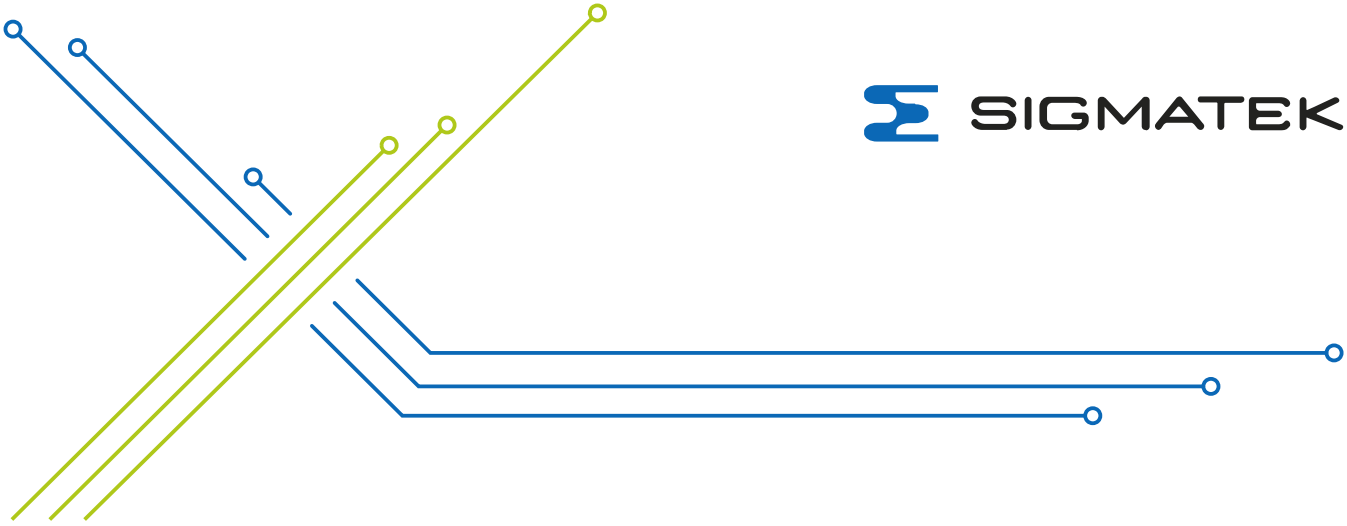

SIGMATEK

ST 152

S-DIAS Stepper Motor Stage Closed Loop

INSTRUCTION MANUAL

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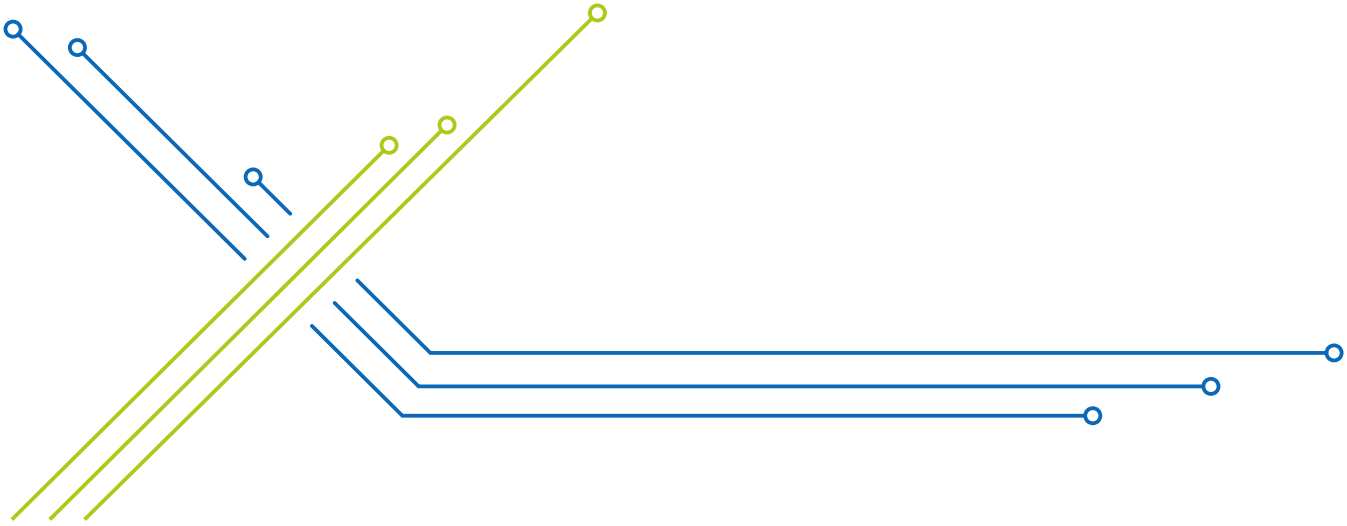

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Translation of the Original Instructions

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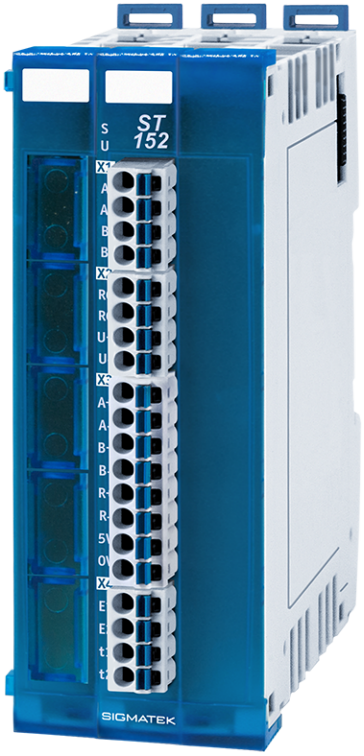
S-DIAS Stepper Motor Stage Closed Loop ST 152



1 stepper motor output stage 50 V/5 A with Closed Loop control

1 brake chopper

1 incremental encoder input RS422/TTL switchable

2 enable inputs +24 V/3.2 mA/0.5 ms with STO functionality

2 latch/digital inputs +24 V/3.7 mA/10 µs

2-phase stepper motors with up to 5 A phase current can be connected to the S-DIAS Stepper Motor Stage Closed Loop ST 152. The module supports an open loop mode (without incremental encoder) and a closed loop mode (with incremental encoder, no vector control). In addition to the current control mode chopper, which is suitable for controlling stepper motors at high speeds and with high accelerations, the module supports a voltage PWM mode chopper, which is suitable for minimizing noise from the motors at low speeds. Step mode selection with up to 256-fold microsteps is automatic. Furthermore, the module offers the option of a load-dependent motor current specification to increase energy efficiency and reduce the motor temperature. The integrated brake chopper provides the connection for an external regen resistor, with which excess energy generated by the braking process of the motor can be dissipated.

The incremental encoder input, which supports RS422 as well as TTL encoders, is provided for position feedback.

With both enable inputs, the safety function STO is implemented.
The 2 latch/digital inputs are provided for the reference motion and monitoring the end positions.

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1 Introduction

1.1 Target Group/Purpose of this Operating Manual

This operating manual contains all information required for the operation of the product.

This operating manual is intended for:

- Project planners
- Technicians
- Commissioning engineers
- Machine operators
- Maintenance/test technicians

General knowledge of automation technology is required.

Further help and training information, as well as the appropriate accessories can be found on our website www.sigmatek-automation.com.

Our support team is happily available to answer your questions or assist you in case of any issues.
Please see our website for our hotline number and business hours.

1.2 Important Reference Documentation

- Safety System Handbook

This and additional documents can be downloaded from our website or obtained through support.

1.3 Contents of Delivery

1x ST 152

2 Basic Safety Directives

2.1 Symbols Used

The following symbols are used in the operator documentation for warning and danger messages, as well as informational notes.

DANGER

Danger indicates that death or serious injury **will occur**, if the specified measures are not taken.

→ To avoid death or serious injuries, observe all guidelines.

Danger indique une situation dangereuse qui, faute de prendre les mesures adéquates, **entraînera** des blessures graves, voire mortelles.

→ Respectez toutes les consignes pour éviter des blessures graves, voire mortelles.

WARNING

Warning indicates that death or serious injury **can** occur, if the specified measures are not taken.

→ To avoid death or serious injuries, observe all guidelines.

Avertissement d'une situation dangereuse qui, faute de prendre les mesures adéquates, **entraînera** des blessures graves, voire mortelles.

→ Respectez toutes les consignes pour éviter des blessures graves, voire mortelles.

CAUTION

Caution indicates that moderate to slight injury **can** occur, if the specified measures are not taken.

→ To avoid moderate to slight injuries, observe all guidelines.

Attention indique une situation dangereuse qui, faute de prendre les mesures adéquates, **peut** entraîner des blessures assez graves ou légères.

→ Respectez toutes les consignes pour éviter des blessures graves, voire mortelles.

DANGER

Electrical voltage

Tension électrique

WARNING

Hot Surfaces

Surfaces chaudes

CAUTION

Danger for ESD-sensitive components.

Les signes de danger pour les composants sensibles aux décharges électrostatiques.

INFORMATION

INFORMATION

→ Provides important information on the product, handling or relevant sections of the documentation, which require particular attention.

2.2 Disclaimer

The contents of this operating manual were prepared with the greatest care. However, deviations cannot be ruled out. This operating manual is regularly checked and required corrections are included in the subsequent versions. The machine manufacturer is responsible for the proper assembly, as well as device configuration. The machine operator is responsible for safe handling, as well as proper operation.

The current operating manual can be found on our website. If necessary, contact our support.

Subject to technical changes, which improve the performance of the devices. The following operating manual is purely a product description. It does not guarantee properties under the warranty.

Please thoroughly read the corresponding documents and this operating manual before handling a product.

SIGMATEK GmbH & Co KG is not liable for damages caused through, non-compliance with these instructions or applicable regulations.

2.3 General Safety Directives

The Safety Directives in the other sections of this operating manual must be observed. These instructions are visually emphasized by symbols.

According to EU Directives, the operating manual is a component of a product. This operating manual must therefore be accessible in the vicinity of the machine since it contains important instructions. This operating manual should be included in the sale, rental or transfer of the product, or its online availability indicated.

Regarding the requirements for Safety and health connected to the use of machines, the manufacturer must perform a risk assessment in accordance with machine directives 2006/42/EG before introducing a machine to the market.

INFORMATION

Operate the unit with devices and accessories approved by SIGMATEK only.

CAUTION

Handle the device with care and do not drop or let fall.
Prevent foreign bodies and fluids from entering the device.
The device must not be opened!

Manipulez l’appareil avec précaution et ne le laissez pas tomber.
Empêchez les corps étrangers et les liquides de pénétrer dans l’appareil.
L’appareil ne doit pas être ouvert!

If the device does not function as intended or has damage that could pose a danger, it must be replaced!

En cas de fonctionnement non conforme ou de dommages pouvant entraîner des risques, l'appareil doit être remplacé !

For your own safety and that of others, compliance with the environmental conditions is essential.

Pour votre propre sécurité et celle des autres, le respect des conditions environnementales est essential.

2.4 Designated Use

The Safety functions implemented in the product are designed for use with safety applications in a PLC control and meet the required conditions for safe operation.

CAUTION

The instructions contained in this operating manual must be followed. For error-free operation, proper transport and storage are essential.
Installation, mounting, programming, initial start-up, operation, maintenance and decommissioning can only be performed by qualified personnel.
Qualified personnel in this context are people, who have completed training or have trained under supervision of qualified personnel and have been authorized to operate and maintain safety-related equipment, systems and facilities in compliance with the strict directives and standards of safety technology (Functional Safety).

Les instructions contenues dans ce manuel technique doivent être suivies.
Pour un fonctionnement sans erreur, le transport et le stockage appropriés sont essentiels.
L'installation, le montage, la programmation, la mise en service initiale, l'exploitation, la maintenance et la mise hors service ne peuvent être effectués que par une personne qualifiée.
Dans ce contexte, on entend par personnel qualifié les personnes qui ont suivi une formation ou qui ont été formées sous la supervision d'un personnel qualifié et qui ont été autorisées à utiliser et à entretenir l'équipement, les systèmes et les installations de sécurité conformément aux directives et aux normes strictes de la technique de sécurité (Sécurité fonctionnelle).

