 1	Set if channel a and b of the safe input 1 on X49a/b are active. Otherwise cleared. This status bit can also be accessed over UPID 1A50h.
		Bit 1	Safe Input 2	Set if channel a and b of the safe input 2 on X49a/b are active. Otherwise cleared. This status bit can also be accessed over UPID 1A51h.
		Bit 2	Safe Output	Set, of the safe digital output on X49a/b is active. Otherwise cleared. This status bit can also be accessed over UPID 1A52h.
		Bit 3	Safety Acknowledge	Set if the acknowledge input on X49a/b is active. Otherwise cleared. This status bit can also be accessed over UPID 1A53h.
		Bit 4-7	_	For internal use.
Safe Input 1	1A50h Bool	-	State of Safe Input 1	Set if channel a and b of the safe input 1 on X49a/b are active. Otherwise cleared. This status bit can also be accessed with UPID 1A05h, bit 0.
Safe Input 2	1A51h Bool	-	State of Safe Input 2	Set if channel a and b of the safe input 2 on X49a/b are active. Otherwise cleared. This status bit can also be accessed with UPID 1A05h, bit 1.
Safe Output	1A52h Bool	-	State of Safe Output	Set, of the safe digital output on X49a/b is active. Otherwise cleared. This status bit can also be accessed with UPID 1A05h, bit 2.
Safety Acknowledge	1A53h Bool	-	State of Safety Acknowledge Input	Set if the acknowledge input on X49a/b is active. Otherwise cleared This status bit can also be accessed with UPID 1A05h, bit 3.

Table 42: Safety IO States

7.8.2.6 Safety Function States

This section contains the variables related to the safety functions.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 0	STO active	Same as UPID 1A10h
		Bit 1	SS1 active	Same as UPID 1A11h
		Bit 2	SOS active	Same as UPID 1A12h
		Bit 3	SS2 active	Same as UPID 1A13h
		Bit 4	SLS 0 active	Same as UPID 1A14h
		Bit 5	SLS 1 active	Same as UPID 1A15h
		Bit 6	SLS 2 active	Same as UPID 1A16h
		Bit 7	SLS 3 active	Same as UPID 1A17h
		Bit 8	Quick Stop ramp down required	Same as UPID 1A18h
		Bit 9	Abort ramp down required	Same as UPID 1A19h
		Bit 10	STO selected	Same as UPID 1A1Ah
		Bit 11	SOS selected	Same as UPID 1A1Bh
		Bit 12	SLS selected	Same as UPID 1A1Ch
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
		Bit 15	Acknowledge Error	Same as UPID 1A1Fh
		Bit 16	Brake Released	Same as UPID 1A20h
		Bit 17	Brake Test Time elapsed	Same as UPID 1A21h
		Bit 18	SBT runs	Same as UPID 1A22h
		Bit 19	Brake Test failed	Same as UPID 1A23h
		Bit 20	Drive Temperature Warning	Same as UPID 1A24h
		Bits 21-31	-	not used
Safety Fn State STO	1A10h Bool	-	STO active	Set if the STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process of a fault reaction from a fault in the safety fault buffer or a demand from safe fieldbus. Cleared if the STO safety function is inactive and torque/force may be generated from the drive. This bit can also be accessed via UPID 1A06h bit 0.

The table is continued on the next page.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State SS1	1A11h Bool	-	SS1 active	Set if the SS1 safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SS1 safety function is inactive This bit can also be accessed via UPID 1A06h bit 1.
Safety Fn State SOS	1A12h Bool	-	SOS active	Set if the SOS safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SOS safety function is inactive. This bit can also be accessed via UPID 1A06h bit 2.
Safety Fn State SS2	1A13h Bool	-	SS2 active	Set if the SS2 safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SS2 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 3.
Safety Fn State SLS 0	1A14h Bool	-	SLS 0 active	Set if the SLS 0 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 0 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 4.
Safety Fn State SLS 1	1A15h Bool	-	SLS 1 active	Set if the SLS 1 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 1 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 5
Safety Fn State SLS 2	1A16h Bool	-	SLS 2 active	Set if the SLS 2 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 2 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 6.
Safety Fn State SLS 3	1A17h Bool	-	SLS 3 active	Set if the SLS 3 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 3 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 7.
Safety Fn State QuickStop ramp down required	1A18h Bool	-	Quick Stop ramp down required	This bit is the command for the MC-SW to execute a Quick Stop speed ramp down. This bit can also be accessed via UPID 1A06h bit 8.
Safety Fn State Abort ramp down required	1A19h Bool	-	Abort ramp down required	This bit is the command for the MC-SW to execute an Abort speed ramp down. This bit can also be accessed via UPID 1A06h bit 9.
Safety Fn State STO Selected	1A1Ah Bool		STO selected	safety module has detected a request for STO, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 10.

The table is continued on the next page.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State SOS Selected	1A1Bh Bool		SOS selected	The safety module has detected a request for SOS, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 11.
Safety Fn State SLS Selected	1A1Ch Bool	-	SLS selected	The safety module has detected a request for one of the four SLS instances. This bit can also be accessed via UPID 1A06h bit 12.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Internal Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an internal event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Fn State Ack Error	1A1Fh Bool	-	Indicates an acknowledge error	An error on the acknowledge input has been detected. The acknowledge input must only be switched when requested. Compare with UPID 1A19h, Safety Fn State Int Event. Recommended action: Check behavior of acknowledge control logic This bit can also be accessed via UPID 1A06h bit 15.
Safety Fn State Brake Released	1A20h Bool	-	Brake is released	Set if the brake is actively driven and should be released (not braking). Cleared if the brake is not driven and should be braking. This bit can also be accessed via UPID 1A06h bit 16.
Safety Fn State Brake Tst time Ov	1A21h Bool	-	Brake Test Time elapsed	Set if the time, specified in parameter 47DAh “SBT Request Interval” is elapsed. A brake test must be performed to clear this flag. Then the interval time restarts counting. Cleared if the brake test interval, specified in parameter 47DAh has not elapsed. This bit can also be accessed via UPID 1A06h bit 17.
Safety Fn State SBT runs	1A22h Bool	-	SBT runs	SBT sequence is running. This bit can also be accessed via UPID 1A06h bit 18.
Safety Fn State Brake Tst Failed	1A23h Bool	-	Brake Test failed	An error during the brake test has been detected. Possible causes: brake does not work correctly, motor has moved. Recommended actions: Check brake, check wiring. This bit can also be accessed via UPID 1A06h bit 19.
Safety Fn State Temp Warning	1A24h Bool		Drive temperature warning is active	Set if the drive internal temperature monitoring has detected an high temperature and has set the temperature warning. Cleared if the drive temperature is ok. This bit can also be accessed via UPID 1A06h bit 20.

Table 43: Safety Function States

7.8.2.7 Safe Velocity and Position

This section contains the variables related to the safety functions on the system board.

Name	UPID Type	Unit	Comments
Safe Velocity	1A28h SInt32	1um/s	This variable contains the actual motor velocity, evaluated by the safety board.
Safe Position	1A29h SInt32	0.1um	This variable contains the actual motor position, evaluated by the safety board.
Safe Speed Limit	1A2Ah SInt32	1um/s	This variable contains the actual speed limit, with which the safety module compares the actual safety velocity (UPID 1A28h).

Table 44: Safe Velocity and Position

7.8.2.8 Safe Brake Test States

Name	UPID Type	Value / Bit	Significance	Comments
SBT IO Request	1A60h Bool	-	Request via IO	This value represents the IO request for SBT. On X4, the digital inputs can be configured to “Req SBT”. Make sure maximal one input is configured to request SBT. If either SBT IO Request or SBT Request becomes active, the SBT will be started.
SBT Request	1A61h Bool	-	Request via Bus	This variable can be written from the RT interface to request SBT. A rising edge starts the SBT sequence. If either the SBT IO Request or the SBT Request becomes active, the SBT will be started.
SBT State	1A42h Enum8	00h	Idle	SBT is in idle state.
		01h	Enable Power Stage	The power stage becomes active and the motor current can be driven.
		02h	Set Positive Current	The current is setting up to the defined brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		03h	Positive Current Applied	The current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		04h	Set Negative Current	The current is setting up to the defined negative brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		05h	Negative Current Applied	The negative current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		06h	Reset Current	The current will be set to zero.

Table 45: SBT Monitoring

7.8.3 Safety State Diagram

The lower part of the following diagram shows the system states from startup to normal operation. Parallel to theses states the monitoring functions are active. In the upper part, the state transitions in case of errors are shown.

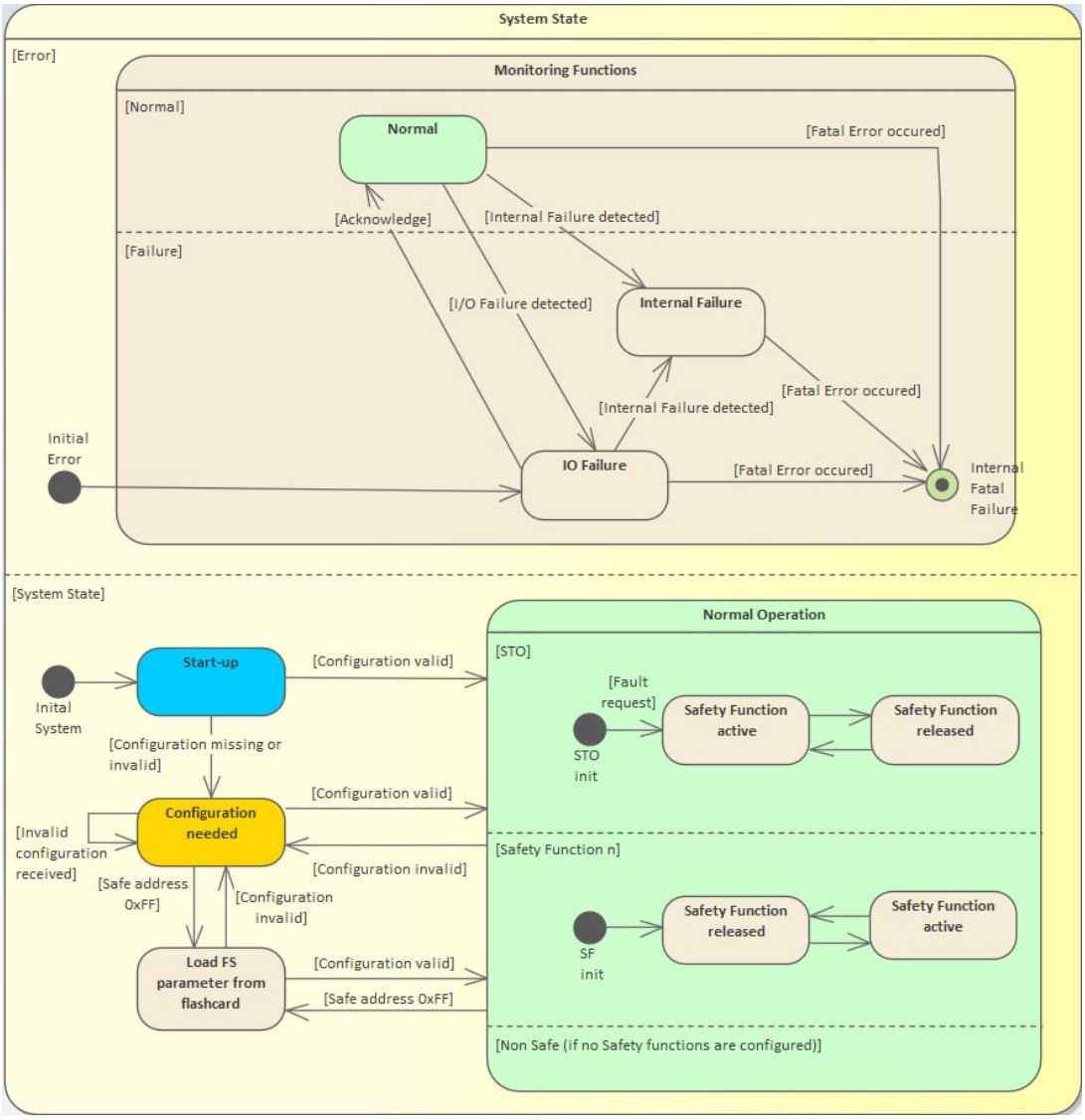


Figure 19: Safety state diagram

7.8.3.1 Safe State

The safe state consists of the following points:

- STO is implemented as safe state, because STO has the highest priority.
- The STO outputs are de-energized.
- The safe digital outputs are de-energized.
- The brakes are applied.
- The software uses the activation sequence for the safety function STO, when entering the safe state.
- If requested via safe fieldbus the brake is allowed to be released during STO.
- If no safety parameters are present, the software assumes the brakes to be present, and all parameterized times and filter settings to be zero

7.8.3.2 Start-up

At startup, the safety FW checks the safety parameters for validity, if the parameters are not valid or the safe address switches S11/S12 are set to FFh at power up, it is changed into the state “Configuration needed”. If a valid configuration is found (CRC and version are correct) the normal operation is called.

At startup, the STO is active and a startup lock event is active, in this state an IO Failure will be displayed. To leave this startup lock state an acknowledge over the safe fieldbus or safe IO is required.

In the delivery state, or when the complete drive firmware is reinstalled or defaulted, the safety parameters are valid but no safety function is active shown by state “Operation No Safety Active”.

7.8.3.3 Configuration needed

This state is entered if the no valid safety configuration is found or if the safe address switches S11/S12 are set to FFh at start-up.

In case of the safe address switches S11/S12 are set to FFh, a valid flash card with a configuration must be inserted. If this is found the process to load the configuration from the flash card is started. This process is described in detail in chapter 7.7.5 - Load and validate all Parameters from the FC .

In case of the safe address switches are not set to FFh or no valid flash card is found, the firmware keeps in this state, the communication to the drive is active and a configuration is awaited. When the configuration is loaded, a restart is necessary.

7.8.3.4 Load FS Parameter From Flashcard

This state is called from configuration needed when the safe address switches S11/S12 are set to FFh at power up. The configuration is automatically loaded from the flash card. For details see 7.7.5 - Load and validate all Parameters from the FC .

When a valid configuration is loaded, the normal operation is started.

7.8.3.5 Normal Operation

After start-up is finished and a valid safety configuration is loaded, the normal operation becomes active. In this state the safety functions are active. Depending on the configuration the brake and position signals are monitored. The safety functions will become active when requested.

7.8.3.6 IO Failure

The state “IO Failure is reached after startup “startup lock” or when an error with IO-wiring is detected. IO failures are active, as long as the error source is present. The IO failures can be acknowledged.

All possible failures are listed in chapter 7.8.3.10 - Failure classification and reaction.

7.8.3.7 Internal Failure

The state “Internal Failure” is reached if a HW failure is detected. If this occurs the HW has normally to be replaced. In this state the communication is still active and the failure is displayed with the LinMot-Talk. The internal failures can only be acknowledged by a reboot (reset, or power cycle).

All possible failures are listed in chapter 7.8.3.10 - Failure classification and reaction.

7.8.3.8 Internal Fatal Failure

The state internal fatal failure is active when the system cannot guarantee a controlled processing. The safe state becomes active. The communication is stopped, in LinMot-Talk the Safety Panel is disabled and does not show the state anymore. The internal fatal failures can only be acknowledged by a reboot (reset, or power cycle).
All possible failures are listed in chapter 7.8.3.10 - Failure classification and reaction.

7.8.3.9 Monitoring Functions

During the start-up sequence and parallel to the normal operation state, a continuous monitoring takes place.

Monitoring consists of the following substates Normal, Internal Failure, IO Failure and Internal Fatal Failure.

The different errors and the reactions are listed in the following chapter.

7.8.3.10 Failure classification and reaction

The table below shows the failures that are detected and their error reaction.

Remark: Failure State clarifies if the failure is fatal or not. Fatal means, that the drive has to be rebooted or power cycled to acknowledge the error.

Failure	Failure State Fatality	Error Code	Communi-cation active	Safe Fieldbus active	Failure Reaction	Comments
Safe Digital Input Fault	IO Failure Non-fatal	01A6h	yes	yes	SS1	An error on the safe inputs is detected. Possible faults: wiring, discrepancy between the two channels, disturbances, … Recommended action: check wiring, check configuration, contact support.
Safe Digital Output Fault	Internal failure Fatal	02A6h	yes	no	STO Safe State	An error on the safe digital output is detected. The internal diagnosis produces test pulses and checks the levels. Possible faults: Test pulses failed, wrong levels Recommended actions: check wiring, check configuration, contact support.
STO Output fault	Internal failure Fatal	03A6h	yes	no	STO Safe State	An error on the STO output is detected. The diagnosis is done internally. Recommended actions: Report error to provider, send drive back for repair or exchange it.
Acknowledge input fault	Internal failure Fatal	04A6h	yes	no	STO Safe State	An Error on the acknowledge input has been detected. The acknowledge input must only be switched when requested. Compare with UPID 1A19h, Drive Fn State Int Event. Recommended action: Check behavior of acknowledge control logic.
Encoder communication fault	Internal failure Fatal	05A6h	yes	no	STO Safe State	The communication to the motor encoder has failed. Possible faults: Wiring, disturbances, cable Recommended actions: Check wiring to motor, contact support.

The table is continued on the next page.

Failure	Failure State Fatality	Error Code	Communi-cation active	Safe Fieldbus active	Failure Reaction	Comments
Encoder fault	IO failure Non-fatal	06A6h	yes	yes	STO	The motor position encoder evaluation has generated an error. The signals are checked for consistency. Recommended actions: Check wiring, check configuration, contact support.
Safe fieldbus fault	IO failure Non-fatal	08A6h	yes	yes	SS1	An error on the safe fieldbus has been detected. Possible faults: Communication without configuration, error in communication Recommended actions: Check firmware, wiring, configuration, PLC configuration. Contact support.
Safety parameter invalid	IO failure Non-fatal	0DA6h	yes	yes	STO	The configuration of the safety parameters is not valid. Recommended actions: Check configuration, make validation. Contact support
Safe fieldbus config	IO failure Non-atal	11A6h	yes	no	SS1	A configuration error concerning the safe fieldbus is detected. Possible fault: Probably there is an active fieldbus communication without a valid configuration. Recommended action: check configuration
Brake output fault	IO failure Non-fatal	12A6h	yes	yes	SS1	The internal diagnosis for the brake output has detected a fault. Recommended actions: check configuration, check cabling, check brake, contact support
Temperature fault	Internal failure Fatal	13A6h	yes	no	STO Safe State	The internal drive temperature has raised too high. Recommended actions: Check cooling (cabinet, fan, …), check application.
CrossCom Timing fault	Internal failure Fatal	14A6h	no	no	STO Safe State	An internal timing problem has been detected. Recommended action: Report error to provider.
Internal Discrepancy	Internal failure Fatal	15A6h	yes	no	STO Safe State	An internal discrepancy between the two monitoring channels has been detected. Recommended action: Report error to provider.
Internal Fault	Internal failure Fatal	16A6h	no	no	STO/SS1	A nonspecific internal fault has been detected. Recommended action: Report error to provider.
IO fault	IO failure Non-Fatal	17A6h	yes	yes	STO/SS1	A nonspecific IO fault has been detected. Recommended action: Report error to provider.
FS Task less calc time	Internal failure Fatal	18A6h	yes	no	STO Safe State	The safety task needs too much calculation time. Recommended action: Contact LinMot support.
FS Task period time too high	Internal failure	19A6h	yes	no	STO Safe State	The safety task period time takes too long. Recommended action: Contact LinMot support
SBT error	none Non-fatal	20A6h	yes	yes	none	An error is detected during the safe brake test. Possible fault: Typically the brake does not hold the motor. Recommended action: Check brake, if it still clamps correctly, check if there is dirt or grease.
SBT state error	none Non-fatal	21A6h	yes	yes	none	The safe brake test has started in the wrong state. Recommended action: Make sure that the SBT is started in the disabled state

Table 46: Failure classification and reaction

7.9 General Safety Settings

7.9.1 General Settings parameters

The parameters for the general settings are located under \Parameters\Safety\General Settings\

Name	UPID Type Unit	Description	Min	Max	Typical
FS Parameter Version	47A0h UInt16 -	This parameter shows the parameter version of the safety parameters. The safety firmware checks if the version fits. In case of a mismatch, a Safety Parameter Invalid error will be reported on UPID 1A03h. *Remark: This parameter should be used as read only, except in case of importing a configuration, with a different FS Parameter Version number.*	-	-	0100h
FS Software Version	47A1h UInt16 -	This parameter shows the software version of the safety parameters, for which they are developed. The safety firmware checks if the version fits. In case of a mismatch, a Safety Parameter Invalid error will be reported on UPID 1A03h *Remark: This parameter should be used as read only, except in case of importing a configuration, with a different FS Software Version number. .*	-	-	0101h
FS Configuration Name	4780h String -	The name of the safety configuration, given by the engineer. This is a string with a maximal size of 24 characters.	-	-	“No Safety”
Speed Computation Time	47A3h UInt8 ms	The speed is computed over this time interval. The software will store the position data for this time interval and compute the difference between the selected entries. The speed is then divided by the time selected.	1ms	10ms	2ms

Table 47: General settings parameters

7.10 PROFIsafe Fieldbus

7.10.1 Description

The drive supports the PROFIsafe interface for safe ETHERNET real time communication with the PLC.

The functional description of the PROFIsafe interface is documented in /MA_PROFIdrive/.

The connectors for the safe field bus are X17 and X18 for looping through.

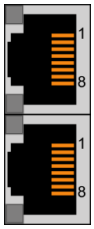
X17 – X18	Real Time Ethernet 10/100 Mbit/s	
	X17 RT ETH In X18 RT ETH Out	Specification depends on RT Bus. Please refer to according documentation.
RJ-45	Warning: Do not connect the real time bus directly to the internet!	

Table 48: X17/X18 Real Time Ethernet 10/100 Mbit/s

- PROFIdrive slave and the PROFINET slave are supported by the drive.
- PROFIsafe Telegram 30 (4-bytes CRC)
- SBT with telegram 701, fieldbus (Parameter Channel) or X4 input
- The drive supports PROFINET minimal cycle times of 1ms.
- The drive supports a cycle time of at least 5ms.
- The PROFIsafe implementation is compatible to the PROFIsafe Masters: Siemens PLC S7 1500

7.10.2 Safe Fieldbus Address

The safe fieldbus address must be set via the S11 and S12 switches. The safe address is a 16 bit value and consists of "CDh" (PROFIsafe) or "4Ch" (FSoE) in the high byte (this value comes from the Vendor ID) and in the low byte is the position of S11 and S12. The same address has to be configured on the PLC side. When starting up the safe fieldbus, this address is checked. Only in case of a match, the bus starts up correctly.

S11 / S12	Safe Address	
	S11	High nibble of safe address low byte
	S12	Low nibble of safe address low byte

Table 49: S11 / S12: Safe Address Switches

Note: The safe address value is shown with variable "Safe Address", UPID 0306h. The upper byte is taken from the Vendor ID and is set fixed to CDh in case of PROFIsafe or 4Ch in case of FSoE.

7.10.3 Safe Fieldbus Configuration

The parameters for setting up the safe fieldbus are located under \Parameters\Safety\General Settings\

Name	UPID Type	Description
Safe Fieldbus Activation	47A4h UInt8	Specified if the safe fieldbus is enabled. The following selections can be done: • 00h: No Safe Fieldbus (Default) • 01h: PROFIsafe • 02h: EtherCAT FSoE

Table 50 Safe Fieldbus Parameters

7.10.4 Structure of Telegram 30

PROFIsafe telegram 30 consists of a control and status word, which mappings are shown in the next subchapters.

7.10.4.1 PROFIsafe control word (S_ STW1)

Bit	Meaning	Value	Significance	Comments
0	STO	1	Deselect STO	Set to 1 if the STO safety function is deactivated immediately if there is no other constraint for STO (Fault entry in Safety Fault Buffer with error response STO or other safety function active with sub state STO).
		0	Select STO	The STO safety function is activated immediately and the DO general state machine is forced to S1 by an internal “coast stop” command. STO can be used with non-safe position sensors.
1	SS1	1	Deselect SS1	The SS1 safety function is deactivated immediately if there is no other constraint for SS1 (Fault entry in Safety Fault Buffer with error response SS1 or other safety function active with sub state STO).
		0	Select SS1	The SS1 safety function is activated immediately and the DO general state machine is forced to S5 by an internal “quick stop” command. At the same time monitoring (t1) is started. After controlled deceleration, STO is activated. SS1 can be used with non-safe position sensors.
2	SS2	1	Deselect SS2	The SS2 safety function is deactivated immediately if there is no other constraint for SS2 (Fault entry in Safety Fault Buffer with error response SS2 or other safety function active with sub state SS2).
		0	Select SS2	The SS2 safety function is activated immediately and the DO general state machine is forced to S5 by an internal “quick stop” command. At the same time monitoring (t1) is started. After controlled deceleration, SOS is activated. SS2 can only be used with safe position sensors.
3	SOS	1	Deselect SOS	The SOS safety function is deactivated immediately if there is no other constraint for SOS (Fault entry in Safety Fault Buffer with error response SOS or other safety function active with sub state SOS).
		0	Select SOS	The ramp down supervision (time out or ramp monitor) is activated. After successful deceleration, the SOS safety function is activated. SS2 can only be used with safe position sensors.
4	SLS	1	Deselect SLS	The SLS safety function is deactivated immediately if there is no other constraint for SLS (Fault entry in Safety Fault Buffer with error response SLS or other safety function active with sub state SLS).
		0	Select SLS	The ramp down supervision (time out or ramp monitor) is activated. After successful deceleration, the SLS safety function is activated. SLS can only be used with safe position sensors.
5, 6, 8	-	-	reserved	Function is not supported.
7	ACK	1	No Significance	
		0	Safety Fault Buffer Fault Acknowledge (1 --> 0)	The group error signal INTERNAL_EVENT is acknowledged with a negative edge; the fault entries in the actual fault situation of the Safety Fault Buffer are shifted to the last acknowledged fault situation. Faults which are still present or not acknowledgeable appear again in the actual fault situation. The general behavior of the Safety Fault Buffer is equal to the standard PROFIdrive fault buffer.
9 10	SLS BIT 0 SLS BIT 1	0-3	SLS level selection	With these two bits the SLS level is selected and requested. SLS BIT 0 is the low, SLS BIT 1 is the high bit of the selection. The SLS is requested with bit 4 in S_STW1. The following mapping is done: 0: select SLS 0 1: select SLS 1 2: select SLS 2 3: select SLS 3
11-15			Device-specific	Definitions not specified.

Table 51: Assignment of the safety control word 1 bits (S_STW1)

7.10.4.2 PROFIsafe Status word (S_ ZSW1)

Bit	Meaning	Value	Significance	Comments
0	STO	1	STO active	The STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process (S_STW), of a fault reaction from a fault in the safety fault buffer or a demand from the PROFIdrive on PROFIsafe Safety Function State Machines.
		0	STO inactive	The STO safety function is inactive and torque/force may be generated from the drive.
1	SS1	1	SS1 active	The SS1 safety function is active. The activation may be a result from a demand of the Safety Application Process (S_STW), of a fault reaction from a fault in the safety fault buffer or a demand from the PROFIdrive on PROFIsafe Safety Function State Machines.
		0	SS1 inactive	The SS1 safety function is inactive.
2	SS2	1	SS2 active	The SS2 safety function is active. The activation may be a result from a demand of the Safety Application Process (S_STW), of a fault reaction from a fault in the safety fault buffer or a demand from the PROFIdrive on PROFIsafe Safety Function State Machines.
		0	SS2 inactive	The SS2 safety function is inactive
3	SOS	1	SOS active	The SOS safety function is active. The activation may be a result from a demand of the Safety Application Process (S_STW), of a fault reaction from a fault in the safety fault buffer or a demand from the PROFIdrive on PROFIsafe Safety Function State Machines.
		0	SOS inactive	The SOS safety function is inactive.
4	SLS	1	SLS active	The SLS safety function is active. The activation may be a result from a demand of the Safety Application Process (S_STW), or a demand from the PROFIdrive on PROFIsafe Safety Function State Machines.
		0	Select SLS	The SLS safety function is inactive.
5, 6	-	-	reserved	Function is not supported.
7	ACK	1	Safety Fault Buffer Fault present (INTERNAL_EVENT)	Unacknowledged faults or currently not acknowledgeable faults are present in the Safety Fault Buffer. The general behavior of the Safety Fault Buffer is equal to the standard PROFIdrive fault buffer.
		0	No Safety Fault present	There is no fault in the Drive Safety Process present (= no fault entry in the actual fault situation of the Safety Fault Buffer).
8	-	-	reserved	Function is not supported.
9-10	SLS BIT 0 SLS BIT 1	0-3	Selected SLS level	With these two bits the selected SLS level shown. SLS BIT 0 is the low, SLS BIT 1 is the high bit of the selection. The following mapping is done: 0: SLS 0 is selected 1: SLS 1 is selected 2: SLS 2 is selected 3: SLS 3 is selected The feedback if SLS active is shown with bit 4 in S_ZSW1.
11	SOS SELECTED		SOS CMD active	This bit is high when the SOS request has been detected. (Otherwise low). If SOS is active is shown with bit 3 in S_ZSW1.
12-15	-	-	reserved	Function is not supported.

Table 52: Assignment of the safety status word 1 bits (S_ZSW1)

7.11 FSoE Fieldbus

7.11.1 Description

The drive supports the FSoE interface for safety over EtherCAT with the PLC.

The functional description of the FSoE is documented in /MA_FSoE/.

The connectors for the safe field bus are X17 and X18 for looping through.

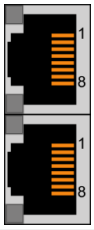
X17 – X18	Real Time Ethernet 10/100 Mbit/s	
	X17 RT ETH In X18 RT ETH Out	Specification depends on RT Bus. Please refer to according documentation.
RJ-45	Warning: Do not connect the real time bus directly to the internet!	

Table 53: X17/X18 Real Time Ethernet 10/100 Mbit/s

- The safety drive profile is supported with a 16bit FSoE controlword; safe PLC -> drive
- The safety drive profile is supported with a 16bit FSoE statusword and a 16 bit safe position; drive -> safe PLC
- SBT is supported with the nonsafe access to UPIDs 1A61h SBT request and 1A42h SBT state
- The drive supports minimal EtherCAT cycle times of 0.5ms.
- The drive supports a safety cycle time of at least 5ms.
- The FSoE implementation is compatible to the Beckhoff FSoE Masters: EL6900 and EL6910

7.11.2 Safe Fieldbus Address

The safe fieldbus address must be set via the S11 and S12 switches. The safe address is a 16 bit value and consists of "4Ch" in the high byte (this value comes from the Vendor ID) and in the low byte is the position of S11 and S12. The same address has to be configured on the PLC side. When starting up the safe fieldbus, this address is checked. Only in case of a match, the bus starts up correctly.

S11 / S12	Safe Address	
	S11 S12	High nibble of safe address Low nibble of safe address

Table 54: S11 / S12: Safe Address Switches

Note: The safe address value is shown with variable "Safe Address", UPID 0306h. The upper byte is set fixed to 4Ch, which is taken from the Vendor ID.

7.11.3 Safe Fieldbus Configuration

Name	UPID Type	Description
Safe Fieldbus Activation	47A4h UInt8	Specified if the safe fieldbus is enabled. The following selections can be done: • 00h: No Safe Fieldbus (Default) • 01h: PROFIsafe • 02h: EtherCAT FSoE

Table 55: Safe Fieldbus Parameter

7.11.4 FSoE Data Structures

The data, which is cyclically transferred between PLC and drive is listed in the following tables. The PLC is the communication master. The drive is the communication slave.

Data sent from the PLC to the drive has the following layout:

Name	Size
FSoE master command	8 bit
FSoE master controlword	**16 bit**
FSoE master CRC_0	16 bit
FSoE master connectionID	16 bit

Table 56 : FSoE data from PLC to drive

Data sent from the drive to the PLC has the following layout:

Name	Size
FSoE slave command	8 bit
FSoE slave statusword	**16 bit**
FSoE slave CRC_0	16 bit
FSoE slave safe position	**16 bit**
FSoE slave CRC_1	16 bit
FSoE slave connectionID	16 bit

Table 57: FSoE data from Drive to PLC

7.11.4.1 FSoE controlword

The following table shows the FSoE controlword, which is sent from the PLC to the drive.

Bit	Meaning	Value	Significance	Comments
0	STO	1	Deselect STO	Set to 1 if the STO safety function is deactivated immediately if there is no other constraint for STO (Fault entry in Safety Fault Buffer with error response STO or other safety function active with sub state STO).
		0	Select STO	The STO safety function is activated immediately, and the DO general state machine is forced to S1 by an internal “coast stop” command. STO can be used with non-safe position sensors.
1	SS1	1	Deselect SS1	The SS1 safety function is deactivated immediately if there is no other constraint for SS1 (Fault entry in Safety Fault Buffer with error response SS1 or other safety function active with sub state STO).
		0	Select SS1	The SS1 safety function is activated immediately, and the DO general state machine is forced to S5 by an internal “quick stop” command. At the same time monitoring (t1) is started. After controlled deceleration, STO is activated. SS1 can be used with non-safe position sensors.
2	SS2	1	Deselect SS2	The SS2 safety function is deactivated immediately if there is no other constraint for SS2 (Fault entry in Safety Fault Buffer with error response SS2 or other safety function active with sub state SS2).
		0	Select SS2	The SS2 safety function is activated immediately, and the DO general state machine is forced to S5 by an internal “quick stop” command. At the same time monitoring (t1) is started. After controlled deceleration, SOS is activated. SS2 can only be used with safe position sensors.
3	SOS	1	Deselect SOS	The SOS safety function is deactivated immediately if there is no other constraint for SOS (Fault entry in Safety Fault Buffer with error response SOS or other safety function active with sub state SOS).
		0	Select SOS	The ramp down supervision (time out or ramp monitor) is activated. After successful deceleration, the SOS safety function is activated. SS2 can only be used with safe position sensors.
4-6	-	-	-	Function is not supported.
7	Error Ack	1	No Significance	-
		0	Safety Fault Buffer Fault Acknowledge (1 --> 0)	The group error signal INTERNAL_EVENT is acknowledged with a negative edge; the fault entries in the actual fault situation of the Safety Fault Buffer are shifted to the last acknowledged fault situation. Faults which are still present or not acknowledgeable appear again in the actual fault situation. The general behavior of the Safety Fault Buffer is equal to the standard FSoE fault buffer.
8	SLS_0	1	Deselect SLS 0	The SLS 0 safety function is deactivated immediately if there is no other constraint for SLS 0 (Fault entry in Safety Fault Buffer with error response SLS 0 or other safety function active with sub state SLS 0).
		0	Select SLS 0	The ramp down supervision (time out or ramp monitor) is activated. After successful deceleration, the SLS 0 safety function is activated. SLS 0 can only be used with safe position sensors.
9	SLS_1			SLS 1 control bit. Same behavior as described for SLS 0 in bit 8.
10	SLS_2			SLS 2 control bit. Same behavior as described for SLS 0 in bit 8.
11	SLS_3			SLS 3 control bit. Same behavior as described for SLS 0 in bit 8.
12-15	-	-	-	Function is not supported.

Table 58: Assignment of the FSoE controlword

7.11.4.2 FSoE statusword

The following table shows the FSoE statusword, which is sent from the drive to the PLC.

Bit	Name	Value	Significance	Description
0	STO Active	1	STO active	The STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the safety application process (FSoE controlword), a request on a safe digital input or a fault reaction from a fault in the safety fault buffer.
		0	STO inactive	STO function is inactive, torque/force may be generated from the drive.
1-2	-	-	unused	Function is not supported.
3	SOS Active	1	SOS active	The SOS safety function is active. The activation may be a result from a demand of the safety application process (FSoE controlword) or a fault reaction from a fault in the safety fault buffer.
		0	SOS inactive	The SOS safety function is inactive.
4-6	-	-	unused	Function is not supported
7	Error	1	Safety Fault Buffer Fault present	Unacknowledged faults or currently not acknowledgeable faults are present in the Safety Fault Buffer. Attention! At startup this bit is set and has to be acknowledged first.
		0	No Safety Fault present	There is no fault in the Drive Safety Process present (= no fault entry in the actual fault situation of the Safety Fault Buffer).
8	SLS_0 Active	1	SLS 0 active	The SLS 0 safety function is active. The activation may be a result from a demand of the safety application process, or a demand from the FSoE controlword.
		0	SLS 0 inactive	The SLS 0 safety function is inactive.
9	SLS_1 Active	1	SLS 1 active	SLS 1 status bit. Same behavior as described for SLS 0 in bit 8.
10	SLS_2 Active	1	SLS 2 active	SLS 2 status bit. Same behavior as described for SLS 0 in bit 8.
11	SLS_3 Actvie	1	SLS 3 active	SLS 3 status bit. Same behavior as described for SLS 0 in bit 8.
12	SS1 Active	1	SS1 active	The SS1 safety function is active. The activation may be a result from a demand of the safety application process, of a fault reaction from a fault in the safety fault buffer or a demand from the FSoE controlword.
		0	SS1 inactive	The SS1 safety function is inactive.
13	SS2 Active	1	SS2 active	The SS2 safety function is active. The activation may be a result from a demand of the safety application process, of a fault reaction from a fault in the safety fault buffer or a demand from the FSoE controlword.
		0	SS2 inactive	The SS2 safety function is inactive
14	-	-	unused	Function is not supported
15	Error Ack State	-		This bit is the processing value of bit 7 (Error Ack) in the FSoE controlword. This bit is used to handshake the error acknowledge.