For your own safety and that of others, the product should be used for their designated purpose only.
Correct EMC installation is also included under designated use.

Pour votre propre sécurité et celle des autres, le produit ne doivent être utilisés qu'à des fins prévues.
Une installation CEM correcte est également incluse dans l'utilisation prévue.

Non-designated use consists of:

- any changes made to the module or the use of damaged modules.
- use of the module inconsistent with the technical margins described in this operating manual or the specifications defined in the technical data.

L'utilisation non désignée consiste en:

- toute modification apportée au module ou l'utilisation des modules endommagés.
- utilisation du module non conforme aux marges techniques décrites dans ce manuel ou aux spécifications définies dans les données techniques.

2.5 Software/Training

The application is created with the software LASAL CLASS 2 and LASAL SCREEN Editor, the Safety application is created using the SAFETYDesigner. Basic information on Safety (Functional Safety) can be found in the Safety System Handbook.

Training for the LASAL development environment, with which the product can be configured, is provided. Information on our training schedule can be found on our website.

3 IT Security

S-DIAS safety modules were developed for integration into a network protected against unauthorized access.

For example, the following dangers can affect the network:

- Unauthorized access
- Data manipulation
- and many other IT security violations

It is the responsibility of the integrator or operator to carry out a risk analysis of the connections between S-DIAS modules and the integration into the overall infrastructure. The following measures, for example, may result from this (if necessary):

- Separation of IT/OT networks (VLANs or physical)
- Firewalls
- Password-protected user accounts
- Data encryption
- and much more

With regard to the functional safety objective, in this case the STO safety function, no direct effects on the function or its integrity are possible, since the function cannot be influenced via communication-based interfaces.

The availability of the overall system (as with all safety functions) can be compromised by external attacks, hence the above measures are necessary.

4 Standards and Directives

4.1 Residual Risks

CAUTION

The following residual risks for the product must be included in the system integrator's risk assessment:

- Release of non-environmentally safe substances, emissions and unusual temperatures
- Hazardous contact voltages
- Effects of operational electrical, magnetic and electromagnetic fields
- Possible effects of information technology devices

Les risques résiduels suivants pour le produit doivent être inclus dans l'évaluation des risques de l'intégrateur de système :

- Libération de substances non respectueuses de l'environnement, émissions et températures inhabituelles
- Tensions de contact dangereuses
- Effets des champs électriques, magnétiques et électromagnétiques opérationnels
- Effets possibles des dispositifs de technologie de l'information

4.2 Safety of the Machine or Equipment

Observe all on-site rules and regulations for accident prevention and occupational safety.

4.3 Directives

The product was constructed in compliance with the following European Union directives and tested for conformity.

4.3.1 Functional Safety Standards

EN IEC 62061	Safety of machinery - Functional safety of safety-related control systems
EN ISO 13849-1	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
EN ISO 13849-2	Safety of machinery - Safety-related parts of control systems - Part 2: Validation
EN IEC 61508-1	Functional safety - Part 1: General requirements
EN IEC 61508-2	Functional safety - Part 2: Requirements for electrical / electronic / programmable electronic safety-related systems
EN IEC 61508-3	Functional safety - Part 3: Software requirements

The issue status of the applied standards can be found in the EU declaration of conformity.

4.3.2 EU Declaration of Conformity

EU Declaration of Conformity

The product ST 152 conforms to the following European directives:

- → 2006/42/EG Machine Directive
- → 2014/30/EU Electromagnetic Compatibility (EMC Directive)
- → 2011/65/EU “Restricted use of certain hazardous substances in electrical and electronic equipment” (RoHS Directive)

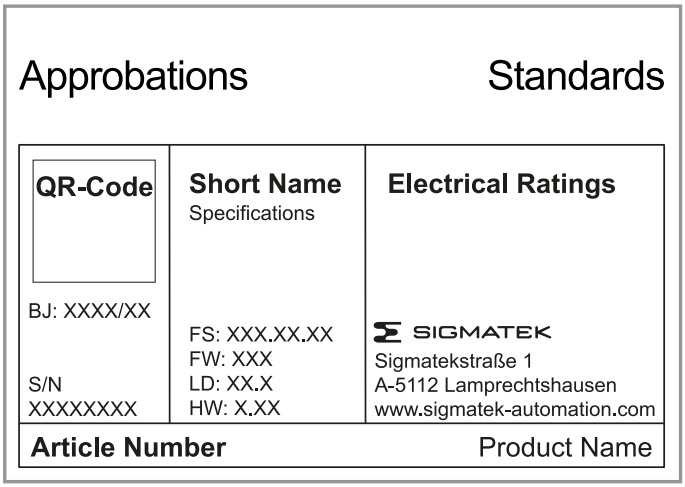
The EU Conformity Declarations are provided on the SIGMATEK website. They can be found in the download area of the respective product.

4.4 Safety-Relevant Parameters

ST 152	Safety parameters SIL 3, PL e / Cat. 4
Safety Function STO (the safety function STO is supported by the module ONLY for operation as a servo motor output stage)	PFH = 1.12E-09
	SFF = 99 %
	$MTTF_D$ = 2100 years
	DC = 99 %

5 Type Plate

The type plate provides information about the product's features. The type plate shown here is only an example.



HW: Hardware version
FS: Safety version number
FW: Firmware version
LD: Logic device version
QR-Code: Serial number

6 Technical Data

6.1 Stepper Motor Output Specification

Type	stepper motor output stage
Operating modes	open loop mode (without incremental encoder feedback)
	closed loop mode (with incremental encoder feedback)
Number of phases	2
Operating voltage	+18-55 V
Current controller frequency	maximum 32 kHz
Output current	maximum 5 A_{RMS}
Output current over the environmental temperature	maximum 5 A continuous current at 45 °C
	maximum 3 A continuous current at 55 °C
DC-link capacitance	4.7 µF
Current Regulator Modes	current control mode chopper
	voltage PWM mode chopper[1)]
Supported Step Operation Modes	full step, half step, 4-/8-/16-/32-/64-/128-/256-fold
	Microstep (switchover occurs automatically)
Support for load-dependent motor current control	yes, sensorless on the basis of the measured back-EMF or via incremental encoder
Voltage measurement	+15-65 V
	with an under voltage < 15 V or over voltage > 60 V, the motor output is shut down through the hardware.
Temperature measurement	0-125 °C
	with temperature warning at 103 °C
	with overtemperature cut-off at 108 °C

INFORMATION

Note on frequency resonance

Operating a stepper motor in the stepper frequency default mode can lead to resonance in certain frequency ranges. This is indicated by loss or torque reduction => the stepper motor loses steps. This phenomenon is a result of the stepper motor construction and depends on the load. The problem can be minimized or avoided in closed-loop mode by means of position feedback using an incremental encoder.

1) The voltage PWM mode chopper, offers the advantage of lower noise compared to the standard current control mode chopper, but is only suitable for low speeds due to the control principle. In the voltage PWM mode chopper, there may be deviations in the set current setpoint at low speeds due to the principle involved. It is therefore necessary to verify the motor current in the application using measurement technology for the speed range used, in order to prevent the motor from being under- or over-energized.

6.2 Brake Chopper Specifications

Number	1
Output	GND switching
Maximum current	6 A[1)]
Short-circuit protection	yes
Regen resistor	external power resistor
Article number	20-014-061-Z1
Regen resistor switching threshold on/off	60 V/55 V

WARNING

Hot surface warning!
A burn hazard exists with physical contact!
During operation, the surface of the brake resistor can become very hot and remain hot sometime after operation.
Avoid physical contact with the surface of the brake resistor, and for a significant time after operation as well.

Avertissement de surface chaude!
Il existe un risque de brûlure par contact physique!
Pendant le fonctionnement, la surface de la résistance de freinage peut devenir très chaude et rester chaude quelque temps après le fonctionnement.
Eviter tout contact physique avec la surface de la résistance de freinage, ainsi que pendant une longue période après le fonctionnement.

[1)] Regen braking must be dimensioned according to the application. For most applications, a resistor is sufficient. If multiple S-DIAS Stepper Motor Stage Closed Loop are driven with one intermediate circuit supply, it is possible to equip only one module with regen braking. The recommended regen resistor (15 Ω/100 W) is available at SIGMATEK under the article number 20-014-061-Z1.

6.3 Incremental Encoder Specifications

Number	1
Input signals	Incremental encoder signals RS422 (A, /A, B, /B, R, /R)
	RS422 level (150 Ω connection, integrated in module)
	Incremental encoder signal TTL (A, B, R)
	TTL level (1200 Ω pull-up, integrated in module)
Input frequency	maximum 125 kHz
Counter frequency	maximum 500 kHz
Signal analysis	4x
Counter resolution	16 bits
Encoder power supply	+5 V/0.2 A short-circuit proof

6.4 Latch/Digital Inputs Specifications

Number	2	
Input voltage	typically +24 V	maximum +30 V
Signal level	low: < +5 V	high: > +15 V
Switch hysteresis	typically +11 V	
Input current	3.7 mA at +24 V	
Input delay	typically 10 µs	

INFORMATION

The latch and digital inputs meet the requirements of EN 61131.

6.5 Enable Inputs Specifications

Number	2	
Input voltage	+24 V DC	
Input voltage range	minimum +18 V	maximum +30 V
Signal level	low: ≤ +5 V	high: ≥ +15 V
Switch hysteresis	typically +11 V	
Input current	3 mA at +24 V	
Input delay	typically 0.5 ms	
Safety Level	complies with the requirements of Category 4, Performance Level "e" according to EN ISO 13849-1 and SIL CL 3 according to EN IEC 62061 or EN IEC 61508.	
Safety function	STO according to EN61800-5-2, section 4.2.2.2	
	The motor is not supplied with energy, which can cause a turn. The stepper motor output stage does not supply energy to the motor, which can generate torque.	

6.6 Electrical Requirements

Supply from S-DIAS bus	+18-55 V DC	
Current consumption of the motor supply	maximum 6 A (load-dependent)	
Supply from S-DIAS bus	+5 V	
Current consumption on the S-DIAS bus (+5 V supply)	-	-
Supply from S-DIAS bus	+24 V	
Current consumption on the S-DIAS bus (+24 V supply)	typically 95 mA (incl. +5 V supply of the incremental encoder)	maximum 135 mA (incl. +5 V supply of the incremental encoder)

INFORMATION

Notes on Voltage Ripples in the Motor Supply

The motor supply (X2) must be connected with an intermediate circuit capacitance appropriate for the application (at least 2000 µF/100 V). Attention must be paid to short cables and appropriate cable cross-sections.
(maximum 15 cm between module and capacitor / 1.5 mm²)
To keep the voltage ripple within the allowable range (< 2 Vss), an electrolyte capacitor of the appropriate value must be connected in parallel to the motor supply terminals. As a reference value for the required capacitance, approximately 2000 µF per Ampere supply current can be assumed. To achieve optimal EMC ratio, it is recommended that the capacitor be mounted near the output stage of the stepper motor and the connection lines be as short as possible.