Table 59: Assignment of the FSoE statusword

7.11.4.3 Transmitted Safe Position

The transmitted slave safe position is 16 bit wide. It is the part from bit 10 to bit 26 of the 32 bit safe position.

The 16 bit safe position has a resolution of 0.1024 mm and a range of 6'710.8864 mm.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
					16 bit transmitted safe position																										
32 bit safe position																															

Table 60: Transmitted safe position

7.12 Safe Digital Inputs

7.12.1 Description

The drive supports two safe digital inputs, which are located on the safe I/O connector X49.

CAUTION	**Digital Inputs Wiring** The wiring of the digital inputs shall be done such, that short circuits between the two channels of a single input are excluded or detected by the driving safe output (for example from the safety PLC).

The X49 connector has the following signal layout:

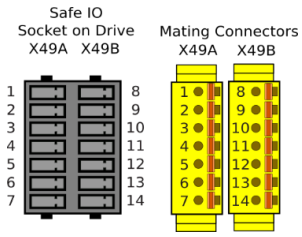
X49	Safe Digital IO	
	1	**X49A** **SafeDigIn 1A- (safe digital input 1 channel A negative)**
	2	**SafeDigIn 1B- (safe digital input 1 channel B negative)**
	3	**SafeDigIn 2A- (safe digital input 2 channel A negative)**
	4	**SafeDigIn 2B- (safe digital input 2 channel B negative)**
	5	DGND
	6	DigInAck- (non-safe Acknowledge negative)
	7	SafeDigOut A (safe digital output channel A)
	8	**X49B** **SafeDigIn 1A+ (safe digital input 1 channel A positive)**
	9	**SafeDigIn 1B+ (safe digital input 1 channel B positive)**
	10	**SafeDigIn 2A+ (safe digital input 2 channel A positive)**
	11	**SafeDigIn 2B+ (safe digital input 2 channel B positive)**
	12	GND
	13	DigInAck+ (non-safe Acknowledge positive)
	14	SafeDigOut B (safe digital output channel B)
		- Use 60/75°C copper conductors only - Conductor cross-section max. 1.5 mm^2 - Stripping length: 10mm.

Table 61: X49 Connector: Safe digital inputs

Both safe digital inputs are realized with two differential channels (channel A and B). Each channel has a positive and negative signal input.

State	Current consumption	Value
Low	< 1 mA	0 to 5 V
High	2 to 10 mA, typically 4 mA @ 24 V	15 to 27 V

Table 62 Safe input level definitions

Item	Description	Value
Nominal operating voltage	The minimal allowed low voltage between the positive and negative input	0 – 24V
Maximal Voltage	The maximal allowed low voltage between the positive and negative input	60 V
Max. reverse Polarity	The inputs are protected against reverse polarity.	60 V

Table 63: Ratings of safe inputs

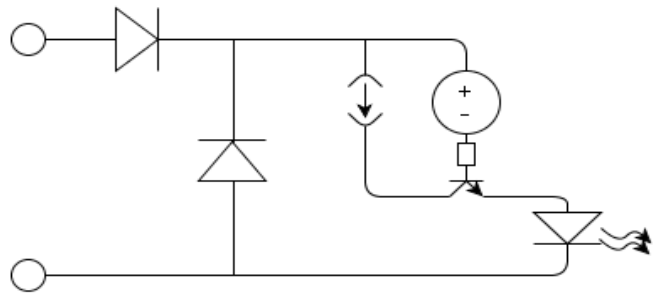


Figure 20: Schematics of a safe digital input (one channel)

7.12.2 Parameters

The safe digital inputs have the following parameters for configuration.

Name	UPID Type	Description
Safe Input 1	47A6h UInt8	Selects the state of a safety function, which is provided at the safe digital output. The following selection can be done: • 00h: Unused (Default) • 01h: STO • 02h: SS1 • 03h: SOS • 04h: SS2 • 05h: SLS 0 • 06h: SLS 1 • 07h: SLS 2 • 08h: SLS 3
Safe Input 2	47A7h UInt8	

Table 64: Safe digital input parameters

Note: The safe digital IOs can be used in parallel with the safe fieldbus.

7.13 Acknowledge Input

7.13.1 Description

The drive supports a non-safe acknowledge input on the safe I/O connector X49.

The X49 connector has the following signal layout:

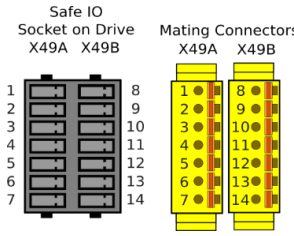
X49	Safe Digital IO	
	1 2 3 4 5 6 7 8 9 10 11 12 13 14	**X49A** SafeDigIn 1A- (safe digital input 1 channel A negative) SafeDigIn 1B- (safe digital input 1 channel B negative) SafeDigIn 2A- (safe digital input 2 channel A negative) SafeDigIn 2B- (safe digital input 2 channel B negative) DGND **DigInAck- (non-safe Acknowledge negative)** SafeDigOut A (safe digital output channel A) **X49B** SafeDigIn 1A+ (safe digital input 1 channel A positive) SafeDigIn 1B+ (safe digital input 1 channel B positive) SafeDigIn 2A+ (safe digital input 2 channel A positive) SafeDigIn 2B+ (safe digital input 2 channel B positive) GND **DigInAck+ (non-safe Acknowledge positive)** SafeDigOut B (safe digital output channel B)
		- Use 60/75 °C copper conductors only - Conductor cross-section max. 1.5 mm^2 - Stripping length: 10 mm.

Table 65: X49 Connector: Acknowledge

The acknowledge input is realized with one differential input, with a positive and negative signal input.

State	Current consumption	Value
Low	< 1 mA	< 5 V
High	2 to 10 mA, typically 4 mA @ 24 V	V15 to 27 V

Table 66: Acknowledge input level definitions

Item	Description	Value
Nominal operating voltage	The minimal allowed low voltage between the positive and negative input	0 – 24 V
Maximal Voltage	The maximal allowed low voltage between the positive and negative input	60 V
Max. reverse Polarity	The inputs are protected against reverse polarity.	60 V

Table 67: Ratings of the acknowledge input

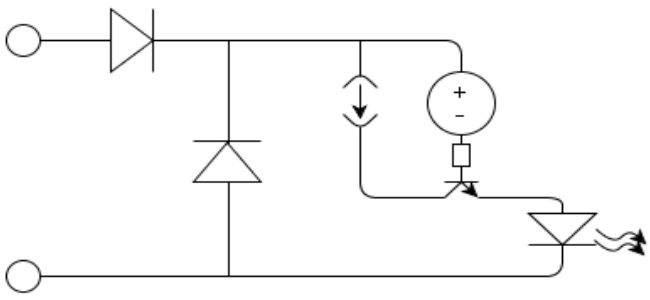


Figure 21: Schematics of the acknowledge input

7.13.2 Parameters

The acknowledge input is not configurable and has no parameters.

7.14 Safe Digital Output

7.14.1 Description

The drive supports one safe digital output, which is located on the safe I/O connector X49.

The X49 connector has the following signal layout:

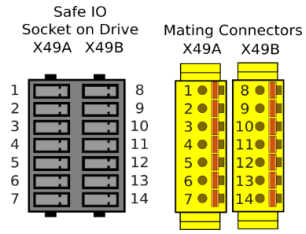
X49	Safe Digital IO	
	1 2 3 4 5 6 7 8 9 10 11 12 13 14	**X49A** SafeDigIn 1A- (safe digital input 1 channel A negative) SafeDigIn 1B- (safe digital input 1 channel B negative) SafeDigIn 2A- (safe digital input 2 channel A negative) SafeDigIn 2B- (safe digital input 2 channel B negative) DGND DigInAck- (non-safe Acknowledge negative) **SafeDigOut A (safe digital output channel A)** **X49B** SafeDigIn 1A+ (safe digital input 1 channel A positive) SafeDigIn 1B+ (safe digital input 1 channel B positive) SafeDigIn 2A+ (safe digital input 2 channel A positive) SafeDigIn 2B+ (safe digital input 2 channel B positive) GND DigInAck+ (non-safe Acknowledge positive) **SafeDigOut B (safe digital output channel B)**
		- Use 60/75 °C copper conductors only - Conductor cross-section max. 1.5 mm^2 - Stripping length: 10mm.

Table 68: X49 Connector: Safe Digital Output

The safe digital output is realized as a dual channel output, with test pulse.

- The output is short circuit safe. The output is not galvanically isolated.
- The output switches 24V, supplied on X4.
- The output is monitored.

State	Current consumption	Value
Low	< 1 mA	< 5 V
High	High, max. 100 mA	> 15 V

Table 69: Output level definitions

Term	Description	Value
Maximal output delay	This time is measured from the request to activate the output in the software to the output not providing any more power to a resistive load	4 ms
Maximal fault reaction time	Within this time, the wrong state of the digital output is detected and the drive has the fault reaction “Safety Output Fault”.	50 ms
Test Pulses	The safety module performs test pulses on the digital outputs. The test pulses have the following characteristics: • The pulse length 1 ms (+/- 10%). • Repetition time: every 1100 ms (+-10%) a test pulse will be produced in high state • The fault reaction is safe output fault. Make sure the safe digital input connected to this digital output can handle the test pulsed. For a better diagnosis, it is recommended to check the test pulses with the connected digital input module.	

Table 70: Characteristics of the safe output

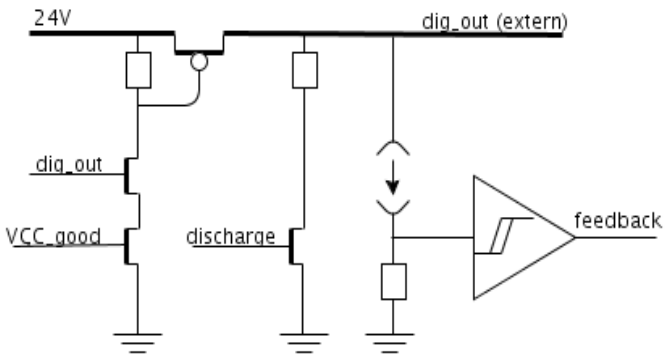


Figure 22: Schematics of the safe digital output (one channel)

7.14.2 Parameters

The safe digital output has the following parameter for configuration.

Name	UPID Type	Description
Safe Output	47A8h UInt8	Selects the state of a safety function, which is provided at the safe digital output. • 00h: Unused (Default) • 01h: STO, outputs the value of the Safety Fn State STO (UPID 1A10h) • 02h: SS1, outputs the value of the Safety Fn State SS1 (UPID 1A11h) • 03h: SOS, outputs the value of the Safety Fn State SOS (UPID 1A12h) • 04h: SS2, outputs the value of the Safety Fn State SS2 (UPID 1A13h) • 05h: SLS, outputs the value of the Safety Fn State SLS (UPID 1A1Ch) • 06h: Brake Output Mirror, outputs the value of Safety Fn State Brake Released (UPID 1A20h) • 07h: High: Safe output always high. E.g. as supply of the safe inputs.

Table 71: Safe digital output parameters

7.15 Safe Position Encoder

7.15.1 Description

For all position-based safety functions (SOS, SBC, SS2, SLS) a safe position encoder is necessary. As different motors have different supervision configurations, the correct setting of the encoder type is necessary. The encoder type must be configured in the parameter section.

WARNING

Sensor Wiring
The wiring to the sensor shall use the original NTI AG (LinMot) cable with a dedicated shielding.

The configuration parameters are located under: \Parameters\Safety\Encoder\

7.15.2 Parameters

Name	UPID Type	Description
Encoder Type	47B2h UInt8	The optional external encoder type can be selected. *Remark: To deactivate the use of an external encoder set the type to “Nonsafe”. The parameter must not be displayed for the user but shall be part of the safety parameters.* • 00h: Nonsafe (Default) • 02h: PS01-23x-HP • 04h: PS01-37x-HP • 05h: PS01-48x-LC • 06h: PS01-48-HP
Encoder Direction	47B3h UInt8	This parameter defines the direction, the safety module evaluates the safe position encoder signals. If the direction is inverse to the non-safe direction, it can be inverted with this parameter. The following selections can be done: • 00h: Normal (Default) • 01h: Inverse

Table 72: STO Parameters

7.15.2.1 Supported Safety Motors

Stator Type	Stator Article Number	Description	Encoder Type Selection
PS01-23x80F-HP-R-2S	0150-21259	Stator HP, IP67 with connector M17/9(m) - Safety	PS01-23x-HP
PS01-23x160H-HP-R-2S	0150-21254	Stator HP, IP67 with connector M17/9(m) - Safety	PS01-23x-HP
PS01-37x120F-HP-C-2S	0150-21251	Stator HP, IP67 with connector M23/9(m) - Safety	PS01-37x-HP
PS01-48x150G-HP-C-2S	0150-22992	Stator HP, IP67 with connector M23/9(m) - Safety	PS01-48-HP
PS01-48x240F-C-2S	0150-21220	Stator, IP67 with connector M23/9(m) - Safety	PS01-48x-LC
PS01-48x240F-HP-C-2S	0150-22991	Stator HP, IP67 with connector M23/9(m) - Safety	PS01-48-HP

Table 73: Supported safety motors

7.16 Safe Torque Off (STO)

The STO function is defined according to EN 61800-5-2

When activating the STO signal, the motor is disabled and no or no reasonable motor current is driven.

The STO is also possible for non-safe position encoders.

On the drive, there is one instance of STO implemented.

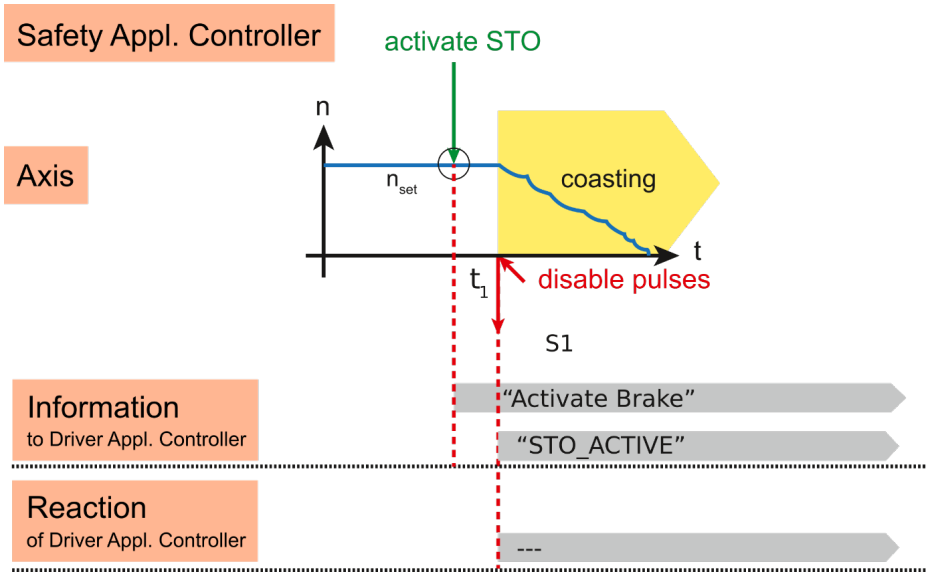


Figure 23: STO Timing

STO can be activated from safe digital inputs or from the safe fieldbus.
On the STO request the brake is immediately activated (if configured). After the time SBC STO_Delay (t1 in figure) STO becomes active and the motor becomes free of force or torque.

7.16.1 Parameters

STO can be configured with the following parameter:

Name	UPID Type Unit	Description	Min	Max	Typical
SBC STO_Delay (t1 in timing diagram)	47D5h UInt16 1 ms	Defines the delay between brake activation and STO.	0 s	60 s	20 ms

Table 74: STO Parameters

If STO shall be requested by a safe digital input, the configuration must be set accordingly, see 7.12.2 - Parameters

If the STO state shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters

If STO shall be requested via safe fieldbus, the safe fieldbus must be activated, see 7.10.3 - Safe Fieldbus Configuration.

7.16.2 Status Signals

The following variables contain the status information about the STO function.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 0	STO active	Same as UPID 1A10h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
Safety Fn State STO	1A10h Bool	-	STO active	Set if the STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the STO safety function is inactive and torque/force may be generated from the drive. This bit can also be accessed via UPID 1A06h bit 0.
Safety Error State	1A02h Enum8	-		This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8	-		In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes
STO Selected	1A1Ah Bool	-	STO selected	The safety module has detected a request for STO, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 10.
STO active	S_ZSW1 Bool	Bit 0	STO active	In case of PROFIsafe S_ZSW1 bit 0 signalizes if STO is active.
STO active	FSoE Status Word Bool	Bit 0	STO active	In case of FSoE bit 0 in statusword signalizes if STO is active.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14

Table 75: STO Status Signals

The safe digital output can be configured to show the STO active signal (UPID 1A10h), when setting the Safe Output UPID 47A8h to 01h: STO.

7.16.3 Detailed Functional Description

7.16.3.1 Activation and timing

STO is activated if one of following request sources is active:

- STO request on safe fieldbus
- STO request on safe digital input
- STO request on SS1 sequence
- STO request as Fault reaction

The STO reaction time to a request over a safe digital input, safe fieldbus or as internal request is less than 10ms.

When no brake is configured, STO will be immediately activated on a request.

When a brake is configured, the drive will close the brake first on a STO request. The safety module will then wait the configurable time 47D5h “SBC STO_Delay” for closing the brake before activating the STO.

The drive also supports to activate the brake together with the STO outputs when parameter 47D5h “SBC STO_Delay” is set to zero.

The drive reports the STO state as reached only, after this activation sequence has finished.

7.16.3.2 Deactivation

The drive only deactivates STO when not STO request is active.