Stepper Motor Braking

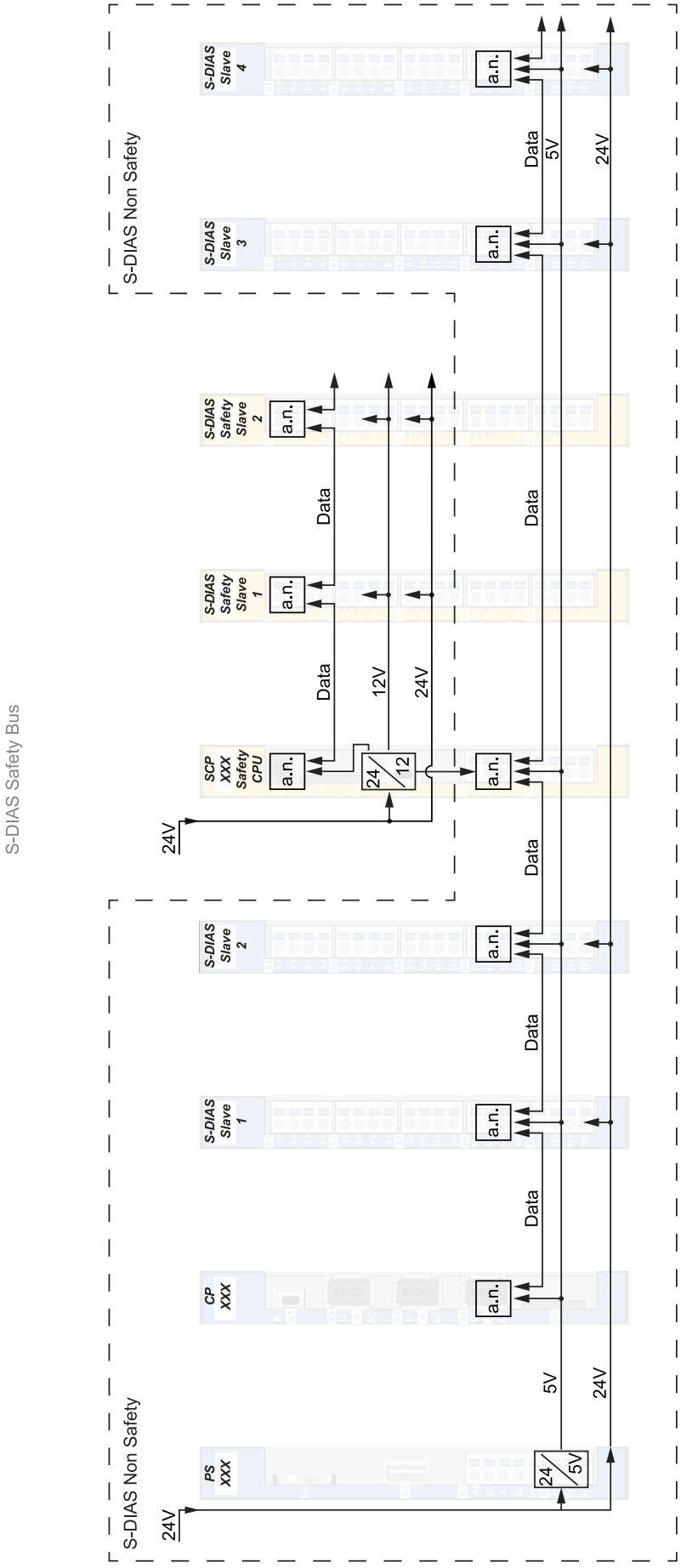
When applying the brake in a stepper motor, a generative process can occur whereby the kinetic energy of the motor is converted into electrical energy. The energy of the motor is thereby fed back into the supply of the stepper motor output stage; this then increases the supply voltage. It should be noted that a regenerative voltage of 65 V at the motor supply connection is not exceeded! The external capacity of the motor supply is may be needed. If the capacitors in the power supply are insufficient, a regen resistor, which converts the excess energy into heat must be connected to the stepper motor output stage. When selecting the power supply, it is important to ensure that it is appropriately feedback-resistant up to the maximum regenerative voltage that occurs.

INFORMATION

Note S-DIAS Supply

If this S-DIAS module is connected to an S-DIAS supply module with several S-DIAS modules, the total current of the modules used must be determined and checked.
The total current of the +24 V supply cannot exceed 1.6 A!
The total current of the +5 V supply cannot exceed 1.6 A!
The specification for the current can be found in the module-specific documentation under "Electrical Requirements".

Incorrectly set parameter or incorrect wiring can lead to destruction of the motor. In particular, motor currents and the I^2T settings (A-I2TT, A-I2TERR) must be monitored, which can be parameterized in the DIAS-Drive Editor via the LASAL Class 2 tool.



a.n. = active node

Wiring S-DIAS Safety in S-DIAS System

- each S-DIAS module is an active module (active node)
- Safety CPU is connected to the S-DIAS bus (incl. +5 V supply)
- Safety bus is independent and separated from the S-DIAS bus

6.7 Miscellaneous

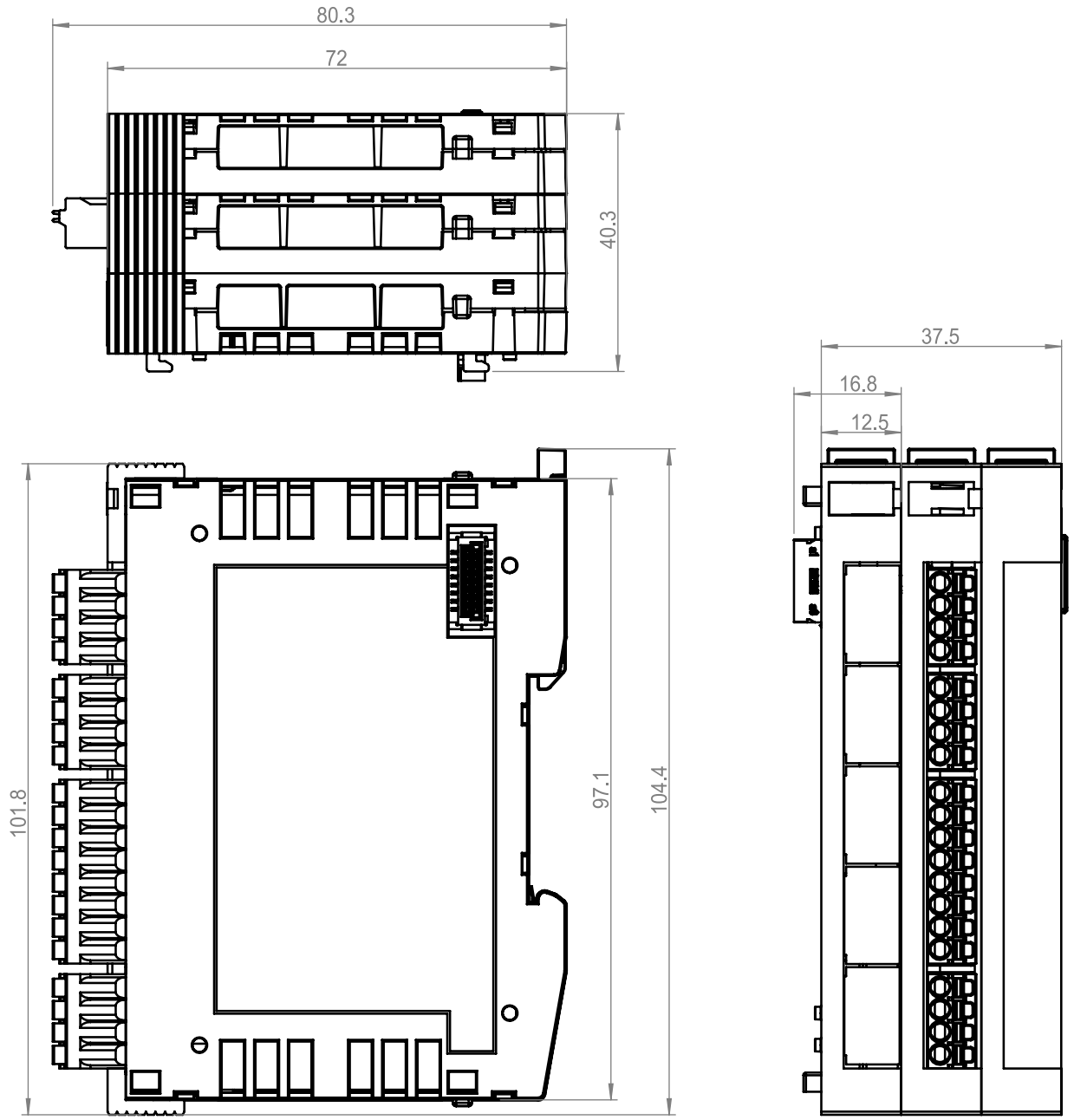
Article number	20-014-152	
Printed circuit board coating	no	
Approvals	CE	yes
	UL	designed according to UL
	Functional Safety	yes, EG-type-examined
	UKCA	no
Mission time	20 years	

6.8 Environmental Conditions

Storage temperature	-25 ... +85 °C	
Environmental temperature	0 ... +55 °C[1)]	
Humidity	0-95 %, non-condensing	
Installation altitude above sea level	0-2000 m without derating > 2000 m up to a maximum of 5000 m with derating of the maximum environmental temperature by 0.5 °C per 100 m	
Operating conditions	pollution degree 2	
Noise emission	≤ 70 dB	
EMC resistance	EN 61000-6-2 (industrial area) EN 61000-6-7 (immunity industry functional safety) (increased requirements according to EN IEC 62061)	
EMC noise generation	EN 61000-6-4 (industrial area)	
Vibration resistance	EN 60068-2-6	3.5 mm from 5-8.4 Hz 1 g from 8.4-150 Hz
Shock resistance	EN 60068-2-27	15 g (147.15 m/s²)
Protection type	EN 60529	IP20

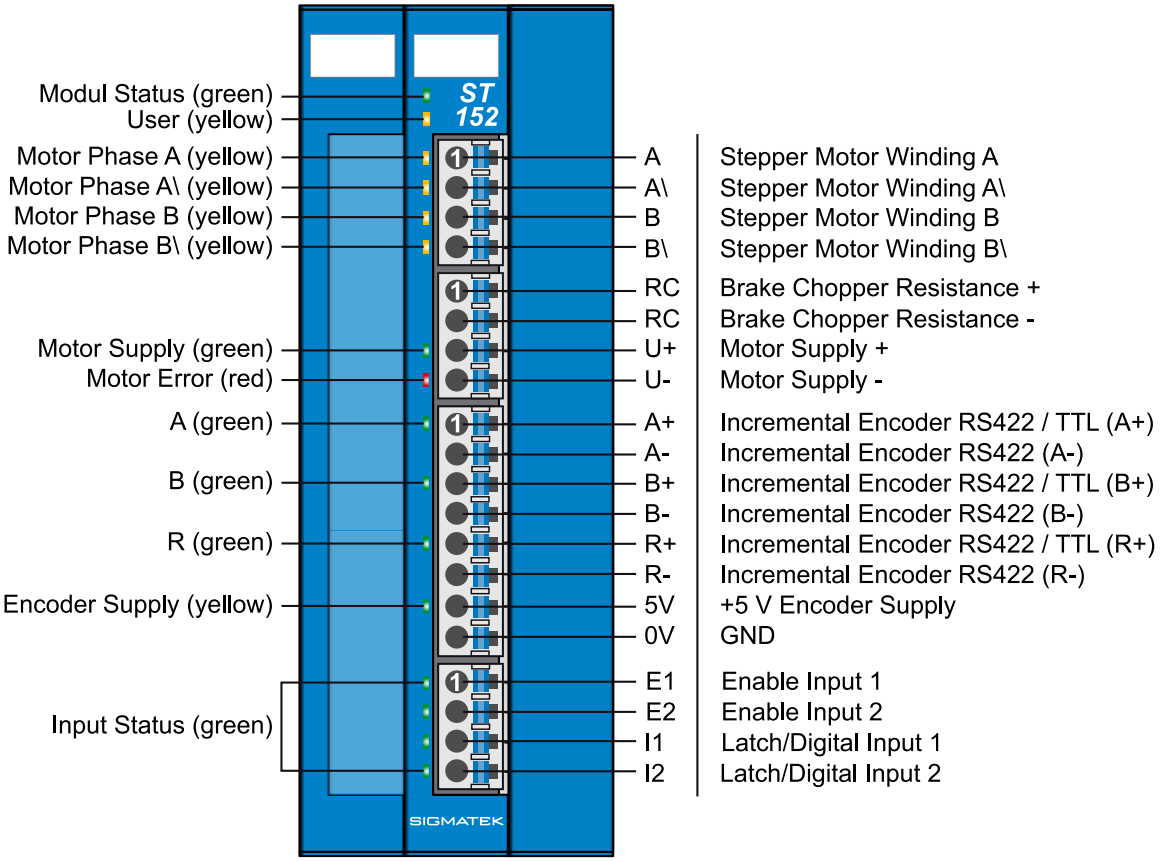
1) maximal 5 A continuous current at 45 °C, maximum 3 A continuous current at 55 °C

7 Mechanical Dimensions



Measurements	37.5 x 104 x 72 mm (W x H x D)

8 Connector Layout



INFORMATION

It is not permitted to plug or unplug the motor supply connector X2 during operation!