7.16.3.3 Fault Reaction

As the STO is the most basic safety function, there is no fault reaction. The system stays with STO active.

7.16.4 Example for the use of STO

Example	Possible Solution
A protective door can only be opened if the torque or force of the motors is turned off	• Activate the STO in the drive • The pulses are suppressed, the motor has no torque or force and it coasts to a standstill.

Table 76: STO Example

7.16.5 Verification and Validation

For the verification for the STO function follow these steps:

- Configure complete drive inclusive the STO source.
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- Activate STO.
- Test reaction time and feedback signals.
- Check if motor is forceless.

7.17 Safe Brake Control (SBC)

The SBC function is defined according to EN 61800-5-2.

The SBC function supplies a safe output signal to control a holding brake.

On the drive, there is one output for the safe brake implemented, it is located on X50 Pin 1 (Brake+) and Pin 2 (Brake -).

The SBC can also be used with non-safe position encoders.

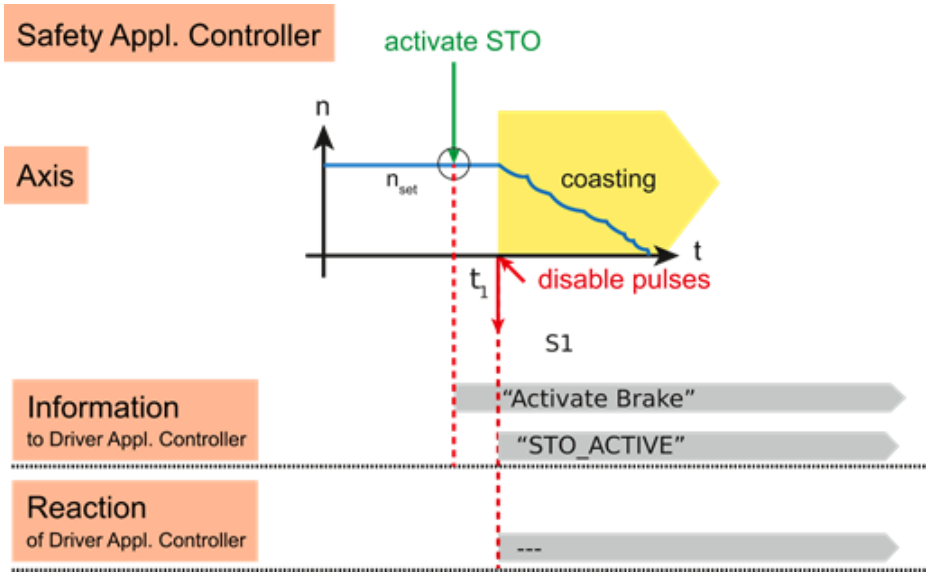


Figure 24: SBC

With the SBC function the monitoring of the brake controlling hardware and the presence of the brake is regularly tested.

The test checks, if the current to the brake can be turned off (the brake is in the safe state, when no current is driven).

The safe brake test (SBT) is described in chapter 7.18 - Safe Brake Test (SBT).

7.17.1 Parameters

The parameters are located under \Parameters\Safety\STO/SBC/SBT\.

Name	UPID Type Unit	Description	Min	Max	Typical
Brake attached	47D4h UInt8 -	Defines if a brake is attached or not. • 00h: Not Attached (Default) • 01h: Attached	-	-	Not Attached
SBC STO_Delay	47D5h UInt16 1ms	Defines the delay between brake and STO, this value is only used if a brake is configured.	0 s	60 s	20 ms

Table 77: SBC/SBT Parameters

NOTICE	**Brake Configuration** If the brake is attached on X50, also the non-safe configuration under "Brake Config", UPIDs 1716h to 1719h, 171Bh and 171Ch have to be set accordingly.

If the state of the brake output shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters

Activating the SBT can have different sources:

- Digital input (non-safe): any digital input on X4 can be mapped to the SBT request.
- PROFIbus: the SBT request can be set with telegram 701
- Fieldbus: The variable SBT Request (UPID 1A61), see table above.

7.17.2 Status Signals

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 0	STO active	Same as UPID 1A10h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
		Bit 16	Brake Released	Same as UPID 1A20h
Safety Error State	1A02h Enum8	-	No Failure	Defines the error state. For details see 7.17.3.1.5 - Error Reaction.
Safety Error Code	1A03h Enum8	-	Error Code	Defines the error code. For details see 7.17.3.1.5 - Error Reaction.
Safety Fn State STO	1A10h Bool	-	STO active	Set if the STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process of a fault reaction from a fault in the safety fault buffer or a demand from safe fieldbus. Cleared if the STO safety function is inactive and torque/force may be generated from the drive. This bit can also be accessed via UPID 1A06h bit 0.
STO Selected	1A1Ah Bool	-	STO selected	The safety module has detected a request for STO, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 10.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Fn State Brake Released	1A20h Bool	-	Brake is released	Set if the brake is actively driven and should be released (not braking). Cleared if the brake is not driven and should be braking. This bit can also be accessed via UPID 1A06h bit 16.
STO active	S_ZSW1 Bool	Bit 0	STO active	In case of PROFIsafe S_ZSW1 bit 0 signalizes if STO is active.
STO active	FSoE Status Word Bool	Bit 0	STO active	In case of FSoE bit 0 in statusword signalizes if STO is active.

Table 78: SBC Status Signals

7.17.3 Detailed Functional Description

The functionality discussed in this chapter is divided in SBC and SBT.

7.17.3.1 Functional Description SBC

7.17.3.1.1 Goal and Function of SBC

The main goal of the SBC is to switch off safely the current for the motor brake. This is realized by a two-channel hardware implementation with feedback signals. When the brake is released (powered) both channels are periodically tested if turn off still works.

7.17.3.1.2 Requirements for Brake

The requirements for the brake or brake valve are the following:

- The connector is described in 6.1.2.3.8 - X50 Safe Brake
- Use brake, which is engaged when not powered.
- Use 24V brake or valve.
- Maximal current: 0.8 A
- The output has no current reduction and not overexcitation.
- At 24V a minimal current of 10mA must flow.
- The brake must be active (braking) when the current is equal or below 10mA.
- Brake must be tolerant for test pulses of 1 ms in high state, every 900 ms.
- The type of brake must fulfill the required safety level for the application.

7.17.3.1.3 SBC Configuration

The SBC is automatically performed as soon as the brake on X50 is configured. The following parameters are used (see also 7.17.1 - Parameters):

- Brake attached (UPID 47D4h): Set to attached.
- SBC STO_Delay (UPID 47D5h): Defines the delay between brake and STO, this value is only used if a brake is configured.
- Also set the non-safe parameters under "Brake Config", UPIDs 1716h to 1719h, 171Bh and 171Ch accordingly.

7.17.3.1.4 SBC Test

The brake output has a low and a high side switch. Each switch can be controlled separately and each switch is monitored if it can turn off the brake current. Thus, the architecture is dual channeled. When the brake output is active (brake is released), every second each switch is tested if it still can switch off.

7.17.3.1.5 Error Reaction

In case of an error, the brake output fault will be generated STO will be activated.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Error State	1A02h Enum8	00h	No Failure	No failure is detected
		01h	IO-Failure	The safety module has detected a failure that may be acknowledged. During this state STO and the brake will be active.
Safety Error Code	1A03h Enum8	00h	No Error	No error is present.
		12h	Brake Output Fault	The internal diagnosis for the brake output has detected a fault. Recommended actions: check configuration, check cabling, check brake, contact support

Table 79: SBC Error States

7.17.4 Example for the Use

Example	Possible Solution
The safe control of a motor holding brake must guarantee the motor is at a standstill.	SBC is (if configured) initiated together with STO. The drive then activates the brake and safely controls the outputs.

Table 80: SBC Example

7.17.5 Verification and Validation

The verification for the SBC function follows these steps:

- Configure complete drive inclusive the safe brake.
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- The brake must be released.
- Disconnect brake.
- Check if the brake output fault must occur.
- Check if motor is in STO.

7.18 Safe Brake Test (SBT)

With the SBT test, a sequence is started, where the brake efficiency is tested. Therefore the motor will produce a force or torque and the brake must hold the motor in position. The following figure shows the sequence:

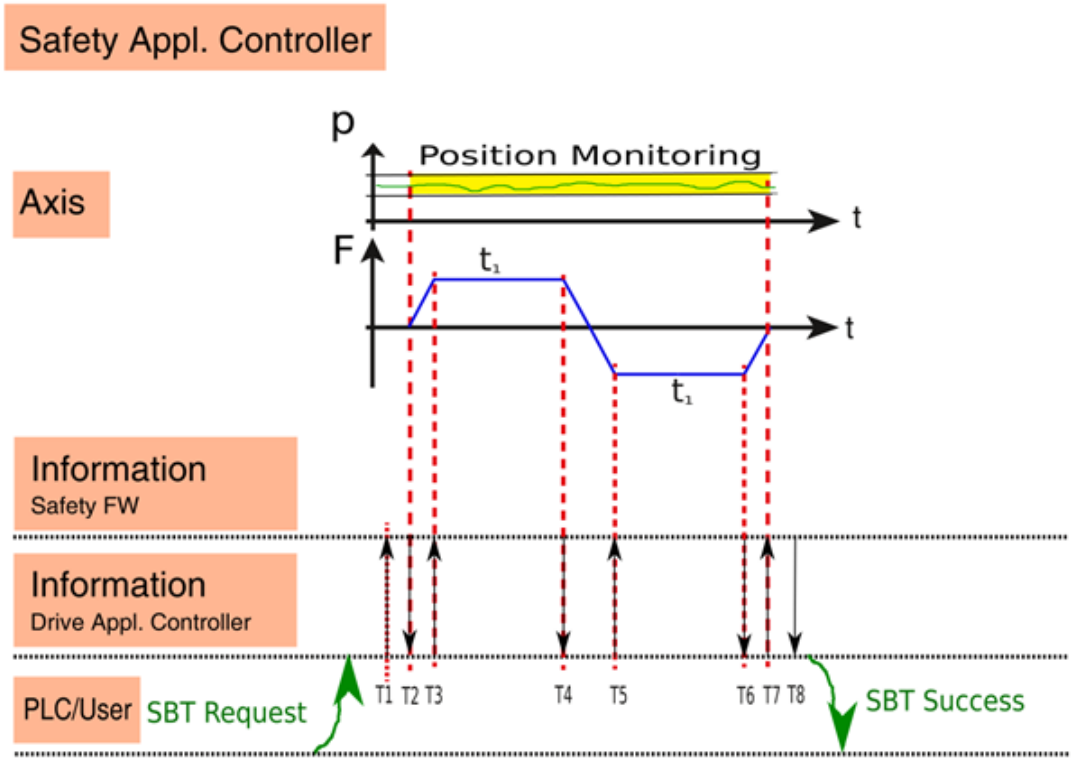


Figure 25: SBT

The SBT sequence is processed in the drive automatically when it is requested. Therefore the motor has to be disabled and the motor is braked. The Safety FW controls and monitors the complete SBT sequence. The following steps are performed (the states can be monitored with the variable SBT State (UPID 1A42h)):

- T1: the external SBT request is sent to the safety FW.
- T2: the safety FW commands the drive appl. controller to ramp up the positive force/torque.
- T3: the drive appl. controller informs the safety FW that the positive force/torque is reached.
- T4: after the configurable SBT apply time the safety FW commands to ramp to the negative force/torque.
- T5: the drive appl. controller informs the safety FW that the negative force/torque is reached.
- T6: after the configurable SBT apply time the safety FW commands to ramp the force/torque to zero.
- T7: the drive appl. controller informs the safety FW that the force/torque is turned off.
- T8: the safety FW finishes the test sequence and sets all feedback signals. The feedback signals are updated and the test is finished.

7.18.1 SBT Parameters

Name	UPID Type Unit	Description	Min	Max	Typical
Brake attached	47D4h UInt8 -	Defines if a brake is attached or not. • 00h: Not Attached (Default) • 01h: Attached	-	-	Not Attached
SBC STO_Delay	47D5h UInt16 1ms	Defines the delay between brake and STO, this value is only used if a brake is configured.	0 s	60 s	1 ms
SBT Force	47D6h UInt32 1 mN	Specifies the required force for the brake in the safe brake test phase for linear motors. After /ISO13849-1/ this value shall be 1.3 times the load force.	0 N	10 kN	1.3 times than the load force
SBT Torque	47D7h UInt32 1 mNm	Specifies the required torque for the brake in the safe brake test phase for rotary motors. After /ISO13849-1/ this value shall be 1.3 times the load torque.	0 Nm	10 kNm	1.3 times than the load torque
SBT Apply Time	47D8h UInt16 1 ms	Defines the time in which the maximal force/torque is applied in positive and negative direction during the safe brake test	0.01 s	30 s	0.25 s
SBT Motion Limit	47D9h UInt32 0.1 um	The maximum allowed motion during the brake test. The fault reaction is to enter the brake failure state.	0.1 um	100 mm	1 mm
SBT Request Interval	47DAh UInt32 1 s	After this time, the warn flag Brake Test Time elapsed (UPID 1A21h) is set, which recommends performing the brake test.	60 s	366 d	8 h
SBT Request	1A61h Bool	Request via Bus This variable can be written from the RT interface to request SBT. A rising edge starts the SBT sequence. If either the SBT IO Request or the SBT Request becomes active, the SBT will be started.			

Table 81: SBT Parameters

If the state of the brake output shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters . Activating the SBT can have different sources:

- Digital input (non-safe): any digital input on X4 can be mapped to the SBT request.
- PROFIbus: the SBT request can be set with telegram 701.
- Fieldbus or any other source: The variable SBT Request (UPID 1A61h), see table above.

7.18.2 Status Signals

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 0	STO active	Same as UPID 1A10h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
		Bit 16	Brake Released	Same as UPID 1A20h
		Bit 17	Brake Test Time elapsed	Same as UPID 1A21h
		Bit 18	SBT runs	Same as UPID 1A22h
		Bit 19	Brake Test failed	Same as UPID 1A23h
Safety Fn State STO	1A10h Bool	-	STO active	Set if the STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the STO safety function is inactive and torque/force may be generated from the drive. This bit can also be accessed via UPID 1A06h bit 0.
STO Selected	1A1Ah Bool	-	STO selected	The safety module has detected a request for STO, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 10.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Fn State Brake Released	1A20h Bool	-	Brake is released	Set if the brake is actively driven and should be released (not braking). Cleared if the brake is not driven and should be braking. This bit can also be accessed via UPID 1A06h bit 16.
Safety Fn State Brake Tst time Ov	1A21h Bool	-	Brake Test Time elapsed	Set if the time, specified in parameter 47DAh “SBT Request Interval” is elapsed. A brake test must be performed to clear this flag. Then the interval time restarts counting. Cleared if the brake test interval, specified in parameter 47DAh has not elapsed. This bit can also be accessed via UPID 1A06h bit 17.
Safety Fn State SBT runs	1A22h Bool	-	SBT runs	SBT sequence is running. This bit can also be accessed via UPID 1A06h bit 18.
Safety Fn State Brake Tst Failed	1A23h Bool	-	Brake Test failed	An error during the brake test has been detected. Possible causes: brake does not work correctly, motor has moved. Recommended actions: Check brake, check wiring. This bit can also be accessed via UPID 1A06h bit 19.
Safety Error State	1A02h Enum8	-	Safety Error State	This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8	-	Safety Error Code	In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes

The table is continued on the next page.

Name	UPID Type	Value / Bit	Significance	Comments
SBT IO Request	1A60h Bool	-	Request via IO	This value represents the IO request for SBT. On X4, the digital inputs can be configured to “Req SBT”. Make sure maximal one input is configured to request SBT. If either SBT IO Request or SBT Request becomes active, the SBT will be started.
SBT Request	1A61h Bool	-	Request via Bus	This variable can be written from the RT interface to request SBT. A rising edge starts the SBT sequence. If either the SBT IO Request or the SBT Request becomes active, the SBT will be started.
SBT State	1A42h Enum8	00h	Idle	SBT is in idle state.
		01h	Enable Power Stage	The power stage becomes active and the motor current can be driven.
		02h	Set Positive Current	The current is setting up to the defined brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		03h	Positive Current Applied	The current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		04h	Set Negative Current	The current is setting up to the defined negative brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		05h	Negative Current Applied	The negative current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		06h	Reset Current	The current will be set to zero.
STO active	S_ZSW1 Bool	Bit 0	STO active	In case of PROFIsafe S_ZSW1 bit 0 signalizes if STO is active.
STO active	FSoE Status Word Bool	Bit 0	STO active	In case of FSoE bit 0 in statusword signalizes if STO is active.

Table 82: SBT/STO Status Signals

7.18.3 Detailed Functional Description

7.18.3.1 Goal and Function of SBT

The safe brake test verifies if the brake is still capable to hold the motor position. Therefore, the motor is controlled to produce a force or torque (in both directions). The brake must hold the motor in position. If the position deviates too much an error will be generated and the SBT has failed.

7.18.3.2 SBT Configuration

All parameters concerning the SBT are described under 7.18.1 - SBT Parameters. Prerequisite is an attached and enabled brake on connector X50. The following parameters can be set:

- Configure a safe or non-safe brake.
- Set the maximal force or torque. The value shall be set to 1.3 times the load force/torque.
- Set the apply time: for how long the force/torque is applied.
- Set the motion limit: which position deviation is acceptable.
- Set the request interval: the drive automatically sets the flag Brake Test Time elapsed (UPID 1A21h), which recommends performing the brake test.

If the brake is not configured and the SBT is started, the error Brake Test Failed will be generated.

7.18.3.3 SBT Test Time expired

With the variable Safety Fn State Brake Tst time Ov (UPID 1A21h) the drive indicates that a safe brake test should be performed. After a power up or reboot this flag is set. After a successful brake test this flag is cleared and will become active after the SBT Request Interval (UPID 47DAh).

7.18.3.4 SBT Preconditions

For starting the SBT the following preconditions must be fulfilled:

- The brake must be configured.
- The motor must be configured.
- The SBT request must be configured (for digital inputs)
- Make sure the motor position is in a safe range (if the brake is not capable to hold the motor, the motor will move at least the distance defined with SBT Motion Limit (UPID 47D9h)
- The drive must be in the Op. Main State "Ready to Switch On".

7.18.3.5 Starting SBT

When the drive is in the Op. Main State "Ready to Switch On", any SBT request will start the brake test.

The SBT request can be done from different sourced:

- Non-safe digital input: any digital input on X4
- Profibus: telegram 701
- Fieldbus or any other source: by setting SBT Request (UPID 1A61h)

SBT Request	Status Flag for Request	Description / Comment
X4.5	SBT IO Request UPID 1A60h	The SBT is requested by setting the input X4.5 high. Parameter Dig In X4.5 Function (UPID 1060h) must be set to Req SBT (0007h). Make sure only one digital input is set to Req SBT, otherwise the behavior may not be defined.
X4.6	SBT IO Request UPID 1A60h	The SBT is requested by setting the input X4.6 high. Parameter Dig In X4.6 Function (UPID 1061h) must be set to Req SBT (0007h). Make sure only one digital input is set to Req SBT, otherwise the behavior may not be defined.
X4.7	SBT IO Request UPID 1A60h	The SBT is requested by setting the input X4.7 high. Parameter Dig In X4.7 Function (UPID 1062h) must be set to Req SBT (0007h). Make sure only one digital input is set to Req SBT, otherwise the behavior may not be defined.
X4.8	SBT IO Request UPID 1A60h	The SBT is requested by setting the input X4.8 high. Parameter Dig In X4.8 Function (UPID 1063h) must be set to Req SBT (0007h). Make sure only one digital input is set to Req SBT, otherwise the behavior may not be defined.
Profibus, Telegram 701	SBT Request UPID 1A61h	The SBT is requested via the control word from telegram 701. The SBT performs always both directions, independent of the request.
Fieldbus, set SBT Request (UPID 1A61)	SBT Request UPID 1A61h	The SBT is requested by setting the variable SBT Request (UPID 1A61) to high.

Table 83: SBT request list

7.18.3.6 SBT Sequence

The brake test is performed autonomous on the drive. The brake keeps blocking all the time. The motor is powered producing a force in both directions. During all the time the position of the motor is watched. The test is passed, if the motor does not move more than SBT Motion Limit (UPID 47D9h) allows.

The following variables display the status of the SBT:

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
		Bit 17	Brake Test Time elapsed	Same as UPID 1A21h
		Bit 18	SBT runs	Same as UPID 1A22h
		Bit 19	Brake Test failed	Same as UPID 1A23h
Safety System State	1A01h Enum8	03h	Operation	The safety module is working normally. In this state, STO or the brake may be active.
		05h	Safe Brake Test	A brake test is processing. The test will be triggered by the drive processor.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Fn State Brake Tst time Ov	1A21h Bool	-	Brake Test Time elapsed	Set if the time, specified in parameter 47DAh “SBT Request Interval” is elapsed. A brake test must be performed to clear this flag. Then the interval time restarts counting. Cleared if the brake test interval, specified in parameter 47DAh has not elapsed or after the SBT has been performed successfully. This bit can also be accessed via UPID 1A06h bit 17.
Safety Fn State SBT runs	1A22h Bool	-	SBT runs	SBT sequence is running. This bit can also be accessed via UPID 1A06h bit 18.
Safety Fn State Brake Tst Failed	1A23h Bool	-	Brake Test failed	An error during the brake test has been detected. Possible causes: brake does not work correctly, motor has moved or no brake is configured (neither non-safe nor safe brake). Recommended actions: Check brake, check wiring. This bit can also be accessed via UPID 1A06h bit 19.
SBT IO Request	1A60h Bool	-	Request via IO	This value represents the IO request for SBT. On X4, the digital inputs can be configured to “Req SBT”. Make sure maximal one input is configured to request SBT. If either SBT IO Request or SBT Request becomes active, the SBT will be started.
SBT Request	1A61h Bool	-	Request via Bus	This variable can be written from the RT interface to request SBT. A rising edge starts the SBT sequence. If either the SBT IO Request or the SBT Request becomes active, the SBT will be started.

The table is continued on the next page.

Name	UPID Type	Value / Bit	Significance	Comments
SBT State	1A42h Enum8	00h	Idle	SBT is in idle state.
		01h	Enable Power Stage	The power stage becomes active and the motor current can be driven.
		02h	Set Positive Current	The current is setting up to the defined brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		03h	Positive Current Applied	The current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		04h	Set Negative Current	The current is setting up to the defined negative brake test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		05h	Negative Current Applied	The negative current has reached the defined test force or torque. The force is defined with UPID 47D6h. The torque is defined with UPID 47D7h.
		06h	Reset Current	The current will be set to zero.

Table 84: SBT Status Signals

The actual test steps are displayed with SBT State (UPID 1A42h). The sequence is finished when state Idle is reached. Then the Safety Fn State SBT runs (UPID 1A22h) will be cleared as well.

The test result is stored in variable Safety Fn State Brake Tst Failed (UPID 1A23h).

If the SBT failed the SBT error must be acknowledged. This is done by switching the Error Acknowledge flag in the control word.

The test can be repeated at any time.

7.18.4 Verification and Validation

The verification for the SBC function follows these steps:

- Configure complete drive inclusive the safe brake, set also SBT force torque.
- Validate the parameters on the drive.
- Startup the drive
- Test if brake is locking.
- Setup the oscilloscope in LinMot-Talk
  - trigger on Safety Fn State SBT runs (UPID 1A22h)
  - monitor Actual Position (UPID 1B8Ah)
  - monitor Demand Current (UPID 1B93h)
- Request the brake test.
- Check if brake test is passed.
- The oscilloscope shot should look like the following figure.

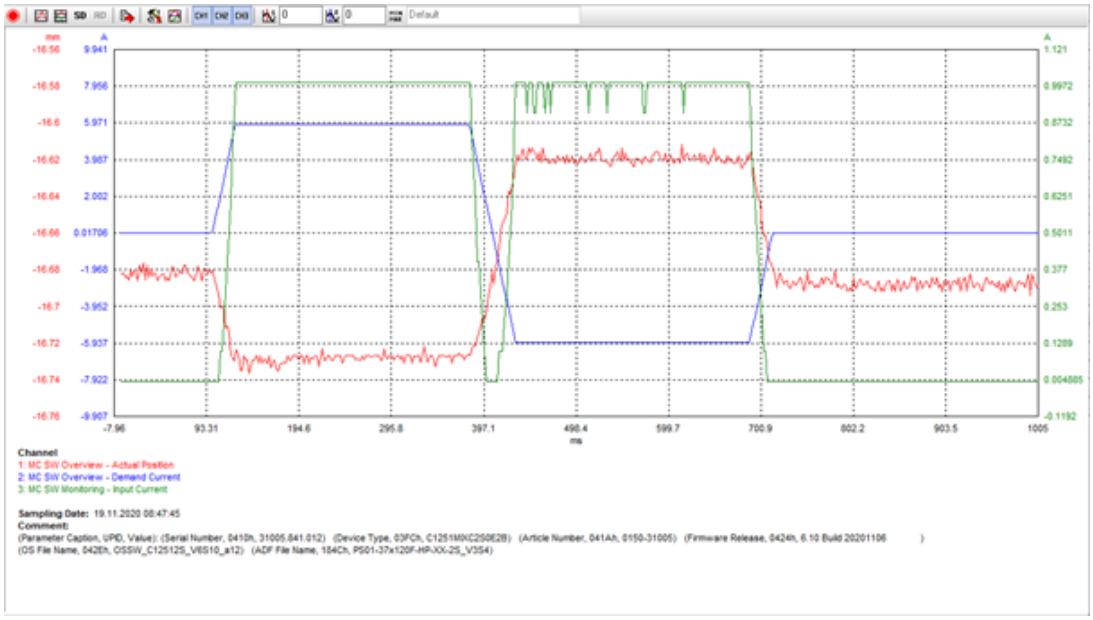


Figure 26: SBT Oscilloscope shot

7.19 Safe Stop 1 (SS1)

The SS1 function is defined according to EN 61800-5-2.

The SS1 function allows a fast braking of the motor to zero speed and afterwards goes into STO.

The controlled braking of the motor with SS1 reduces the risk, increases the productivity of a machine and allows to reduce the safety clearance within the machine. This is because of the active braking of the motor compared to STO only. Expensive and wearing mechanical brakes can be omitted very often.

The SS1 can also be used with non-safe position encoders.

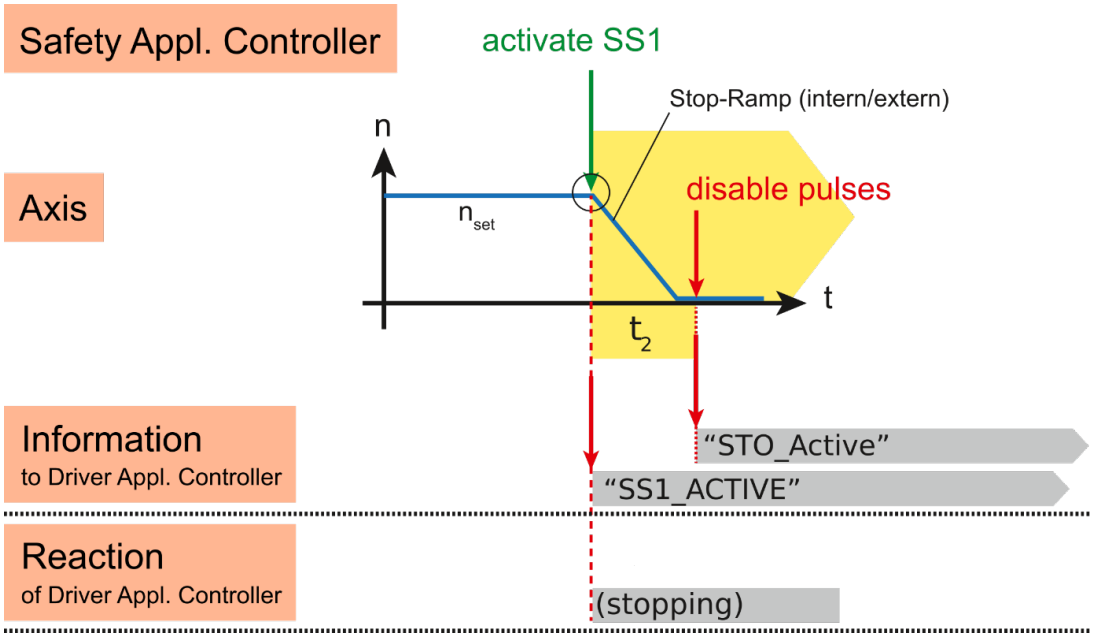


Figure 27: SS1 Timing

SS1 can be activated from safe digital inputs or from the safe fieldbus.

On the SS1 request the motor ramps down, after the configurable Stop Ramp Down Time (t2 in figure) the STO becomes active.

7.19.1 Parameters

Name	UPID Type Unit	Description	Min	Max	Typical
SS1 Stop Source	47E0h UInt8 -	Specifies if the stop is generated in the drive or by the external setpoint generator: • 00h: Internal Quick Stop (Default): With this selection the drive itself initiates the stop function (Quick Stop) • 02h: External Stop: With this selection the stop has to be commanded by the external setpoint generator (PLC).	-	-	Internal Quick Stop
Stop Ramp Down Time (t2 in figure)	47E7h UInt16 1 ms	The stop ramp down time starts, when SS1 is activated. Ramp down is active. The ramp down is not supervised. After this time STO is active.	2 ms	60 s	0.5 s

Table 85: SS1 Parameters

If SS1 shall be requested by a safe digital input, the configuration must be set accordingly, see 7.12.2 - Parameters

If the SS1 state shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters

If SS1 shall be requested via safe fieldbus, the safe fieldbus must be activated, see 7.10.3 - Safe Fieldbus Configuration.

7.19.2 Status Signals

The following variables contain the status information about the SS1 function:

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 0	STO active	Same as UPID 1A10h
		Bit 1	SS1 active	Same as UPID 1A11h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
Safety Fn State STO	1A10h Bool	-	STO active	Set if the STO safety function is active and torque/force is removed from the drive. The activation may be a result from a demand of the Safety Application Process of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the STO safety function is inactive and torque/force may be generated from the drive. This bit can also be accessed via UPID 1A06h bit 0.
Safety Fn State SS1	1A11h Bool	-	SS1 active	Set if the SS1 safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SS1 safety function is inactive This bit can also be accessed via UPID 1A06h bit 1.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Error State	1A02h Enum8	-		This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8	-		In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes
STO active	S_ZSW1 Bool	Bit 0	STO active	In case of PROFIsafe S_ZSW1 bit 0 signalizes if STO is active.
STO active	FSoE Status Word Bool	Bit 0	STO active	In case of FSoE bit 0 in statusword signalizes if STO is active.
SS1 active	S_ZSW1 Bool	Bit 1	SS1 active	In case of PROFIsafe S_ZSW1 bit 1signalizes if STO is active.
SS1 active	FSoE Status Word Bool	Bit 12	SS1 active	In case of FSoE bit 12 in statusword signalizes if SS1 is active.

Table 86: SS1 Status Signals

The safe digital output can be configured to show the SS1 active signal (UPID 1A11h), when setting the Safe Output UPID 47A8h to 02h: SS1.

7.19.3 Detailed Functional Description

7.19.3.1 Activation and timing

SS1 is activated if one of following request sources is active:

- SS1 request on safe fieldbus
- SS1 request on safe digital input
- SS1 request as fault reaction

The SS1 reaction time to a request over a safe digital input, safe fieldbus or as internal request is less than 10ms.

The sequence, which is performed when SS1 is activated, depends on the SS1 Stop Source (UPID 47E0h) selection:

SS1 Stop Source = Internal Quick Stop: The drive automatically initiates the stop function. The non-safe firmware is addressed to perform a quickstop. So it will do the following steps:

- Quickstop
- Activate brake after Quickstop has been executed.
- Turn off the motor after the Apply Delay Time (UPID 2710h) for the brake.

Parallel to the actions done in the non-safe firmware, the safety module does the following steps:

- Set Safety SS1active flag
- Wait the Stop Ramp Down Time (UPID 47E7h)
- Activate the brake (if configured)
- Wait the SBC STO_Delay time (if brake is configured)
- Set Safety STO active flag, state STO is active.

SS1 Stop Source = External Stop: The stop has to be done by an external setpoint generator. The safety module does the following steps:

- Set Safety SS1active flag
- Wait the Stop Ramp Down Time (UPID 47E7h)
- Activate the brake (if configured)
- Wait the SBC STO_Delay time (if brake is configured)
- Set Safety STO active flag, state STO is active.

7.19.3.2 Deactivation

SS1 is only deactivated when no possible request sources are active.

7.19.3.3 Fault Reaction

STO is the end state of SS1. As STO is the most basic safety function, there is no fault reaction. The system stays with STO active.

7.19.4 Examples for the Use

Example	Possible Solution
An emergency stop button is pressed and the connected drive must brake the motor as fast as possible and when stopped disable the force/torque.	• An emergency stop button is safely wired to the drive. • SS1 is configured on the digital inputs. • Pressing the emergency stop button activates the SS1, the motor brakes and results forceless.
On pressing one central emergency stop button, all drives in a machine must stop their motors as fast as possible and remain in STO state.	• The machine PLC is wired with the central emergency stop button. • The machine is wired with any supported safe fieldbus. • The drives are configured to react on a SS1 request from the safe fieldbus. • On pressing the emergency button, the PLC will distribute the SS1 request over the safe fieldbus to all connected drives.

Table 87: SS1 Examples

7.19.5 Verification and Validation

The verification for the SS1 function follows these steps:

- Configure complete drive inclusive the SS1 source and SS1 Stop source (UPID 47E0h)
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- Start a motor command.
- Activate SS1 while motor is moving.
- Dependent on the SS1 Stop source, the drive ramps down the motor of in case of internal quick stop is selected. Otherwise the PLC must command the stop function.
- Test reaction time and feedback signals.
- Check if motor is forceless.
- If a brake is configured, check if it is activated.

7.20 Safe Operating Stop (SOS)

The SOS function is implemented according to EN 61800-5-2

The function SOS holds the motor with zero speed on its position. The position is controlled and safely monitored

No mechanical components are necessary to keep the motor against an eventual counterforce in position. Because of the short response time and because the position control is active all the time the down- and set-up-time is reduced.

The activation can be done via safe digital IO's or a safe field bus (configurable).

One instance of SOS is implemented.

The SOS can only be realized with safe position encoders.

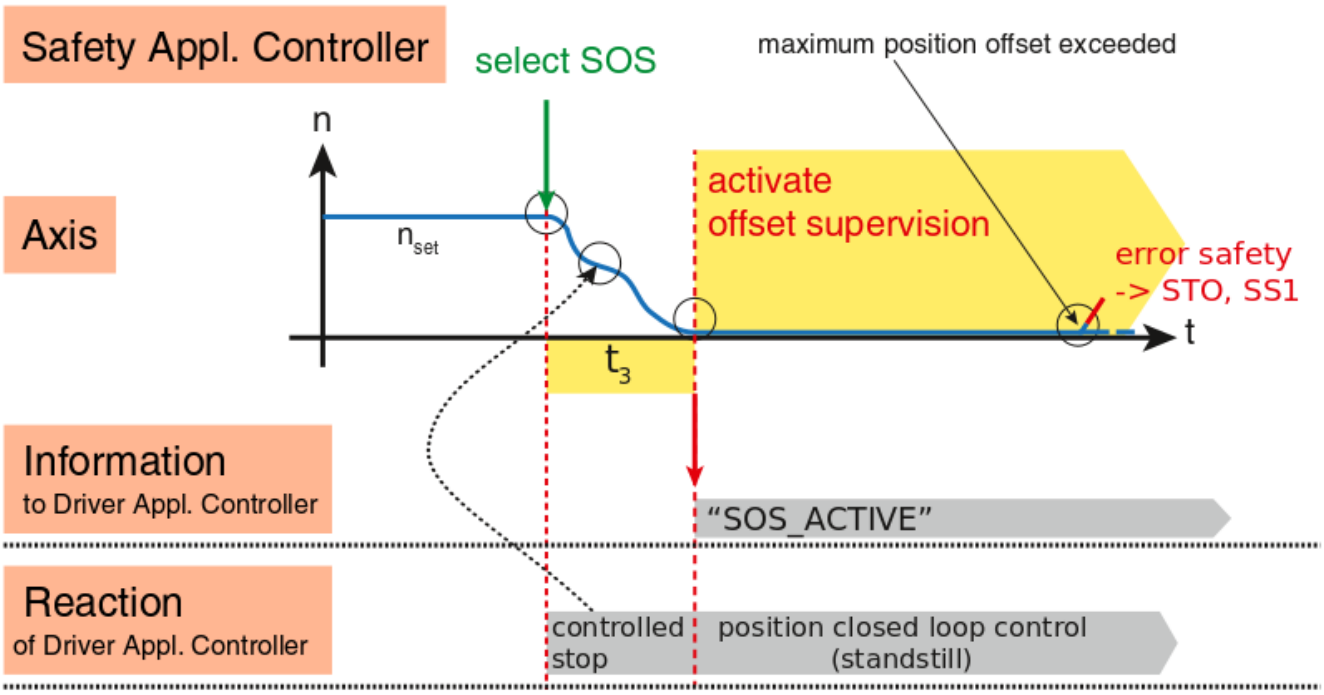


Figure 28: SOS Timing

In the "Safe Operation Stop" state the speed of the device is zero and the drive holds the motor at this position in a limited range. With the activation of SOS, a timer is started. After the time t3 the SOS becomes active and the offset supervision is activated.