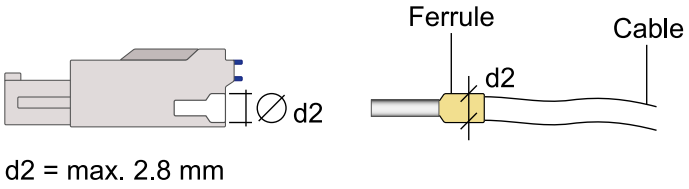
8.1 Applicable Connectors

X1-X4: Connectors with spring terminals (included in delivery)

The spring terminals are suited for the connection of ultrasonically compacted (ultrasonically welded) stranded wire.

Connection capacity:

Stripping length/sleeve length	10 mm
Mating direction	parallel to conductor axis or to circuit board
Conductor cross section rigid	0.2-1.5 mm²
Conductor cross section flexible	0.2-1.5 mm²
Conductor cross section, ultrasonically compacted	0.2-1.5 mm²
Conductor cross section AWG/kcmil	24-16
Conductor cross section flexible with ferrule without plastic sleeve	0.25-1.5 mm²
Conductor cross section flexible with ferrule with plastic sleeve	0.25-0.75 mm² (reason for reduction d2 of the ferrule)

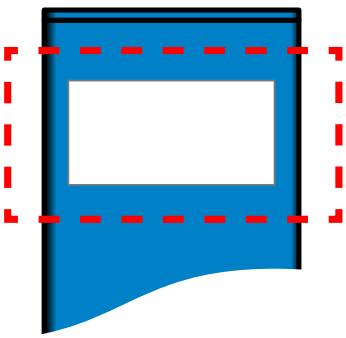


d2 = max. 2.8 mm

8.2 Status LEDs

Module status	green	ON	module active
		OFF	no supply available
		BLINKING (5 Hz)	no communication
User	yellow	ON	adjustable by application (e.g. the module LED can be set to blinking through the visualization so that the module is easily found in the control cabinet)
		OFF	
		BLINKING (2 Hz)	
		BLINKING (4 Hz)	
Motor phase A, A\, B, B\	yellow	ON	motor phase active
		OFF	no phase control
Motor supply	green	ON	motor supply available, motor active
		OFF	motor supply not available
		BLINKING	motor supply available, motor inactive
Motor error	red	ON	stepper motor output stage error (external enable inputs E1 & E2, inactive/missing or internal module error, STO error)
		OFF	no errors
Encoder signal A, B, R	green	ON	encoder signal HIGH
		OFF	encoder signal LOW
Encoder power supply	yellow	ON	encoder supply OK
		OFF	no encoder supply
Enable input 1,2	green	ON	input ON
		OFF	input OFF
Latch/digital input 1,2	green	ON	input ON
		OFF	input OFF

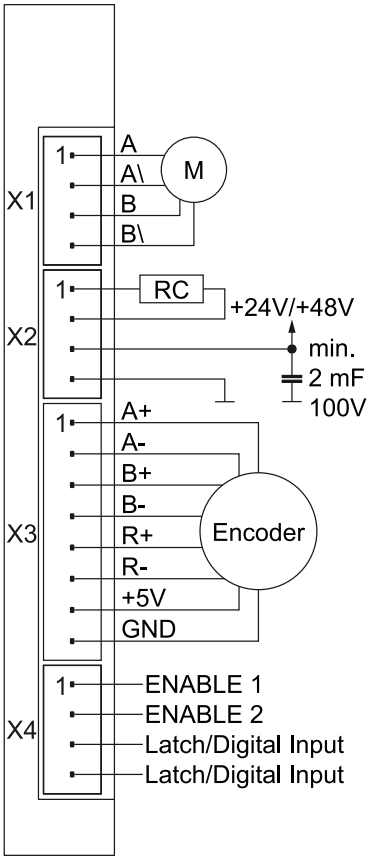
8.3 Label Field



The labeling field is printed directly on the module.

9 Wiring

9.1 Wiring Example



9.2 Note

The following installation guidelines should be observed:

- The DIN rail must have an adequate mass connection.
- The shielding must be connected to a shielding bus.
- To wire the incremental encoder, a shielded cable is required. With an RS422 encoder, the use of shielded, twisted pair cables is recommended. The shield must be placed as close as possible before the module.
- For the motor wiring, a shielded cable is required. The shield must be placed as close as possible to the module.
- The ground bus should be connected to the control cabinet if possible!
- The maximum cable length for the encoder, motor and brake chopper cables is 30 meters.

INFORMATION

The ground bus should be connected to the control cabinet when possible!

CAUTION

The S-DIAS module **CANNOT** be connected/disconnected while voltage is applied!

CAUTION

The operator must ensure that no interference from ESD affects the product.

10 Additional Safety Information

The Safety function “STO” is an integrated part of the DC motor output stage. It meets all necessary requirements for safe operation in SIL 3 according to EN IEC 62061 or EN IEC 61508 and in compliance with PL e. Cat. 4 in accordance with EN ISO 13849-1.

CAUTION

The instructions contained in this document must be followed.

- The ST 152 can only be powered by supplies that meet the requirements for SELV or PELV in compliance with EN 60204.
  For error-free operation, proper transport and storage are essential. See chapter 14 Transport/Storage.
- Installation, mounting, programming, initial start-up, operation, maintenance and decommissioning can only be performed by qualified personnel.
- Qualified personnel in this context are people, who have completed training or have trained under supervision of qualified personnel and have been authorized to operate and maintain safety-related equipment, systems and facilities in compliance with the strict guidelines and standards of safety technology.

For your own safety and that of others, the safety modules should be used for their designated purpose only. Correct EMC installation is also included in the designated use.

ATTENTION

Les instructions contenues dans ce document doivent être suivies.

- Pour un fonctionnement sans erreur, le transport et le stockage appropriés sont essentiels. Voir le chapitre 14 Transport/Storage pour plus d’informations.
- L’installation, le montage, la programmation, la mise en service initiale, l’exploitation, la maintenance et la mise hors service ne peuvent être effectués que par une personne qualifiée.
- Dans ce contexte, on entend par personnel qualifié les personnes qui ont suivi une formation ou qui ont été formées sous la supervision d’un personnel qualifié et qui ont été autorisées à utiliser et à entretenir l’équipement, les systèmes et les installations de sécurité conformément aux directives et aux normes strictes de la technique de sécurité.

Pour votre propre sécurité et celle des autres, les modules de sécurité ne doivent être utilisés qu’à des fins prévues. Une installation CEM correcte est également incluse dans l’utilisation prevue.

CAUTION

Non-designated use consists of:

- any changes made to the module or the use of damaged modules.
- use of the module inconsistent with the technical margins described in this manual or the speciation's defined in the technical data (see chapter 6 Technical Data).

The main power supply for the servo amplifier must be disconnected using the main switch for the following instances:

- Cleaning, maintenance or repairs
- Extended still-stand periods

CAUTION

L'utilisation non désignée consiste en:

- toute modification apportée au module ou l'utilisation des modules endommagés.
- utilisation du module non conforme aux marges techniques décrites dans ce manuel ou aux spécifications définies dans les données techniques (voir chapitre6 Technical Data).

L'alimentation principale du variateur doit être débranchée à l'aide de l'interrupteur principal dans les cas suivants:

- Nettoyage, entretien ou réparation
- périodes d'immobilisation prolongées

DANGER

Failure to follow the above safety measures can lead to severe injuries.

- Only trained personnel are authorized to install the "safe restart lock" STO (Safe Torque off) and set the parameters.
- All control devices (switches, relays, PLC, etc.) and the control cabinet must meet the requirements for EN ISO 13849.
  This includes:
  - Door switches, etc. with at least IP54 protection.
  - Control cabinet with at least IP54 protection.
- Appropriate cables must be used, and proper cable termination on the module side must be ensured (see the chapter “8.1 Applicable Connectors” => Connection capacity).
- All cables that affect safety (e.g. control cables for the ENABLE 1 and ENABLE 2 inputs) must be laid in a cable duct outside of the control cabinet: Short or crossed circuits in the signal lines must be avoided! See EN ISO 13849.

DANGER

Le non-respect des mesures de sécurité ci-dessus peut entraîner des blessures graves.

- Seul un personnel qualifié est autorisé à installer le "blocage de redémarrage sûr" STO (Safe Torque off) et à régler les parameters.
- Tous les appareils de commande (interrupteurs, relais, API, etc.) et l'armoire de commande doivent satisfaire aux exigences de la norme EN ISO 13849.
  Il s'agit des éléments suivants :
  - interrupteurs de porte, etc. avec une protection d'au moins IP54
  - armoire de commande avec une protection d'au moins IP54.
- Il convient d'utiliser des câbles adaptés et de veiller à ce que les extrémités des câbles soient correctement raccordées côté module (voir le chapitre 8.1 Applicable Connectors" => Connection capacity).
- Tous les câbles affectant la sécurité (par ex. les câbles de commande pour les entrées ENABLE 1 et ENABLE 2) doivent être posés dans un conduit de câbles de raccordement à l'extérieur de l'armoire électrique. Eviter les courts-circuits ou les courts-circuits croisés dans les lignes de signalisation! Voir EN ISO 13849.

DANGER

If external forces influence axes that are used with the STO safety function (e.g. hanging load), additional measures must be taken (such as an electromagnetic double-surface spring brake, instead of a permanent magnet brake).

Si des forces externes influencent les axes utilisés avec la fonction de sécurité STO (par ex. charge suspendue), des mesures supplémentaires doivent être prises (par ex. un frein à ressort électromagnétique à double surface au lieu d'un frein à aimant permanent).

WARNING

Hot surface warning!
Physical contact poses a burn hazard!
With unfavorable installation and operating conditions, the surface of the S-DIAS drive module can reach temperatures up to 76 °C and remain hot for some time after operation.

Avertissement de surface chaude !
Le contact physique présente un risque de brûlure !
En cas de conditions d'installation et de fonctionnement défavorables, la surface du module d'entraînement S-DIAS peut atteindre des tempé-ratures allant jusqu'à 76 °C et rester chaude pendant un certain temps après utilisation.

10.1 STO

The ST 152 supports the safety functions STO (Safe Torque Off) and meets the requirements for Category 4 Performance Level "e" according to EN ISO 13849-1 and SIL 3 according to EN IEC 62061 or EN IEC 61508.

For his purpose, the servo amplifier has two safe inputs ENABLE 1 and ENABLE 2.

Only PELV/SELV power supply units may be used as the +24 V power supply.

10.2 Function

The safety functions in the ST 152 are controlled over two digital inputs.

The following table shows the status that the ENABLE 1 and ENABLE 2 inputs must assume to enable normal operation or trigger the safety function.

Input Status		Description
ENABLE 1	**ENABLE 2**	
Open	Open	**Safe status of the drive system**
Open	Low	
Low	Open	
Low	Low	
High	High	**Drive system ready**

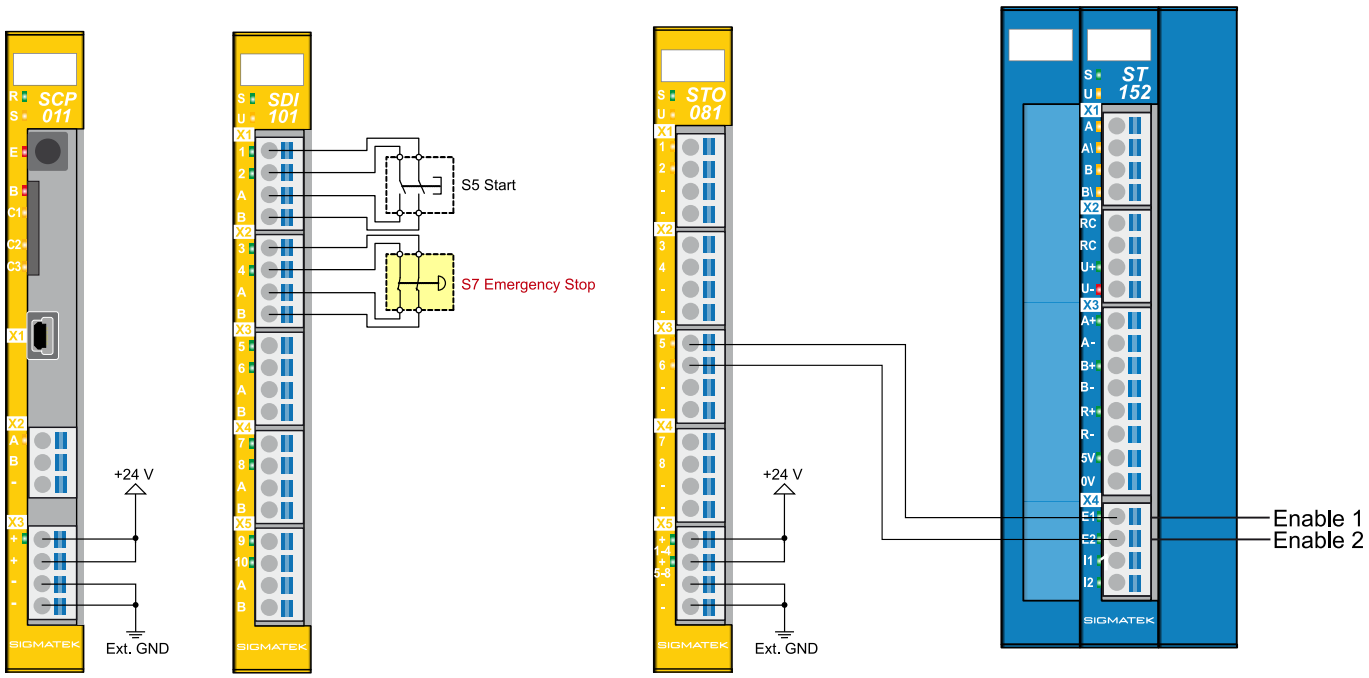
If the ENABLE 1 and ENABLE 2 are changed from any status to the "Drive Ready" status, the servo amplifier is not immediately enabled. In order to set the system to the status “Drive system ready”, a change from “Low-Low” to “High-High” has to be executed. The reason for this is that, for example, sticky contacts of switching devices are detected.

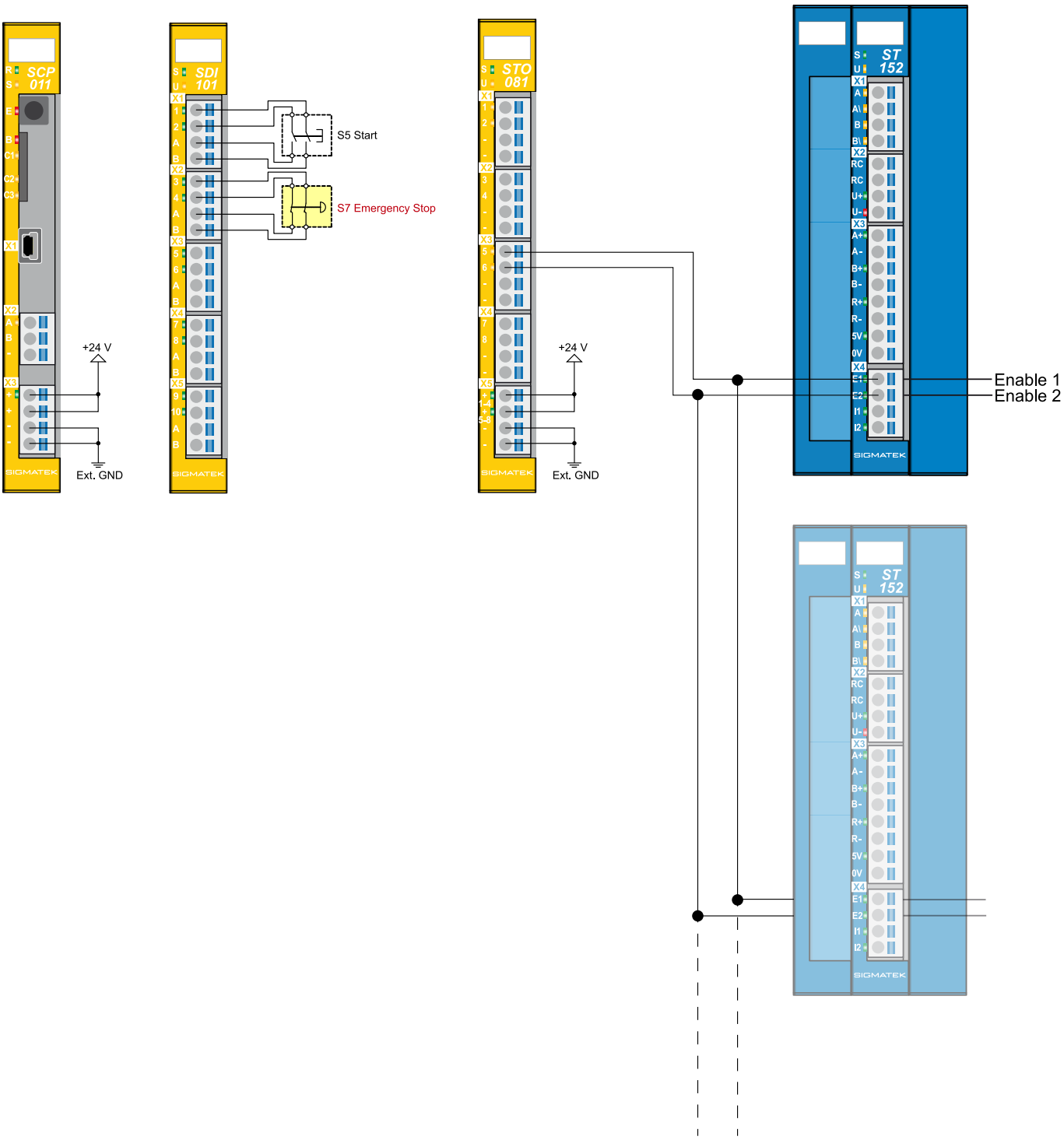
11 Wiring Examples

In the following sub chapters, wiring examples are provided. It must be ensured that all constructive measures etc. are complied with and applied in order to fulfill the requirements of the category used.

11.1 Performance Level e, Category 4 or SIL 3 - Safety PLC

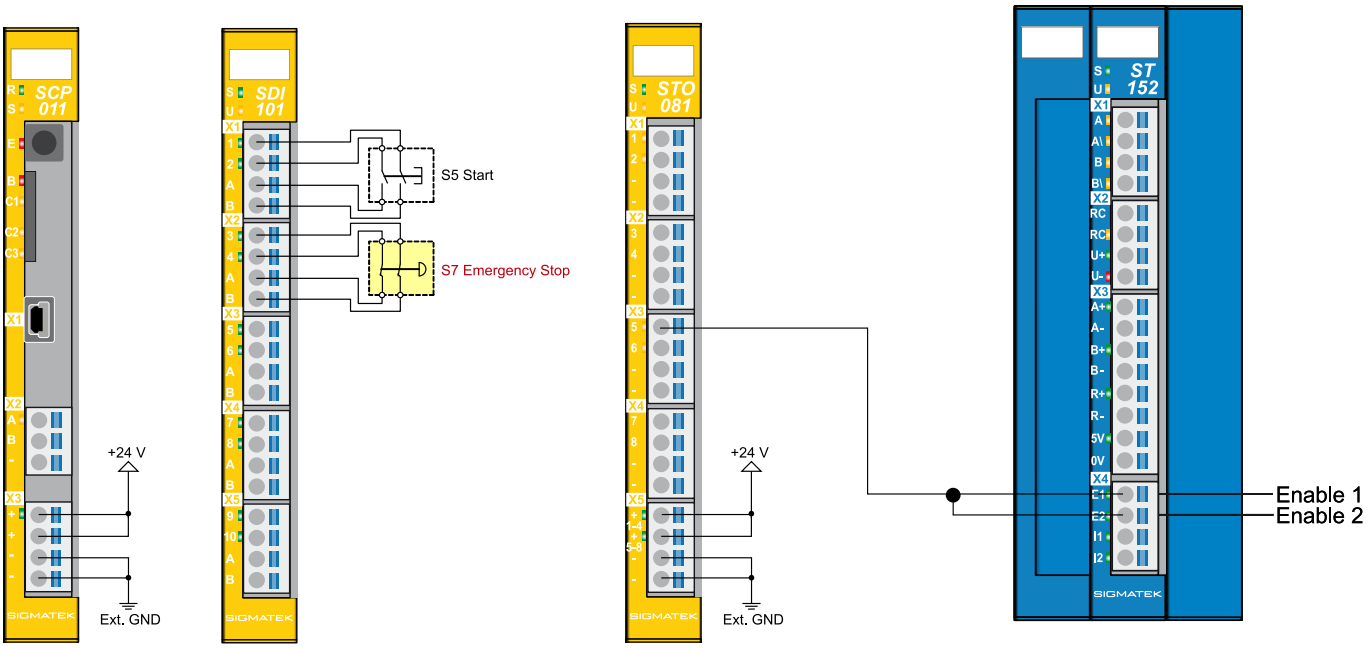
To meet the requirements of category 4, performance Level "e" for EN ISO 13849-1 and SIL 3 according to EN IEC 62061 or EN IEC 61508, two error-proof output of a Safety PLC must be used. Cross-circuit detection between the two lines via the output tests of the STO 081 is hereby possible.