If configured, the safety module shall monitor the position of the motor to be within the offset supervision limits.

If configured, the safety module shall keep the SOS state active, until the restart is acknowledged via the safe fieldbus or the acknowledge input.

7.20.1 Parameters

Name	UPID Type Unit	Description	Min	Max	Typical
SOS Activation Delay (t3 in figure)	47E1h UInt16 1 ms	The time the drive may take to slow down before activating SOS	0 s	60 s	0 s
SOS Position Tolerance +/-	47E2h UInt32 0.1 um	The limit within the position is accepted.	0.1 um	100 mm	1 mm
SOS Fault Reaction	47E3h UInt8 -	Configuration of the fault reaction. • 02h: STO (Default) • 03h: SS1	-	-	STO

Table 88: SOS Parameters

If SOS shall be requested by a safe digital input, the configuration must be set accordingly, see 7.12.2 - Parameters

If the SOS state shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters

If SOS shall be requested via safe fieldbus, the safe fieldbus must be activated, see 7.10.3 - Safe Fieldbus Configuration.

7.20.2 Status Signals

The following variables contain the status information about the SOS function.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 2	SOS active	Same as UPID 1A12h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
Safety Fn State SOS	1A12h Bool	-	SOS active	Set if the SOS safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SOS safety function is inactive. This bit can also be accessed via UPID 1A06h bit 2.
Safety Error State	1A02h Enum8	-		This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8	-		In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes
SOS Selected	1A1Bh Bool	-	SOS selected	The safety module has detected a request for SOS, this can also be an internal event. This bit can also be accessed via UPID 1A06h bit 11.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
SOS Active	S_ZSW1 Bool	Bit 3	SOS Active	In case of PROFIsafe S_ZSW1 bit 3 signalizes if SOS is active.
SOS Active	FSoE Status Word Bool	Bit 3	SOS Active	In case of FSoE bit 3 in statusword signalizes if SOS is active.

Table 89: SOS Status Signals

The safe digital output can be configured to show the SOS active signal (UPID 1A12h), when setting the Safe Output UPID 47A8h to 03h: SOS.

7.20.3 Detailed Functional Description

7.20.3.1 Activation and timing

SOS is activated if one of following request sources is active:

- SOS request on safe fieldbus
- SOS request on safe digital input
- SOS request in SS2 sequence
- SOS request as fault reaction

The SOS reaction time to a request over a safe digital input, safe fieldbus or as internal request is less than 10ms.

When SOS is activated, the safety module does the following monitoring:

- Wait the SOS Activation Delay (UPID 47E1h)
- The actual position is stored.
- The SOS state becomes active and is displayed with the status signals.
- The position monitoring is activated. If the position deviation is more than allowed by the parameter SOS Position Tolerance +/- (UPID 1A12h), the configured fault reaction will be initiated (configuration parameter SOS Fault Reaction
  UPID 47E3h)

7.20.3.2 Deactivation

SOS is only deactivated when no possible request sources is active.

7.20.3.3 Fault Reaction

If the supervision detects a failure, it will activate STO or SS1 depending on the parameter SOS Fault Reaction (UPID 47E3h).

7.20.4 Example for the Use

Example	Possible Solution
Opening a protective door must only be possible if the motors are safely standstill. To guarantee, that the motors keep still, even when some counterforce is active, SOS is requested.	• Configure SOS over safe digital IO’s or safe fieldbus. • The higher-level controller or PLC stops the motors and then activates the configured SOS safety function. • Standstill is then safely monitored on the drive.

Table 90: SOS Example

7.20.5 Verification and Validation

The verification for the SOS function follows these steps:

- Configure complete drive inclusive the SOS source, SOS Activation Delay (UPID 47E1h), SOS Position Tolerance (UPID 47E2h) and SOS Fault Reaction (47E3h).
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- Activate SOS.
- Test reaction time and feedback signals.
- Check if the motor is still powered and position controlled.
- Move the motor within the SOS Position Tolerance.
    - No error must be produced.
- Move the motor out of the position tolerance (check both sides).
    - The configured error behavior must be performed.

7.21 Safe Stop 2 (SS2)

The SS2 function is implemented according to EN 61800-5-2

The SS2 function allows a fast braking of the motor to zero speed and afterwards goes into SOS. In the case of an error during deceleration, the SOS state cannot be reached.

Because the position control stays active, the normal operation can be immediately continued without homing if the safe function is deactivated. This ensures short down and set-up times and as well high productivity.

The activation can be done by safe digital IO's or a safe field bus (configurable).

In the "Safe Stop 2" state the drive reduces the speed to zero as SS1, but in contrast to SS1 the motor is not switched off.

The SS2 can only be realized with safe position encoders.

One instance of SS2 is implemented.

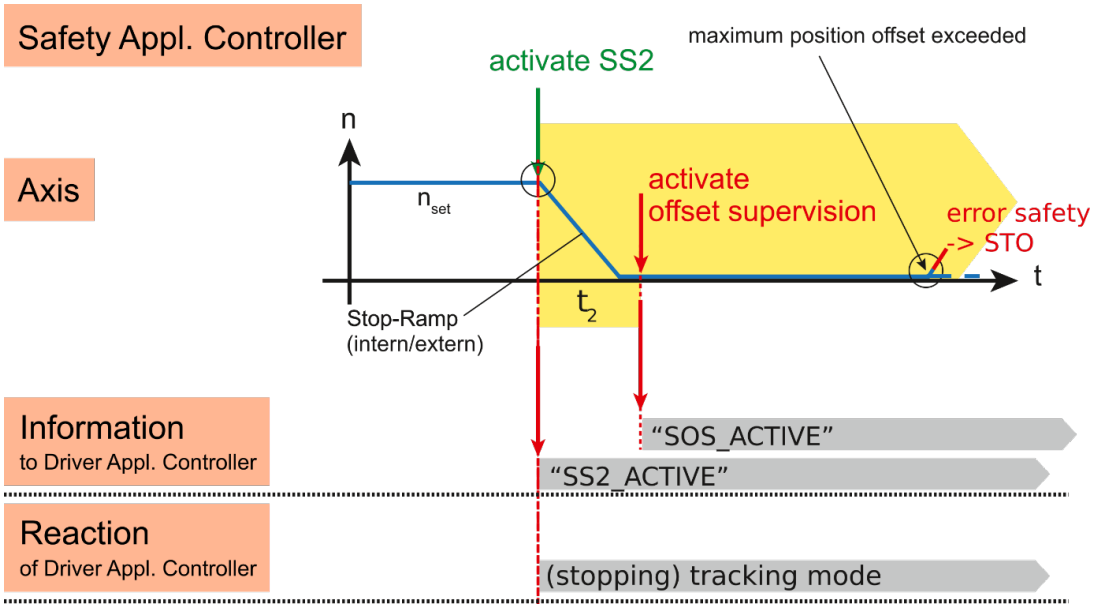


Figure 29: SS2 Timing

7.21.1 Parameters

Name	UPID Type Unit	Description	Min	Max	Typical
SS2 Stop Source	47E4h UInt8	Specifies if the stop is generated in the drive or by the external setpoint generator. • 01h: Internal Abort (Default): With this selection the drive itself initiates the stop function (Quick Stop) • 02h: External Stop: With this selection the stop has to be done by the external setpoint generator (PLC).	-	-	Internal Abort
Stop Ramp Down Time (t2 in figure)	47E7h UInt16 1 ms	The stop ramp down time starts, when SS2 is activated. Ramp down is active. The ramp down is not supervised. After this time SOS becomes active.	2 ms	60 s	0.5 s

Table 91: SS2 Parameters

If SS2 shall be requested by a safe digital input, the configuration must be set accordingly, see 7.12.2 - Parameters
If the SS2 state shall be displayed with the safe digital output, the configuration must be set accordingly, see 7.14.2 - Parameters
If SS2 shall be requested via safe fieldbus, the safe fieldbus must be activated, see 7.10.3 - Safe Fieldbus Configuration.

7.21.2 Status Signals

The following variables contain the status information about the SS2 function.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 2	SOS active	Same as UPID 1A12h
		Bit 3	SS2 active	Same as UPID 1A13h
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
Safety Fn State SOS	1A12h Bool	-	SOS active	Set if the SOS safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SOS safety function is inactive. This bit can also be accessed via UPID 1A06h bit 2.
Safety Fn State SS2	1A13h Bool	-	SS2 active	Set if the SS2 safety function is active. The activation may be a result from a demand of the Safety Application Process, of a fault reaction from a fault in the safety fault buffer or a demand from the safe fieldbus. Cleared if the SS2 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 3.
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Error State	1A02h Enum8	-		This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8	-		In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes
SOS Active	S_ZSW1 Bool	Bit 3	SOS active	In case of PROFIsafe S_ZSW1 bit 3 signalizes if SOS is active.
SOS Active	FSoE Status Word Bool	Bit 3	SOS active	In case of FSoE bit 3 in statusword signalizes if SOS is active.
SS2 Active	S_ZSW1 Bool	Bit 2	SS2 active	In case of PROFIsafe S_ZSW1 bit 2 signalizes if SS2 is active.
SS2 Active	FSoE Status Word Bool	Bit 13	SS2 active	In case of FSoE bit 13 in statusword signalizes if SS2 is active.

Table 92: SS2 Status Signals

The safe digital output can be configured to show the SS2 active signal (UPID 1A13h), when setting the Safe Output UPID 47A8h to 04h: SS2.

7.21.3 Detailed Functional Description

7.21.3.1 Activation and timing

SS2 is activated if one of following request sources is active:

- SS2 request on safe fieldbus
- SS2 request on safe digital input
- SS2 request as Fault reaction

The SS2 reaction time to a request over a safe digital input, safe fieldbus or as internal request is less than 10ms.

The sequence, which is performed when SS2 is activated, depends on the SS2 Stop Source (UPID 47E4h) selection:

SS2 Stop Source = Internal Abort:

The drive automatically initiates the stop function. The non-safe firmware is addressed to perform a quickstop. So it will do the following steps:

- Quickstop
- Stay at end position of quick stop with motor controlled.

Parallel to the actions done in the non-safe firmware, the safety module does the following steps:

- Set Safety SS2 active flag.
- Wait the Stop Ramp Down Time (UPID 47E7h).
- Set Safety SOS active flag, state SOS is active. The behavior for monitoring and failure reaction is according to the configuration for the SOS.

SS1 Stop Source = External Stop:

The stop has to be done by an external setpoint generator. The safety module does the following steps:

- Set Safety SS2 active flag.
- Wait the Stop Ramp Down Time (UPID 47E7h).
- Set Safety SOS active flag, state STO is active. The behavior for monitoring and failure reaction is according to the configuration for the SOS.

7.21.3.2 Deactivation

SS2 shall only be deactivated if all possible request sources are inactive

7.21.3.3 Fault Reaction

The drive shall only deactivate the SS2 behavior after all SS2 requests have been removed.

7.21.4 Example for the Use

Example	Possible Solution
For handling in a machine, the protective door must be opened only if the motor is in the safe standstill state.	• Configure the SS2 in the drive • After braking, the drive activates the SOS and the protective door can be opened.

Table 93: SS2 Example

7.21.5 Verification and Validation

The verification for the SS2 function follows these steps:

- Configure complete drive inclusive the SS2 source, SS2 Stop Source (UPID 47E4h), Stop Ramp Down Time (UPID 47E7h)
- Also configure the parameters for SOS.
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- Start a motor command.
- Activate SS2 while motor is moving.
- Dependent on the SS2 Stop source, the drive ramps down the motor of in case of internal quick stop is selected. Otherwise, the PLC must command the stop function.
- Test reaction time and feedback signals.
- Check if the drive is in the SOS state.
- Perform the tests for SOS (7.20.5 - Verification and Validation)

7.22 Safe Limited Speed (SLS)

The SLS function is implemented according to EN 61800-5-2

The SLS function monitors the speed of the motor and ensures that it stays below a certain limit.

The SLS function can reduce stand still times or make set-up procedures easier or even faster. The overall effect is a higher availability of the machine. No external components like speed monitoring devices are necessary anymore.

The activation can be done by configuration via safe digital IO's or a safe field bus.

In case of PROFIsafe, there is one instance with four speed levels (SLS 0 to SLS 3), which are configurable independently.

In case of FSoE, there are four completely independent instances (SLS 0 to SLS 3).

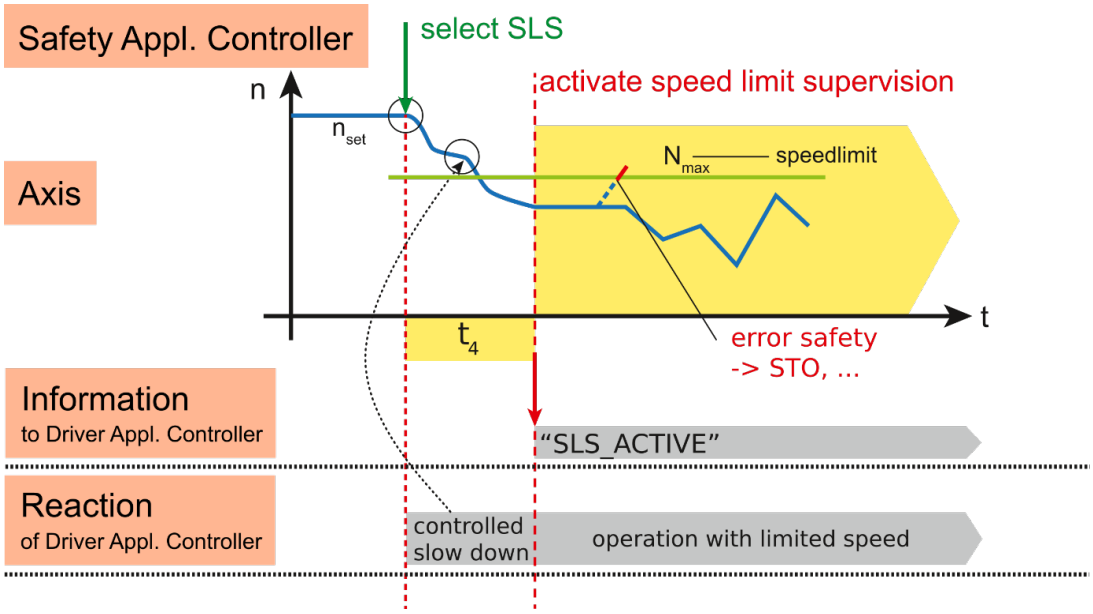


Figure 30: SLS Timing

After the activation of SLS, the speed is reduced to be within a limit. When the time t4 has elapsed, the drive activates the SLS state. In the SLS state the speed is monitored to be within the limit +/- n_SLS. If the limit is exceeded, the motor is stopped.

7.22.1 Parameters for SLS

Name	UPID Type Unit	Description	Min	Max	Typical
SLS Ramp Down Time (t4 in figure)	47F8h UInt16 1 ms	The maximum time for the ramp down. After this time, the SLS monitoring becomes active.	2 ms	60 s	0.5 s
SLS 0 Speed Limit	47F0h UInt32 1 um/s	Defines the limit within the speed is accepted. If the speed exceeds this limit, the defined fault reaction for SLS 0 will be done.	1 um/s	2 m/s	0.25 m/s
SLS 0 Fault Reaction	47F1h UInt8 -	Configurable fault reaction for SLS 0. • 02h: STO (Default) • 03h: SS1 • 04h: SS2 • 05h: SOS	-	-	STO
SLS 1 Speed Limit	47F2h UInt32 1 um/s	Defines the limit within the speed is accepted. If the speed exceeds this limit, the defined fault reaction for SLS 1 will be done.	1 um/s	2 m/s	0.25 m/s
SLS 1 Fault Reaction	47F3h UInt8 -	Configurable fault reaction for SLS 1. • 02h: STO (Default) • 03h: SS1 • 04h: SS2 • 05h: SOS	-	-	STO
SLS 2 Speed Limit	47F4h UInt32 1 um/s	Defines the limit within the speed is accepted. If the speed exceeds this limit, the defined fault reaction for SLS 2 will be done.	1 um/s	2 m/s	0.25 m/s
SLS 2 Fault Reaction	47F5h UInt8 -	Configurable fault reaction for SLS 2. • 02h: STO (Default) • 03h: SS1 • 04h: SS2 • 05h: SOS	-	-	STO
SLS 3 Speed Limit	47F6h UInt32 1 um/s	Defines the limit within the speed is accepted. If the speed exceeds this limit, the defined fault reaction for SLS 3 will be done.	1 um/s	2 m/s	0.25 m/s
SLS 3 Fault Reaction	47F7h UInt8 -	Configurable fault reaction for SLS 3. • 02h: STO (Default) • 03h: SS1 • 04h: SS2 • 05h: SOS	-	-	STO
Speed Computation Time	47A3h UInt8 1 ms	The speed is computed over this time interval. The software will store the position data for this time interval and compute the difference between the selected entries. The speed is then divided by the time selected	1 ms	10 ms	2 ms

Table 94: SLS Parameters

If SLS shall be requested by a safe digital input, the configuration must be set accordingly, see 7.12.2 - Parameters
If the SLS state shall be displayed with the safe digital output, the configuration must be set, see 7.14.2 - Parameters .
If SLS shall be requested via safe fieldbus, the safe fieldbus must be activated, see 7.10.3 - Safe Fieldbus Configuration.


WARNING

SLS Speed Limit Configuration
The speed monitoring can be influenced by the speed computation time, the motor current and different other effects in the motor sensor system, like wearing out, slider position, etc.
To make sure that the speed monitoring does not respond, the commanded target speed in the SLS should be much lower than the selected SLS Speed Limit parameter.
For more practical information see 7.20.5- Verification and Validation

7.22.2 Status Signals

The following variables contain the status information about the SLS function.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Word	1A06h UInt32	Bit 4	SLS 0 active	Same as UPID 1A14h
		Bit 5	SLS 1 active	Same as UPID 1A15h
		Bit 6	SLS 2 active	Same as UPID 1A16h
		Bit 7	SLS 3 active	Same as UPID 1A17h
		Bit 12	SLS selected	Same as UPID 1A1Ch
		Bit 13	Error active	Same as UPID 1A1Dh
		Bit 14	Acknowledge is required	Same as UPID 1A1Eh
Safety Fn State SLS 0	1A14h Bool	-	SLS 0 active	Set if the SLS 0 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 0 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 4.
Safety Fn State SLS 1	1A15h Bool	-	SLS 1 active	Set if the SLS 1 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 1 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 5
Safety Fn State SLS 2	1A16h Bool	-	SLS 2 active	Set if the SLS 2 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 2 safety function is inactive. This bit can also be accessed via UPID 1A06h bit 6.
Safety Fn State SLS 3	1A17h Bool	-	SLS 3 active	Set if the SLS 3 safety function is active. The activation may be a result from a demand of the Safety Application Process, or a demand from the safe fieldbus. Cleared if the SLS 3safety function is inactive. This bit can also be accessed via UPID 1A06h bit 7.
Safety Fn State SLS Selected	1A1Ch Bool	-	SLS selected	The safety module has detected a request for one of the four SLS instances. This bit can also be accessed via UPID 1A06h bit 12.

Continued on next page.

Name	UPID Type	Value / Bit	Significance	Comments
Safety Fn State Error	1A1Dh Bool	-	Error active	This flag is set if an error on the safety module is active. Cleared if no error is active. This bit can also be accessed via UPID 1A06h bit 13.
Safety Fn State Int Event	1A1Eh Bool	-	Acknowledge is required	Set if an explicit acknowledge is required as an interface event. Cleared if no acknowledge is required. This bit can also be accessed via UPID 1A06h bit 14
Safety Error State	1A02h Enum8			This variable shows the error state of the safety functions. The variable is described in detail in 7.7.2.3- Safety Error State
Safety Error Code	1A03h Enum8			In case of an error, the error code is shown here. The error codes are described in detail in 7.7.2.4- Safety Error Codes
SLS Active	S_ZSW1 Bool	Bit 4	SLS Active	In case of PROFIsafe S_ZSW1 bit 4 signalizes if SLS is active.
SLS BIT 0 SLS BIT 1	S_ZSW1 2xBool	Bit 9 Bit 10	SLS Limit Selection	In case of ProfiSafe: With these two bits the selected SLS level shown. SLS BIT 0 is the low, SLS BIT 1 is the high bit of the selection. The following mapping is done: 0: SLS 0 is selected 1: SLS 1 is selected 2: SLS 2 is selected 3: SLS 3 is selected The feedback if SLS active is shown with bit 4 in S_ZSW1.
SLS 1 Active	FSoE Status Word Bool	Bit 8	SLS 1 Active	In case of FSoE bit 8 in statusword signalizes if SLS 1 is active.
SLS 2 Active	FSoE Status Word Bool	Bit 9	SLS 2 Active	In case of FSoE bit 9 in statusword signalizes if SLS 2 is active.
SLS 3 Active	FSoE Status Word Bool	Bit 10	SLS 3 Active	In case of FSoE bit 10 in statusword signalizes if SLS 3 is active.
SLS 4 Active	FSoE Status Word Bool	Bit 11	SLS 4 Active	In case of FSoE bit 11 in statusword signalizes if SLS 4 is active.

Table 95: SS1 Status Signals

The safe digital output can be configured to show the SLS active signal. When one of the SLS 0 to 3 becomes active, the output is driven. The configuration is done with the parameter Safe Output UPID 47A8h, set to 05h: SLS.

7.22.3 Detailed Functional Description

7.22.3.1 Activation and Timing

SLS is activated if one of following request sources is active:

- SLS request on safe fieldbus
- SLS request on safe digital input

There are 4 speed levels which can be selected. For each speed level a separate fault reaction can be defined. In case of multiple requests for different speed levels, the one with the lowest speed is executed.

The SLS reaction time to a request over a safe digital input, safe fieldbus or as internal request is less than 10ms.

When a SLS request is detected and the maximal speed limit is reduced, the SLS Ramp Down Time (UPID 47F8h) (t4 in figure above) will be awaited, until SLS becomes active. If the maximal speed is switched from a lower to a higher level, the new speed limit becomes active immediately, so no ramp down time is awaited.

When SLS is active, the speed monitoring is done. If the actual speed is detected as higher than the configured speed limit, the error reaction will be executed.

The status signals for the SLS monitoring, including the ones for the safe fieldbus telegram 30, are described in 7.22.2 - Status Signals.

7.22.3.2 Deactivation

SLS shall only be deactivated if all possible request sources are inactive.

7.22.3.3 Fault Reaction

The fault reactions can be defined for each of the four instances of the SLS separately. All fault reactions behave as described in the corresponding functional description:

- STO, see chapter 7.16 - Safe Torque Off (STO)
- SS1, see chapter 7.19 - Safe Stop 1 (SS1)
- SS2, see chapter, 7.21 - Safe Stop 2 (SS2)
- SOS, see chapter 7.20 - Safe Operating Stop (SOS)

7.22.4 Example for the Use

Example	Possible Solution
For setting up a machine, a machine operator must be able to approach the machine by opening the protective door and slowly move the machine with an acknowledgement button nearby.	• Configure and select the SLS function in the drive via safety inputs or safe fieldbus. • The drive monitors safely the speed of the motor.

Table 96: SLS Example

7.22.5 Verification and Validation

The verification for the SLS function follows these steps:

- Configure complete drive inclusive the SLS source and al parameters for SLS (7.22.1 - Parameters for SLS)
- Validate the parameters on the drive.
- Startup the drive.
- Enable the motor.
- For each configured speed limit check
    - activate SLS
        - Check reaction and status.
        - Move motor up to 50% of SLS speed limit. Start first test with this speed.
            - No error must occur.
            - Check the recorded safety speed to check the margin to the limit.
            - Setup the oscilloscope in LinMot-Talk to check the safety speed margin to the limit.
                - monitor Safe Speed Limit (UPID 1A2Ah)
                - monitor Safe Velocity (UPID 1A28h)
                - optionally monitor Safe Position (UPID 1A29h)

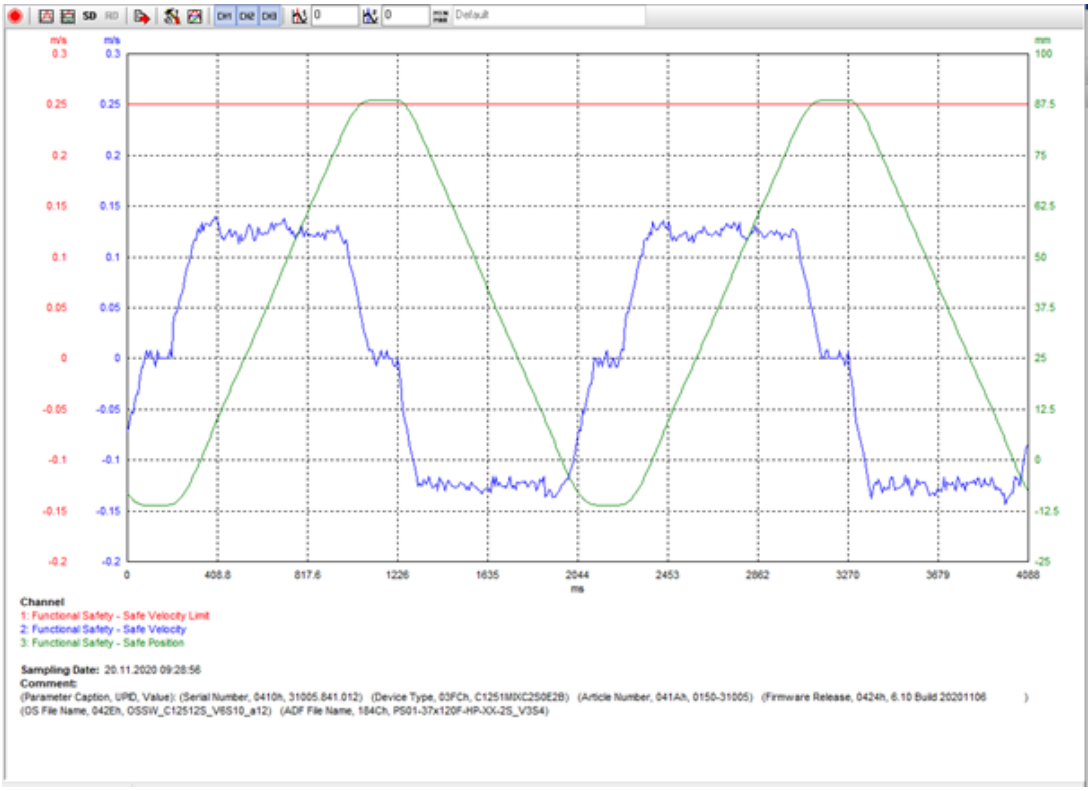


Figure 31: SLS Oscilloscope Shot: This shot shows the margin of the safety velocity

The monitored safe velocity may be disturbed by different effects:

- fast changing motor current (worse if higher)
- monitoring Speed Computation Time (UPID 47A3h) (worse if shorter)
- position sensor specific non-idealities

The margin between the monitored safe velocity and the safe speed limit should be at least 30%. Otherwise the SLS monitoring will stop too early.

- Move motor faster than SLS speed limit.
  - Error must occur.
  - Check error behavior according to the configuration.

7.23 Safe Brake on X50

The connector X50 provides the link to the safe brake. If a brake is configured, it is monitored by the SBC (safe brake control) function. The following table gives information about the pinout and the requirements for the safe brake.
The brake can be connected directly or a brake control unit can be used in between. The electrical characteristics listed in the table below correspond with the brake output signals on X50.

X50	Safe Brake	
	5 4 3 2 1	Do not connect Do not connect PE Safe Brake - Safe Brake +
Spring cage connectors (have to be ordered separately: see chapter 6.1.3)	• Use 60/75 °C copper conductors only. • Conductor cross-section max. 1.5 mm^2 • Stripping length: 10 mm • Use brake, which is engaged when not powered. • Use 24 V brake or valve, capable for 100 % duty cycle. • Maximal current: 0.8 A • At 24 V a minimal current of 10 mA must flow • The brake must be active (braking) when the current is equal or below 10mA. • Brake must be tolerant for test pulses of 1 ms, where no current is driven.	

Table 97: X50 Connector: Safe Brake

The dimensioning of the brake should be such that it can hold 1.3 times the nominal force or torque.

8 Planning a Safety Project with LinMot Components

This chapter provides an overview of the general planning process for a safety project using LinMot products.

CAUTION

Machinery Directive
This description applies only to machines as defined by the Machinery Directive.
Standards
The relevant standards must be available to the user. The following description cannot replace the standard. Typically, the current version of EN ISO 13849-1 and EN ISO 13849-2 or EN 62061 should be available as a minimum. Further useful information can be found in IFA report 2/2017

NOTICE

Type C standard
Before you start the following process, you should check whether a type C standard is available for your machine. If this is the case, please follow the steps and instructions given there. If no type C standard is available, you can use the process described below as a guide for the steps to be performed.
Use LinMot-Designer for Dimensioning
For a safe and reliable function of a machine, it is important, that the dimensioning of the used components is adequate. Use the LinMot-Designer to select the fitting components. Also consider a thermal reserve.

8.1 Identifying the risks and hazards

DIN EN ISO 12100 defines an iterative process for risk minimization, for eliminating hazards or for reducing the risk at machines. It describes the process of risk minimization in a three-step method. In the first step, the machine should be designed to be inherently safe. If this is not possible, technical protective measures can be taken to minimize the risk. In the last step, user information about the residual risk can be provided. In the first step, the risks and hazards and thus the safety functions must be identified. machine manufacturers require precise knowledge of the operation of their machine in order to identify risks and hazards. Referring to Annex B of EN ISO 12100:2010 is helpful for this purpose. This risk and hazard analysis should be carried out by persons with knowledge in different areas (mechanics, electrics, hydraulics, software, maintenance, ...). All operating modes and conditions must be considered, including commissioning, maintenance/servicing, normal operation and decommissioning. The reasons for or against a particular decision should also be documented. Make sure that your arguments and justifications are understandable and conclusive. In this context, it is particularly important to note that safety measures must not yet be considered when assessing the risk. When all persons involved in the process agree with the result of the analysis, it should be signed by all.

8.2 Determining the PLr / SIL

For each safety function (SF) of the machine identified in the risk and hazard analysis, the machine manufacturer or user must determine the required Performance Level or SIL Level. The SIL level is determined based on the description in Annex A of EN 62061. The performance level is determined based on the risk graph for determining the PLr according to /ISO13849-1/. Information on the risk graph can be found in Annex A of /ISO13849-1/.

8.3 Specification of the safety functions

For each safety function identified, it is necessary to specify how the risk should be reduced in accordance with the EN ISO 12100 strategy for risk reduction. Risks and hazards whose residual risk is to be reduced by inherently safe design or user information must be specified but are not part of this description. The following explanations refer only to safety functions, the residual risk of which is to be reduced by technical protective measures. For these safety functions, the iterative design process for safety-related parts of the control system (SRP/CS) is carried out in accordance with /ISO13849-1/.

8.4 Specification of the measures

The machine manufacturer should compile a detailed description of each identified safety function (SF) whose residual risk is to be reduced by means of technical protection measures. This description contains information about the hazard, the type of measures taken to reduce the hazard and the required Performance Level or SIL Level for this safety function. For each SF, the description of the measures must include the category according to /ISO13849-1/ and the components to be used, together with their safety parameters (MTTFd, DC, CCF, SFF). Information on operating states and characteristics is required. These include the operating modes, the cycle time, the response times or process safety time, the ambient conditions, the frequency of execution, the operating times, the behavior of the machine in the event of energy loss and more. More detailed information on this can be found in chapter 5.2 of EN 62061 and chapter 5 of /ISO13849-1/. The machine manufacturer must specify and document the description of the safety-related program for the PLC when using a safety PLC. In addition, the function blocks to be used and the sensors and actuators, the parameterization of the components must also be specified, since this can influence the maximum achievable PL.

8.5 Implementation of the safety functions

The following table gives the information about the safety function, their applicable standards and the link for the detailed information in this safety manual.

Safety Function	Applicable Standard	Link
STO (Safe Torque Off)	EN 61800-5-2	7.16 - Safe Torque Off (STO)
SBC (Safe Brake Control)	EN 61800-5-2	7.17 - Safe Brake Control (SBC)
SS1 (Safe Stop 1)	EN 61800-5-2	7.19 - Safe Stop 1 (SS1)
SOS (Safe Operating Stop)	EN 61800-5-2	7.20 - Safe Operating Stop (SOS)
SS2 (Safe Stop 2)	EN 61800-5-2	7.21 - Safe Stop 2 (SS2)
SLS (Safe Limited Speed)	EN 61800-5-2	7.22 - Safe Limited Speed (SLS)

Table 98: Implementation of the safety functions

The safety characteristics for all safety functions are listed under 7.2.1 - Boundary of the Safety Compliant System

8.6 Proof of achievement of the Performance Level

Once the safety project for the identified safety functions (SF) has been realized, the performance level achieved for these safety functions is calculated and verified. Support and examples for the calculation can be found with SISTEMA software assistant from IFA or Siemens Tool.

8.7 Validation of the safety functions

Extract from EN ISO 13849-2:2013, Chapter 4.1: validation guidelines.

- The purpose of the validation procedure is to confirm that the design of the safety-related parts of the control system (SRP/CS) supports the specification of the safety requirements of the machines. The validation must show that each SRP/CS meets the requirements of EN ISO 13849-1:2015, particularly with regard to the specified safety characteristics of the safety functions, as intended by the design.
- the requirements for the specified Performance Level (see EN ISO 13849-1:2015, 4.5):
  - the requirements for the specified category (see EN ISO 13849-1:2015, 6.2),
  - the measures for controlling and prevent systematic failures (see EN ISO 13849-1:2015, Annex G)
  - the software requirements, if applicable (see EN ISO 13849-1:2015, 4.6), and
  - the ability to provide a safety function under the expected conditions.
- the ergonomic design of the user interface, e.g. to discourage the user to act in a dangerous manner by circumventing the SRP/CS (see EN ISO 13849-1:2015, 4.8).

The validation should be carried out by persons who not involved in the SRP/CS design.
NOTE "Independent person" does not necessarily mean that a test by a third party is necessary.
Further information about the validation can be found in EN ISO 13849-2:2013, for example in figure 1, overview of the validation procedure, and in EN ISO 13849-1:2015.

8.8 Instructions for checking the SF

All implemented safety functions (SF) have to be checked for correctness. This includes both normal operation and the function in the event of a fault. Some of the test cases can be read from the defined safety function with its described measures for risk minimization. For each function, the possible fault scenarios must be defined and checked accordingly. This information must be recorded in a test specification or acceptance protocol. The following list shows some fault scenarios to be considered:

- Discrepancy error of two safe inputs
- Line interruption of the fieldbus used.
- Feedback error of the actuators
- Failure of the power supply
- Cross-circuit / external feed / line interruption in the wiring
- Violation of a defined limit, e.g. speed limit for axis functions and checking of the defined error behavior.
- ...

The validation must also ensure that all hazards identified by the risk assessment are covered by appropriate measures and that these measures have actually been implemented.
This applies especially to the life cycle phases of installation/assembly and maintenance. It must be ensured that any necessary changes or extensions to the safety project are only made after the design engineer (machine manufacturer) has been notified and the safety specification has been changed by the manufacturer. A check to see whether an extension of the test specification is necessary must also be carried out. This applies in particular to machines that are assembled and put into operation at the end customer's premises. The test must cover the following points as a minimum:

- I/O Check of the safe inputs and outputs
- Verification of the parameterization of all safety components (watchdog times, sensor tests, safe fieldbus address, etc.)
- Check of the safety functions during normal operation.
- Check of the safety functions in the event of an error.
- Check of the safe drive functions during normal operation.
- Check of the safe drive functions outside the defined safety limits.
- Check of the safe drive functions in the event of a power failure.

9 Commissioning

This chapter guides through the commissioning of a safety application. Precondition is that the safety application is planned and verified according to chapter 8 - Planning a Safety Project with LinMot Components Planning a Safety Project with LinMot Components.


CAUTION

Qualified Personnel
Make sure the installation and parameterization is done by personnel, which is educated and familiar with the safety topic and the kind of work, which it is involved doing the commissioning.