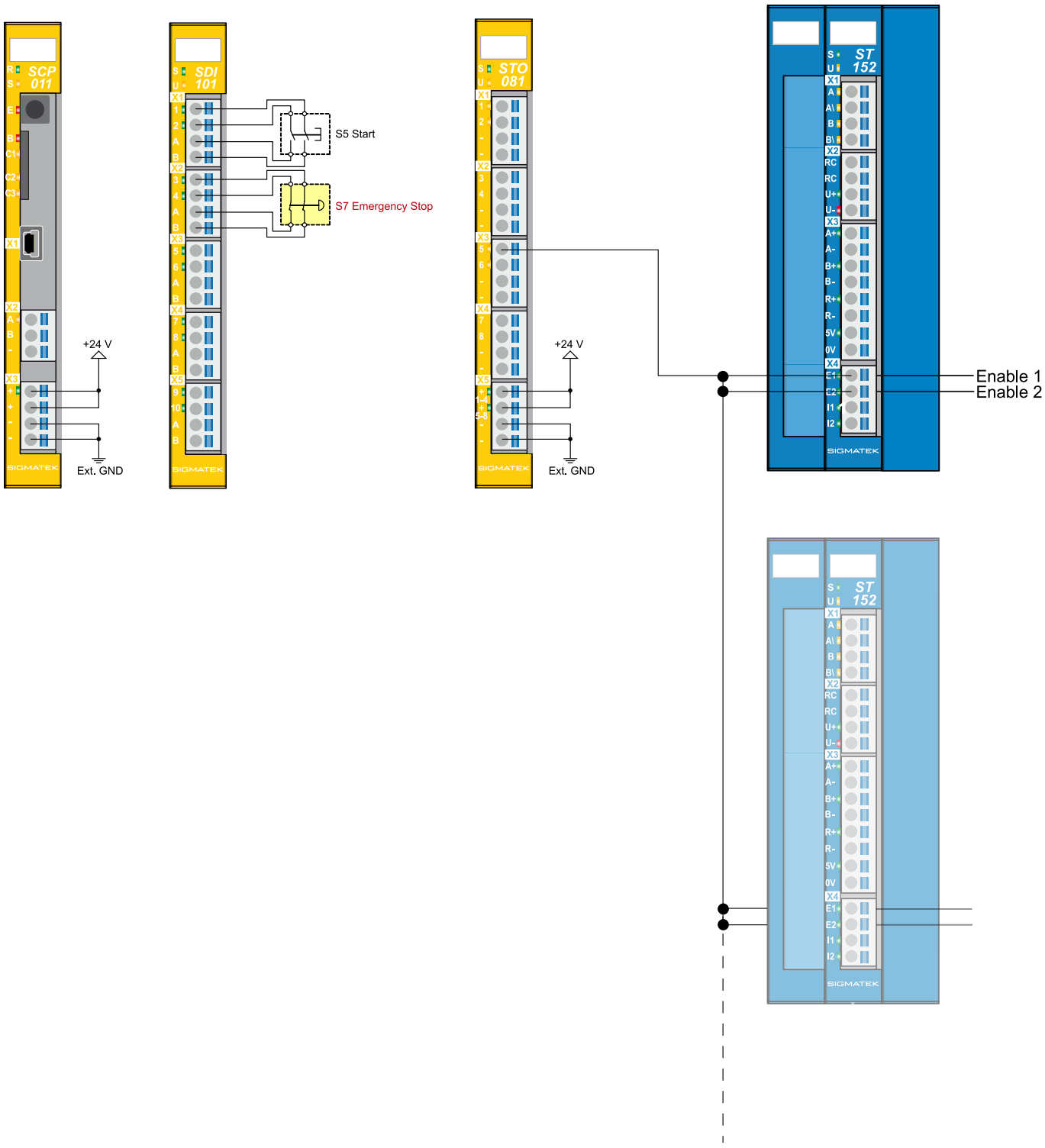



SCP 011
SDI 101
STO 081
ST 152
S5 Start
S7 Emergency Stop
+24 V
Ext. GND
+24 V
Ext. GND
Enable 1
Enable 2
SIGMATEK

11.2 Performance Level e, Category 3 or SIL 3 - Safety PLC

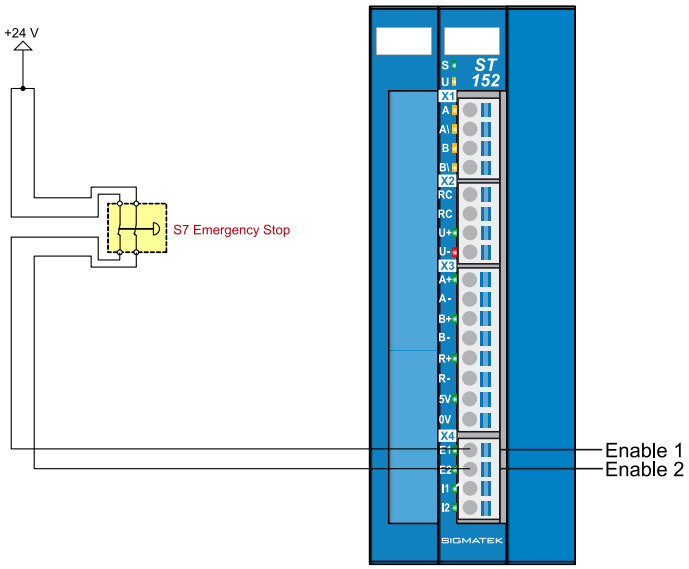
To meet the requirements of safety category 3, performance level "e" for EN ISO 13849-1 and SIL 3 according to EN IEC 62061 or EN IEC 61508, an error-proof output of a safety PLC must be used. The reason of category 3 here, is that cross-circuit detection between the two lines is not possible. To achieve the stated performance level, a fault exclusion for the wiring is also necessary for this connection. In addition, the wiring must be within the control cabinet.

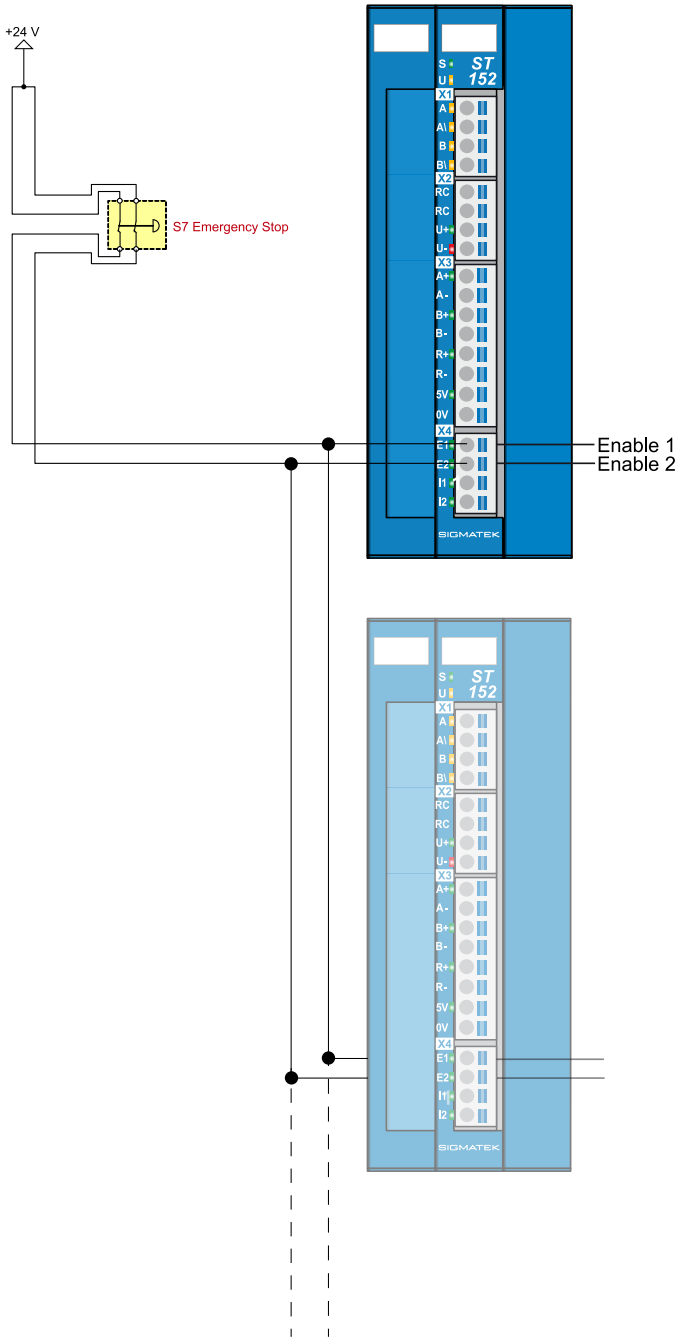



SCP 011
SDI 101
STO 081
ST 152
S5 Start
S7 Emergency Stop
+24 V
Ext. GND
+24 V
Ext. GND
Enable 1
Enable 2
SIGMATEK

11.3 Performance Level e, Category 4 or SIL 3 - Conventional

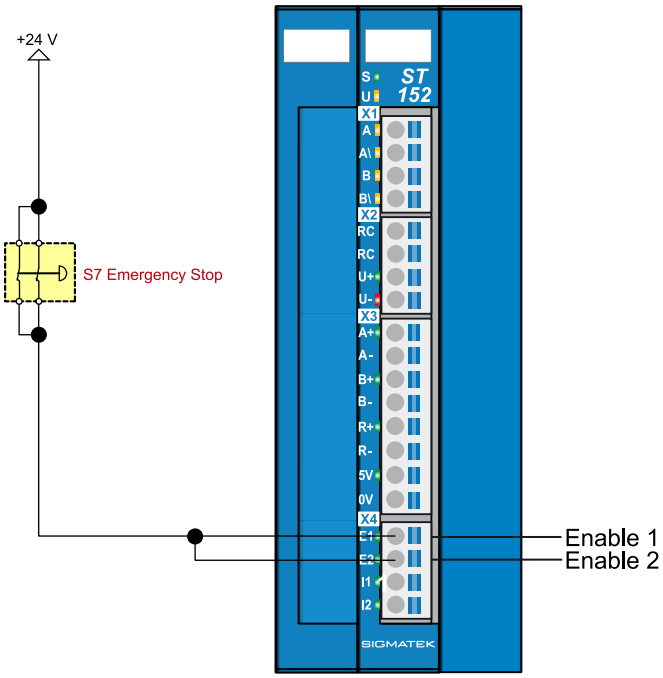
To meet the requirements of safety category 4, performance level "e" for EN ISO 13849-1 and SIL 3 according to EN IEC 62061 or EN IEC 61508, the placement of the lines must comply with EN ISO 13849-2, table D.4 (separate placement, prohibiting of error via short circuits between wires) as cross-circuit detection is not possible here.

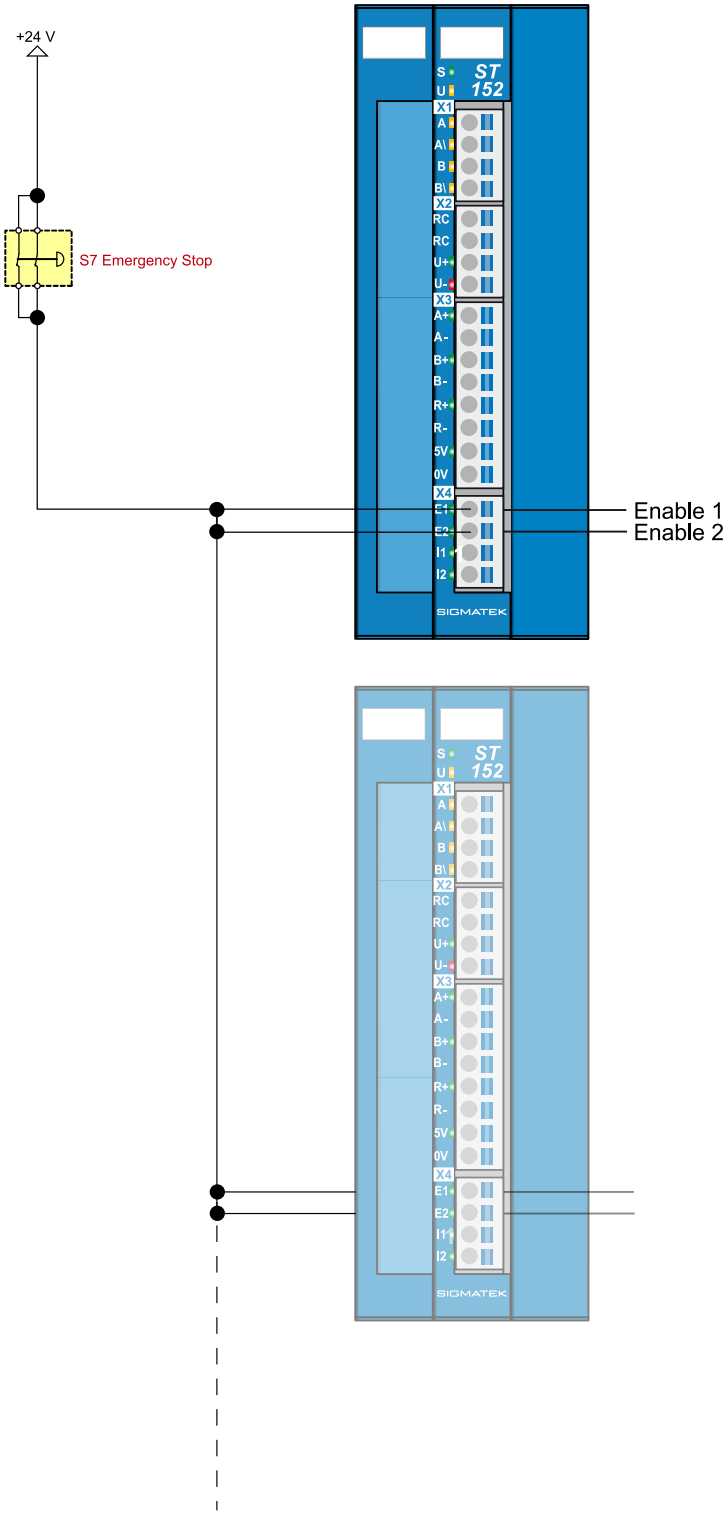



+24 V
S7 Emergency Stop
ST 152
X1
A
A\
B
B\
X2
RC
RC
U+
U-
X3
A+
A-
B+
B-
R+
R-
5V
0V
X4
E1
E2
I1
I2
SIGMATEK
Enable 1
Enable 2

11.4 Performance Level e, Category 2 or SIL 2 - Conventional

This involves 1-channel wiring, whereby the Enable inputs are tested separately. Here, no cross-circuit detection is possible.