9.1 HW Installation

For the hardware installation make sure the following guidelines and information is considered:

- Safety notes of this safety manual
  - Chapter 5 - General Safety Notes LinMot Products
  - Chapter 6.1.2 - Safety relevant Drive Installation Instructions
- Wiring: make sure the wiring done such that:
  - The cross sections are well dimensioned.
  - The isolation is sufficient.
  - Minimal bending radius are considered.
  - Moving cables are realized with trailing chain or robot cables.
  - The connections are correct.
  - Necessary fuses are placed.
- Mechanical mounting: make sure that:
  - Installation guides are implemented.
  - The minimal mounting distances (drives, sliders, etc.) are fulfilled.

9.2 FW Installation

Install a valid firmware and check if the installation is done correctly. The firmware installation is done with LinMot-Talk.

The following FW releases are certified for the use in the functional safety context:

Release	Safety Software Type UPID 0302h	Safety Software Version UPID 0301h	CRC MCU 1 UPID 0303h	CRC MCU 2 UPID 0304h
6.10 Build 20211122 and newer	0001h: PROFIsafe	0101h	581AF05Bh	FEA01533h
6.12 Build 20230620 and newer	0001h: PROFIsafe	0101h	581AF05Bh	FEA01533h
	0002h: FSoE	0101h	8AE64B3Ah	A493B87Eh

Table 99: Release firmware versions

Under \Variables\OS Safety Module\ the values can be checked:

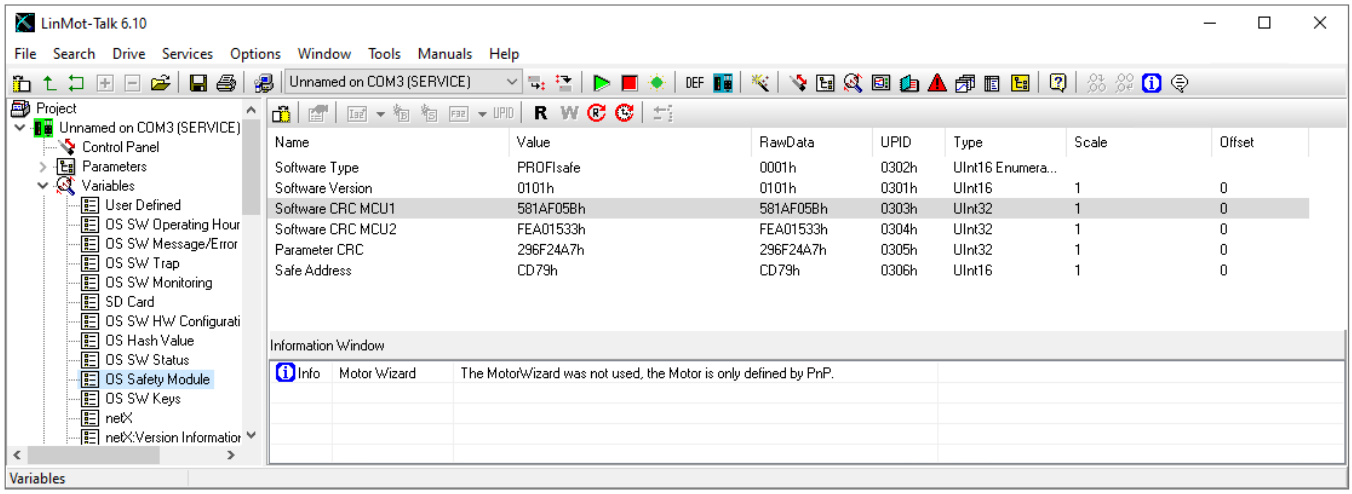


Figure 32: Safety Module Values

9.3 Drive Configuration

9.3.1 Using a Configuration

If a configuration is already available for the application, the following steps have to be done:

- Load the configuration with LinMot-Talk under --> File --> Import.
- Set the correct safe bus address on safe address switches S11/S12
- Set correct bus address on the ID switches S1/S2

9.3.2 Using no Configuration

All parameters and setting on the drives must be done. This can be done with LinMot-Talk, its manual can be found in [6]. Setup the following parts:

- Start the motor wizard, which guides through the configuration of the motor and its application (load, mounting, cable length, friction, …).
- Safety parameters, see chapter 7.5 - Safety Parameters Overview and following.
- Setup additional non-safe parameters, those which are not covered by the motor wizard.
- Define curves in LinMot-Talk, if necessary.
- Define the command table (CT) in LinMot-Talk, if necessary.
- Set the correct safe bus address on safe address switches S11/S12
- Set correct bus address on the ID switches S1/S2

9.4 Safety Parameter Verification and Validation

Before the safety parameters become active, they have to be verified and validated. (It is not relevant, if the configuration has imported from or it has created).
Follow the instructions in chapter 7.6.2 - Validate the Safety Parameters.
The LinMot system can now be started and the functional tests can be done. If modifications in the configuration have to be done, go back to chapter 9.3.2 - Using no Configuration

9.5 Acceptance Tests

Before the machine can be operatively used fulfilling the functional safety requirements, the acceptance tests and the machine documentation has to be done. This is described in chapter 10.2 - Acceptance Tests.

10 Acceptance Tests and Protocols

WARNING

Responsibilities
The machine manufacturer is responsible for carrying out and documenting the acceptance test.

10.1 Introduction

According to the EC Machinery Directive and DIN EN ISO 13849-1 it is necessary to check the safety-related functions and machine parts after commissioning. This is done by a so-called acceptance test.
The acceptance test is used to check the functionality of the safety monitoring and stop functions used in the drive. The test objective is to verify proper implementation of the defined safety functions and test mechanisms (measures for forced checking procedure (test stop)) and to examine the response of specific monitoring functions to explicitly entered values outside tolerance limits. The test must cover all drive-specific safety functionality.
The purpose of the acceptance test is: The measured values (e.g. distance, time) and the system behavior identified (e.g. initiation of a specific stop) can be used for checking the plausibility of the configured safety functions. The objective of an acceptance test is to identify potential configuration errors and/or to document the correct function of the configuration. The measured values are typical values (not worst-case values). They represent the behavior of the machine at the time of measurement. These measurements cannot be used to derive real values (e.g. maximum values for over-travel distances).

10.1.1 Requirements

The acceptance test requirements (configuration check) for electrical drive safety functions base on DIN EN 61800-5-2, Section 7.1 Point f). The acceptance test "configuration check" is cited in this standard.

- Description of the application including a picture.
- Description of the safety-relevant components, including software versions, that are used in the application.
- List of the safety related functions used.
- Results of all tests of these safety functions, using the specified testing procedure.
- List of all safety-relevant parameters and their values in the drive
- Checksum, test date and confirmation by testing personnel

A complete acceptance test is required when first commissioning the safety functionality on a machine. The acceptance tests must be carried out for each individual drive. Safety-related function expansions transfer of the commissioning settings to other series machines, hardware changes, software upgrades or similar activities permit the acceptance test to be performed with a reduced scope if necessary. A summary of conditions which determine the necessary test scope or proposals in this context is provided below.

10.1.2 Requirements for the acceptance test

- The machine is properly wired.
- All safety equipment (such as protective door monitoring devices, light barriers, emergency limit switches) are connected and ready for operation.
- Commissioning of the position control must be completed, as e.g. the over-travel distance may otherwise change as a result of a changed dynamic response of the drive control. These include, for example:
    - Configuration of the setpoint channel
    - Control in the higher-level controller
    - Configuration of the position controller

10.1.3 Acceptance Test

The acceptance test comprises 2 parts:

- Checking whether the safety functions in the converter are correctly set:
    - Does the position control handle the configured application cases in the machine?
    - Do the set interface, times and monitoring functions match the configuration of the machine?
- Checking whether the safety-relevant functions in the plant or machine function correctly. This part of the acceptance test goes beyond the drive acceptance test:
    - Is all safety equipment such as protective door monitoring devices, light barriers or emergency-off switches connected and ready for operation?
    - Does the higher-level control correctly respond to the safety-relevant feedback signals of the drive?
    - Do the drive settings match the configured safety-relevant function in the machine?

10.1.4 Documentation

The documentation consists of the following parts:

- Description of the safety-relevant components and functions of the machine or plant.
- Report of the acceptance test results.
- Report of the settings of the safety functions (ASCII report) and configuration of safe address switches.
- Complete drive configuration (readout by LinMot-Talk)
- The documentation must be signed by the person who carried out the acceptance test.

10.2 Acceptance Tests

The following list contains points which are required for the acceptance of the safety project. This list is not exhaustive. These points must be checked after the initial start-up and after each configuration modification:

- Implementation or changes must only be done by qualified personnel.
- Printout of the ASCII report of the safety parameters
- Checking of the entire safety project for correctness according to the previous chapter
- Implementation and printout of the acceptance protocol
- Signature by programmer and customer
- This information should be added to the machine documentation.
- …

 WARNING	**Authorized Persons** Personnel from the machine manufacturer, who, on account of their technical qualifications and knowledge of the safety functions, are in a position to perform the acceptance test in the correct manner.

 DANGER	**Unwanted motion due to incorrect parameter changes** Incorrect parameter changes for safety functions can result in unwanted motion leading to death or severe injury. • After making a change to a parameter for the safety functions, always perform an acceptance test for the function in question. • Document the values calculated in an acceptance report. **Unsafe operating states due to manipulation of the safety parameters after the acceptance test** Incorrect parameter changes to safety functions after an acceptance test can result in unwanted motion resulting in severe injury or death. • To prevent access to your plants and systems by unauthorized persons, implement access restrictions and take precautions. • To avoid incorrect changes to the configuration and parameters of the safety functions, take the precautions described in this manual. • If any changes have been made and they are intentional, repeat the acceptance test for the safety functions affected. The purpose of the acceptance test is to ensure and document safe operation of the plant. Correct any unintentional changes back to the original values and repeat the acceptance test

Either a complete or a partial acceptance test has to be performed. A complete acceptance test is required when first commissioning the safety functionality on a machine. The acceptance tests must be carried out for each individual drive. Safety-related function expansions transfer of the commissioning settings to other series machines, hardware changes, software upgrades or similar activities permit the acceptance test to be performed with a reduced scope if necessary. A summary of conditions which determine the necessary test scope or proposals in this context is provided below.
A partial acceptance test has to be performed on any replacement or minor changes on a machine.

10.3 Complete Acceptance Test

10.3.1 Documentation

Documentation of the machine and of safety functions

1. Machine description (with overview)
2. Specification of the used safety components (such as drive, stator, slider)
3. Function table:
    a. Active monitoring functions depending on the operating mode and the protective door.
    b. Other sensors with protective functions
    c. The table is part or is the result of the configuring work.
4. Used safety functions for each drive.
5. Information about safety equipment
6. Drive configurations (safety and non-safety)
7. HW configurations (e.g. ID switches, safe address switches)

10.3.2 Functional and diagnostic safety tests

Detailed function test and evaluation of safety functions used. For some functions, trace recordings of individual parameters can be used. If a listed function is not used, no test has to be performed.

1. Encoder parameterization test
    a. Check the configuration of the encoder (such as Type, pole pitch, …)
2. Test the safety function "Safe Torque Off" (STO)
3. Test of the SI function "Safe Stop 1" (SS1)
4. Test of the SI function "Safe Brake Control" (SBC)
5. Test of the SI function "Safe Stop 2" (SS2)
6. Test of the SI function "Safe Operating Stop" (SOS)
7. Test of the SI function "Safely-Limited Speed" (SLS)
    a. Test all used instances.
8. Testing the "Safe Brake Test" (SBT) diagnostics function

10.3.3 Conclusion of the Report

Report of the commissioning status tested and countersignatures:

1. Inspection of safety parameters
2. Logging of checksums (for each drive)
3. Issuing of the safety password and documenting this process (do not specify the safety password in the report!)
4. Configuration backup and backup of the project
5. Countersignature

10.4 Partial Acceptance Test

10.4.1 Documentation

Documentation of the machine and of safety functions

1. Extending/changing the hardware data
2. Extending/changing the software data (specify version)
3. Extending/changing the function table:
    a. Active monitoring functions depending on the operating mode and the protective door.
    b. Other sensors with protective functions
    c. The table is part or is the result of the configuring work.
4. Extending/changing the safety functions per drive
5. Extending/changing the specifications of the safety equipment
6. Extending/changing the drive configurations (safety and non-safety)
7. Extending/changing the HW configurations (e.g. ID switches, safe address switches)

10.4.2 Functional and diagnostic safety tests

Detailed function test and evaluation of SI functions used. For some functions, trace recordings of individual parameters can be used. If a listed function is not used, no test has to be performed.

1. Encoder parameterization test
    a. Check the configuration of the encoder (such as Type, pole pitch, …)
2. Test the safety function "Safe Torque Off" (STO)
3. Test of the SI function "Safe Stop 1" (SS1)
4. Test of the SI function "Safe Brake Control" (SBC)
5. Test of the SI function "Safe Stop 2" (SS2)
6. Test of the SI function "Safe Operating Stop" (SOS)
7. Test of the SI function "Safely-Limited Speed" (SLS)
    a. Test all used instances.
8. Testing the "Safe Brake Test" (SBT) diagnostics function

10.4.3 Functional testing of actual value acquisition

WARNING

Axis movement during the acceptance test
The operation causes the machine to move.

- Take suitable measures to ensure that nobody is in the danger zone during the acceptance test.

1. General testing of actual value acquisition
    a. After exchanging the component, initial activation and brief operation in both directions.
2. Test of failsafe actual value acquisition
    a. Only if a safe encoder is activated.
    b. Briefly operate the drive in both directions.
3. Encoder parameterization test
    a. Only if a safe encoder is activated.
    b. Only required on an encoder replacement

10.4.4 Conclusion of the Report

Report of the commissioning status tested and countersignatures:

1. Extension of checksums (for each drive)
2. Countersignature

10.5 Test Scope for Specific Measures

A complete acceptance test is required when first commissioning of the safety functionality on a machine or major modifications have been made. Major modifications mean functional changes, not only replacing components with the same functionality (which is typically for maintenance).

For the acceptance tests after maintenance measures the following table shows which tests have to be repeated:

Measure	Chapter 10.4.1 - Documentation	Chapter 10.4.2 - Functional and diagnostic safety tests	Chapter 10.4.3 - Functional testing of actual value acquisition	Chapter 10.4.4 - Conclusion of the Report
Replacement of the slider	No	No	Yes	Yes
Replacement of the motor	No	No	Yes	Yes
Replacement of the drive	Yes Points 1 and 2	No	Yes	Yes
Replacement of the cable	No	No	No	Yes
Replacement of Power supply	No	No	No	Yes
Safety Parameter Change	Yes Points 4 to 6	Yes Test the appropriate functions	Yes	Yes
Transfer of project data into other machines (series commissioning)	Yes	Yes Only the safety functions	Yes	Yes
Safety Firmware Update / Change	Yes Point 2	Yes if new safety functions are to be used	Yes Point 1	Yes

Table 100: Acceptance tests after replacements

11 Operation and Maintenance

To keep a machine as safe as possible, it is necessary to perform tests regularly. Some of them can be done during operation, others have to be done during the maintenance window. Problems detected during operation must be evaluated if the safe operation can still be guaranteed.

11.1 Operation

During the operation different tests must be done. The following list shows what item must be checked and which action has to be followed:

Item	Recommended test interval	Action required
Brake Test	According to configuration	When the flag SBT Request (UPID 1A61h) becomes active, a brake test must be performed as soon as it is possible (e.g. next finished production cycle, within the next hour, …) If the brake test is failed a soon maintenance must be planned.
Errors reported	Cyclically read by PLC	If the drive reports an error, it will stop and enter a safe state. The error has to be checked and adequate measures have to be done.
Warnings reported	Cyclically read by PLC	A warning gives the possibility to react as long as full operation is still available. It is advisable to react on warnings adequately. E.g. if a temperature warning is present, slow down the machine or increase cooling.

Table 101: Checks during operation

11.2 Maintenance

A periodic maintenance has to be planned. The interval is dependent on the application and has to be evaluated during the development of the safety project. Maintenance should be done at least once a year. The maintenance has to be documented.

The following safety items have to be checked during maintenance:

Item	Description	Recommended Action
Isolation	Check visually if there is any damage visible on connectors, cables, wires. Also focus on moved cables.	Replace defective parts (cable, connector, …)
Clean and Lubricate	Remove the slider from the stator. Clean the slider and stator. Lubricate again.	Clean and lubricate
Optical check of slider	Check optically, if the slider has any damage like dents, scratches, cracks, etc.	Replace slider if damaged
Bearings	Check if bearings are worn out. Check if stator bearing is worn out	Replace stator if worn out.
Corrosion	Check if parts have traces of corrosion	Find and eliminate cause. Replace corroded parts.
Mechanical links	Check if mechanical links are still stable. Check for loose screws.	Tighten loose screws.
Warnings / Errors	Read out the message and error log of the drive. For checking the error log, at least the signal supply must be turned on.	Check messages if they are still relevant. Eliminate the cause.
Firmware	Check if there is a newer firmware. A newer firmware shall only be installed, if the new functionality or fixed bugs are relevant for the application.	Update firmware (only if really necessary).
Configuration	Check if the configuration has to be changed. This can be necessary for functional reasons or because of logged error or warn messages.	Change configuration (only if really necessary).

Table 102: Checks during maintenance

12 Appendix

12.1 Terms and abbreviations

For the application of this document, the terms and abbreviations are used according to IEC 61508-4.

12.1.1 Additional Abbreviations

Abbreviation	Description
FC	Flash Card, Memory Card
FS	Functional Safety
FSoE	Fail Safe over EtherCAT, Safety over EtherCAT
FW	Firmware
HFT	Hardware Fault Tolerance
LMT	LinMot-Talk
PL	Performance Level
PLC	Programmable Logic Controller
SF	Safety Function
SM02	Safety Module or Safety Board. Responsible for monitoring the safety functions.
UPID	Unique Parameter ID, is an unambiguous identification of a parameter or variable. The number for the UPID is displayed as a 16 bit hex value, e.g. 1A43h.

Table 103: Additional abbreviations

12.2 Change History

Version	Description of Changes	Date/ Signature
1.0	Initial version	2021-10-22 / Ro
1.1	Updates for Build 6.10 20211122. FS Version and MCU CRCs updated. Table 91, Figures 9, 10, 11 ,14, 15, 17 and 32.	2021-11-23 / Ro
1.2	FSoE inserted, Chapter 7.10.3, 7.11 an d7.18.1.	2023-06-20/ Ro

Table 104: Change History