+24 V
S7 Emergency Stop
ST 152
X1
A
A\
B
B\
X2
RC
RC
U+
U-
X3
A+
A-
B+
B-
R+
R-
5V
0V
X4
E1
E2
I1
I2
SIGMATEK
Enable 1
Enable 2

12 Description of Functions

12.1 Current Regulator Modes

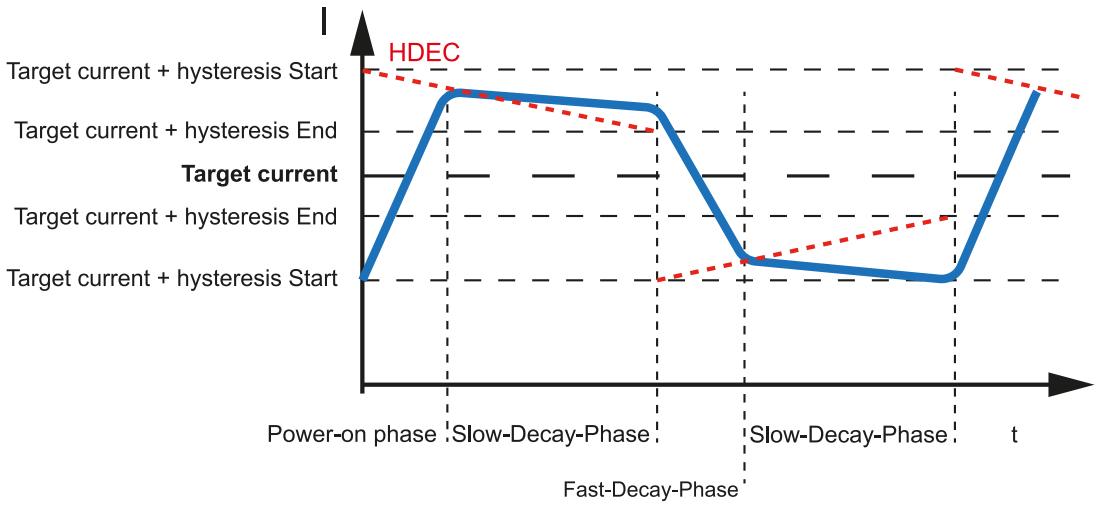
12.1.1 Current Control Mode Chopper

The current control mode chopper is the current control mode configured by default. This mode allows for stable torque and good current control of the stepper motor over a wide speed range. This current control mode is required for closed loop mode. The motion controller integrated in the module can regulate the current setting in this mode.

The current control mode chopper is an accurate and easy-to-use chopper mode that automatically determines the optimal length for the fast decay phase. Parameters are available to optimize the chopper for the respective application.

Each chopper cycle consists of a turn-on phase, a slow decay phase, a fast decay phase, and a second slow decay phase. The time of the two slow decay phases gives the upper limit for the chopper frequency.

Representation of chopper cycle



A minimum current ripple for the motor current is impressed with the hysteresis start setting. The set current ripple must be higher than the current ripple caused by resistance losses in the motor in order to achieve the best microstep results. This allows the chopper to regulate the current precisely, both when the target current is rising and falling. The time required to impress the current ripple in the motor coil also decreases the chopping frequency. Therefore, a higher hysteresis setting results in a lower chopper frequency. The motor inductance limits the chopper's ability to follow a changing motor current.

The best setting is found by starting with a low hysteresis setting (e.g. with hysteresis off: hysteresis start value HSTRT=0, hysteresis end value HEND=0) and increasing HSTRT until the motor runs smoothly at low speed settings. This is best checked by measuring the motor current either with a current probe or by measuring the voltages across current-sensing resistors. If the hysteresis is set too low, a small irregularity between the two half-waves will be visible when the sine waveform is checked near the zero crossing. At medium speeds (i.e. 100 to 400 full steps per second), a hysteresis setting that is too low can cause the motor to hum and vibrate more. A too high hysteresis setting will result in a reduced chopper frequency and increased chopper noise, but will not improve the sine waveform. The best setting for the hysteresis is

almost independent of the motor, since motors with higher currents typically also have lower coil resistance. For most applications, a low to medium value is suitable for the hysteresis (e.g. effective hysteresis = 4).

In some cases, the hysteresis principle could cause the chopper frequency to become too low, e.g. if the coil resistance is high compared to the supply voltage.

This is avoided by splitting the hysteresis setting into a start setting (HSTRT+HEND) and an end setting (HEND). An automatic hysteresis decrementer (HDEC) interpolates between the two settings by decrementing the hysteresis value in steps. At the beginning of each chopper cycle, the hysteresis begins with a value equal to the sum of the start and end values (HSTRT + HEND) and decreases during the cycle until either the chopper cycle ends or the hysteresis end value (HEND) is reached. This way, the chopper frequency is stabilized at high amplitudes and low supply voltage when the frequency gets too low. This prevents the frequency from reaching the audible range.

Two parameters control the current control mode chopper mode:

Parameters	Description	Setting	Comment
HSTRT	Setting the hysteresis start value. This value is an offset compared to the hysteresis end value HEND.	0–7	HSTRT= 1-8 The value is added to HEND
HEND	Setting the hysteresis end value. Sets the end value of the hysteresis after a certain number of decrements. The sum HSTRT+HEND must be ≤16.	0-2	-3 to -1 negative HEND
		3	0 HEND
		4-15	1 to 12 positive HEND

With HSRT = 0 and HEND = 0, the hysteresis is deactivated.

Example 1 (minimum hysteresis, with hysteresis start value 4 and hysteresis end value 3):

HEND=6 (sets an effective end value of 6-3=3)

HSTRT=0 (sets an effective starting value with minimum hysteresis, i.e. 1: 3+1=4)

Example 2 (minimum hysteresis, with hysteresis start value 7 and hysteresis end value 4):

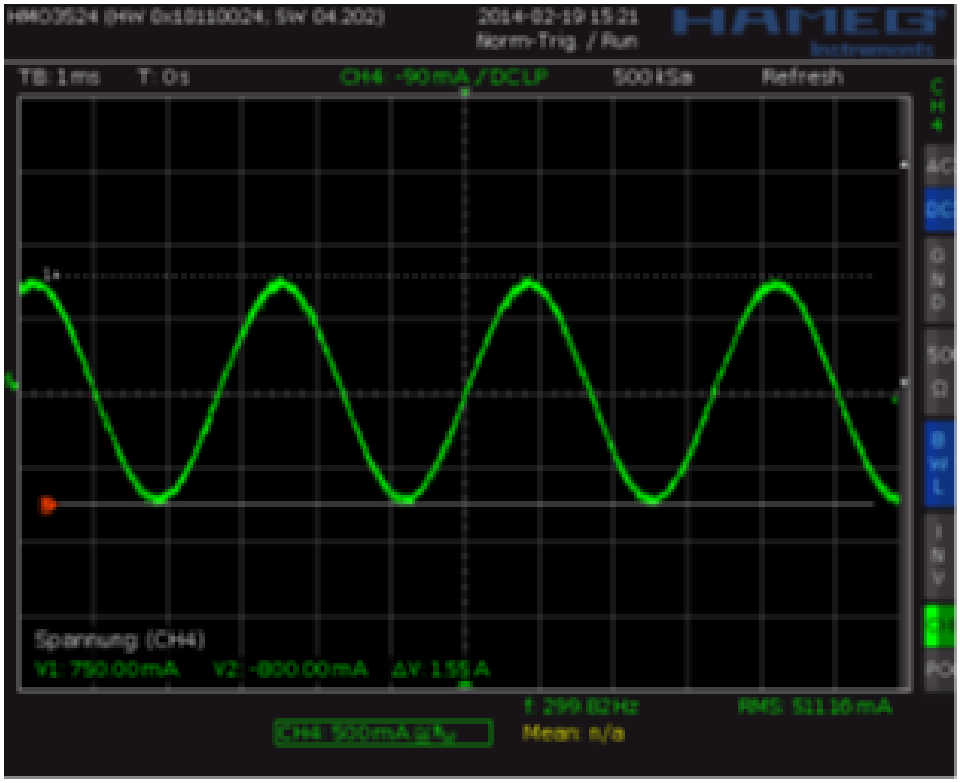
HEND=0 (sets an effective end value of -3)

HSTRT=6 (sets an effective start value for hysteresis end +7: 7-3=4)

12.1.2 Voltage PWM Mode Chopper

The voltage PWM mode chopper offers a low-noise operating mode for stepper motors. This chopper mode is only possible for the open loop mode. It is based on a voltage-controlled PWM. The output voltage is adjusted so that the resulting current approximates the set current. This process is therefore limited to low speeds at which the back-EMF is not yet effective. When at a standstill or moving slowly, the motor is almost silent. The motor operates vibration-free at low speeds. In the voltage PWM chopper mode, the motor current is generated by applying a certain effective voltage to the coil using a voltage-controlled PWM. To achieve the best performance, the voltage PWM mode chopper can adapt to the application using automatic tuning. The optional configuration allows the adjustment of the setting in special cases or the storage of initial values for the automatic adjustment algorithm. For high-speed drives, the current control mode chopper in combination with the voltage PWM mode chopper should be considered.

Motor current sine wave with voltage PWM mode chopper

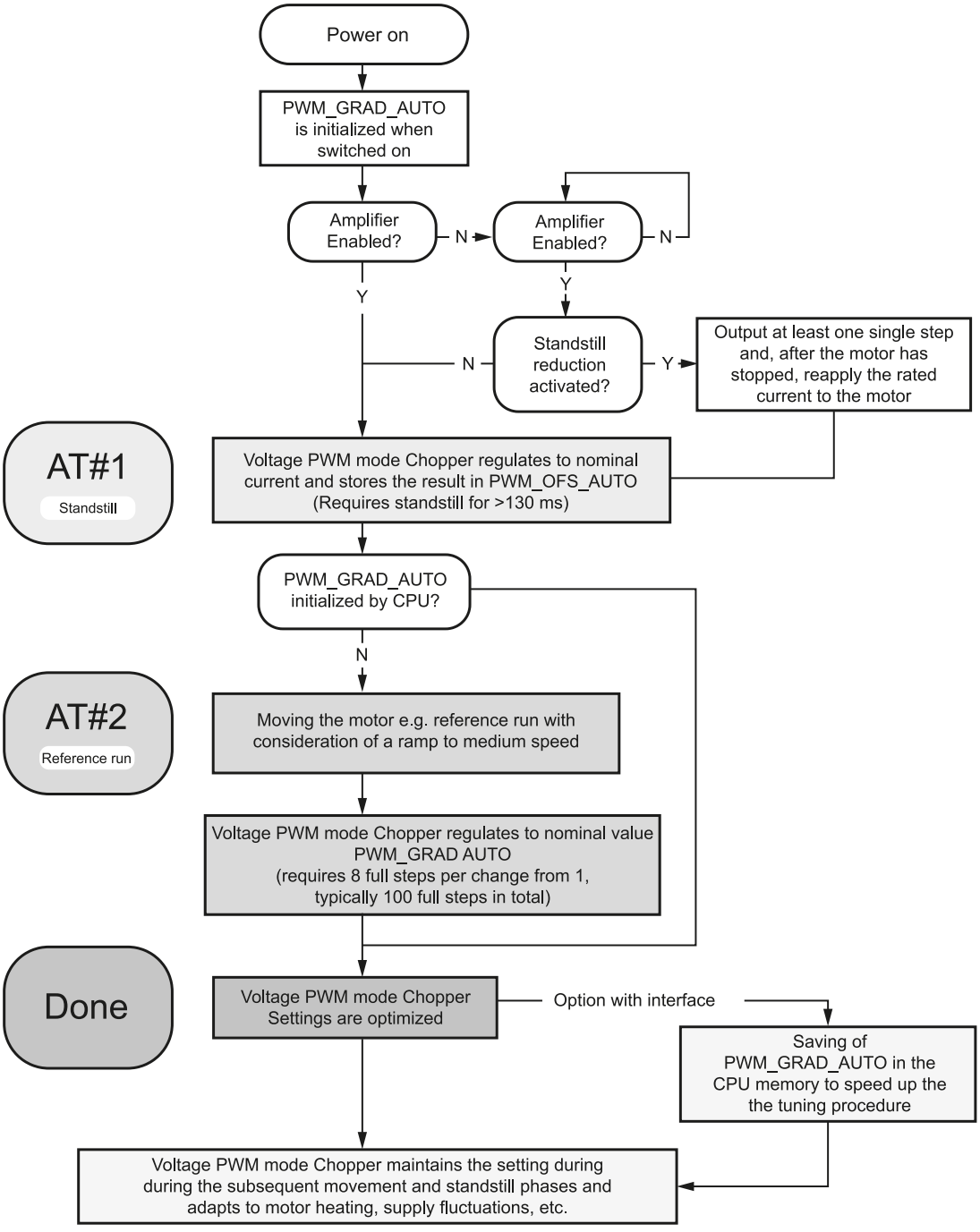


12.1.3 Automatic Tuning

The voltage PWM mode chopper integrates an automatic tuning process (AT) that automatically adjusts the most important operating parameters to the motor. In this way, the voltage PWM mode chopper enables high motor dynamics and supports the ramp-down of the motor to very low currents. To achieve optimal results, only two steps need to be taken:

- Starting the motor from standstill with rated current (AT#1).
- Moving the motor at an average speed, e.g. as part of a reference run procedure (AT#2).

Flow diagram of automatic tuning



The basic conditions for AT#1 and AT#2 are listed in the following table:

Step	Parameters	Conditions	Required duration
AT#1	PWM_OFS_AUTO	• When the motor is at a standstill and the current scale (CS) is identical to the operating current (IRUN). • When the standstill reduction is activated, an initial step pulse switches the drive back to the operating current or sets IHOLD to IRUN. • Motor end stage supplied. **Attention:** The motor end stage can reduce the chopper frequency during AT#1. Use reduced standstill current IHOLD<IRUN to avoid longer periods with a lower chopper frequency.	≤ 130 ms
AT#2	PWM_GRAD_AUTO	• Moving the motor at a speed at which a significant back-EMF is generated and at which the full operating current can be reached. Conditions: • 1.5*PWM_OFS_AUTO*(IRUN+1)/32 < PWM_SCALE_SUM < 4*PWM_OFS_AUTO*(IRUN+1)/32 • PWM_SCALE_SUM < 255. **Note:** A typical range is 60-300 RPM.	8 full steps are required to change +/- 1. For a typical motor with PWM_GRAD_AUTO set to 50 or less, up to 400 full steps are required, starting from the default value of 0.

INFORMATION

The tuning process is successful if PWM_SCALE_AUTO goes to zero during the constant speed phase in AT#2 tuning.

CAUTION

Operating in voltage PWM chopper mode without proper tuning, especially for low resistance motors and fast deceleration settings, can result in high motor currents during a deceleration ramp. The automatic process must be followed. It is recommended to use a specified initial value for the PWM_OFS and PWM_GRAD settings, depending on the motor type. Protect the end stage and the power supply by additionally setting the overcurrent protection.

Changing GLOBALSCALER or the power stage supply invalidates the result of the automatic tuning. However, the automatic tuning adjusts to changing conditions when the AT#1 or AT#2 conditions are met.

12.1.4 Voltage PWM Mode Chopper Options

To bring the motor current to a specific value, the effective PWM voltage is scaled depending on the actual motor speed. To drive the motor at the target current, several additional factors influence the required voltage level. The motor resistance, its back-EMF (i.e. directly proportional to its speed) and the current level of the supply voltage.

Two modes of PWM regulation are provided:

- the automatic tuning mode (AT) with current feedback (pwm_autoscale = 1, pwm_autograd = 1) and
- a speed-controlled forward mode (pwm_autoscale = 0). The feed-forward speed-controlled mode does not respond to a change in the supply voltage or to events such as an engine shutdown, but it does offer a very stable amplitude.

A current measurement is not used and is also not required. This is ideal if the motor type and supply voltage are known. It is therefore recommended to use the automatic mode, unless the current control is not satisfactory under the given operating conditions.

It is recommended to use application-specific initialization parameters that are adapted to the motor type and the supply voltage. In order to react to parameter changes, e.g. due to motor heating or changes in the supply voltage, the regulator should also be operated in automatic tuning mode (pwm_autoscale=1).

INFORMATION

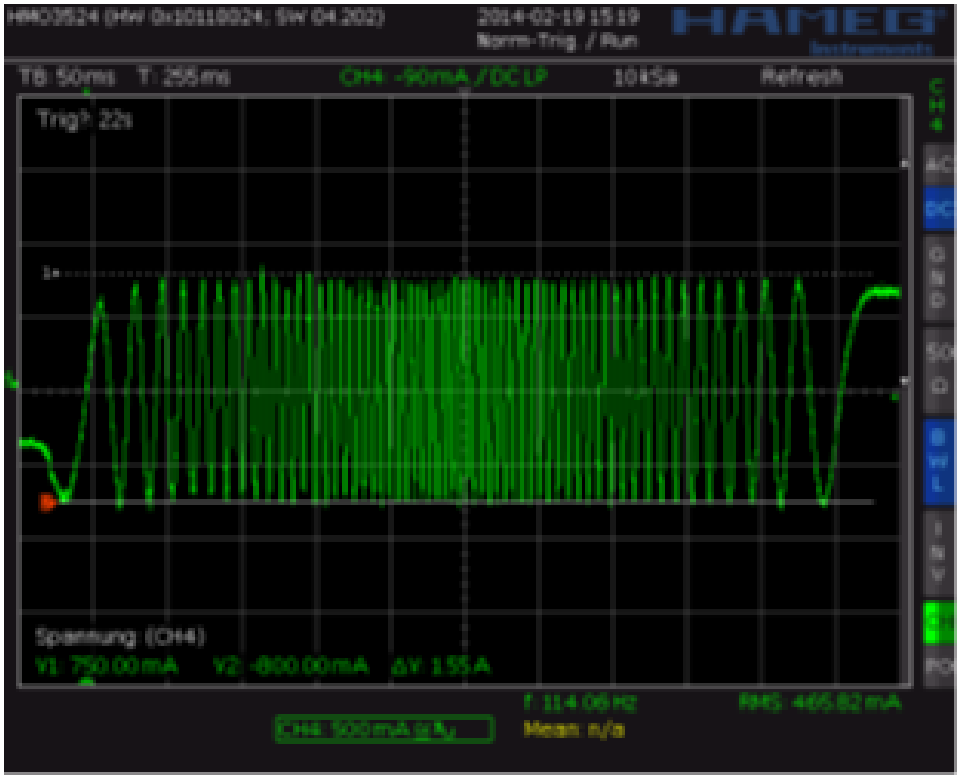
To reduce the jitter of the motor current amplitude, a specified PWM_GRAD should be used and pwm_autograd = 0 should be set. The non-automatic mode (pwm_autoscale=0) should only be considered for known motor and operating conditions. In this case, careful programming via the interface is required. The operating parameters PWM_GRAD and PWM_OFS can initially be determined in automatic tuning mode.

12.1.5 Voltage PWM Mode Chopper: Functionality

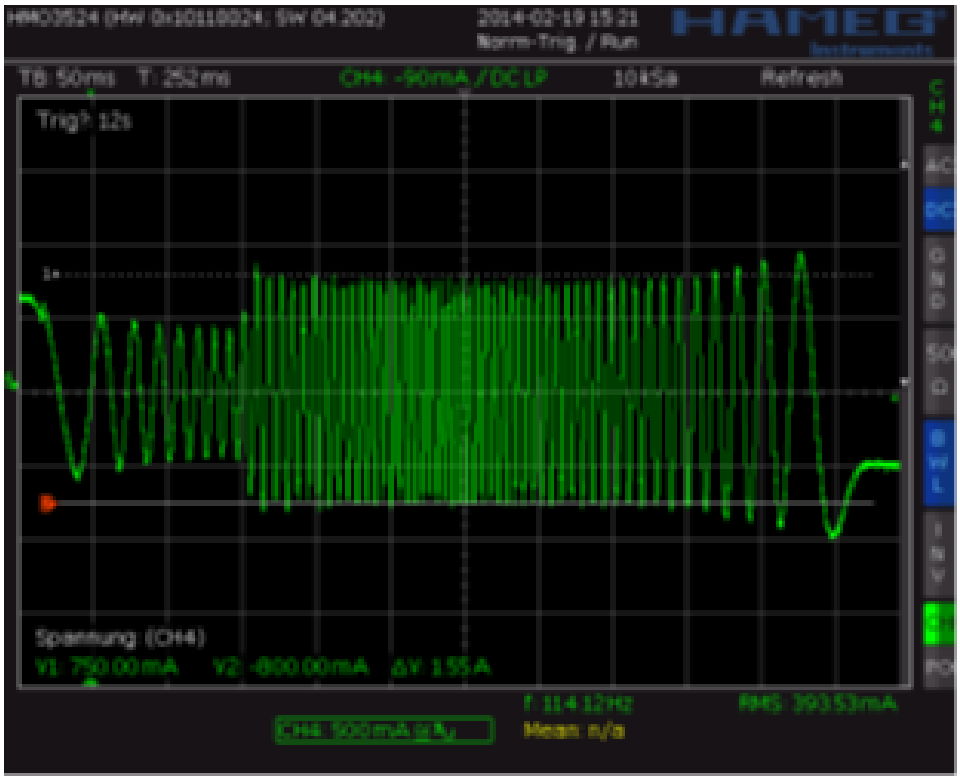
In voltage PWM mode, the autoscale function (pwm_autoscale = 1, pwm_autograd = 1) regulates the motor current to the desired current setting. Automatic scaling is used as part of the automatic tuning (AT) process and for subsequent monitoring of changes in motor parameters. The measured motor current during the chopper's on-time is used by the proportional controller for the regulation of PWM_SCALE_AUTO in order to adjust the motor current to the target current. PWM_REG is the proportionality coefficient for this regulator. For stable and smooth control behavior, the proportionality coefficient should generally be as small as possible, but large enough for the motor end stage to react quickly to changes caused by varying the parameters (e.g. changing the mechanical load).

With a careful selection of the reference speed and the acceleration, a minimal setting of the control gradient is often sufficient (PWM_REG=1). The setting of PWM_REG should be optimized for the fastest required acceleration and deceleration ramp. The quality of the PWM_REG setting in the AT#2 phase and the completed automatic tuning procedure (or non-automatic settings for PWM_OFS and PWM_GRAD) can be examined by monitoring the motor current during an acceleration phase.

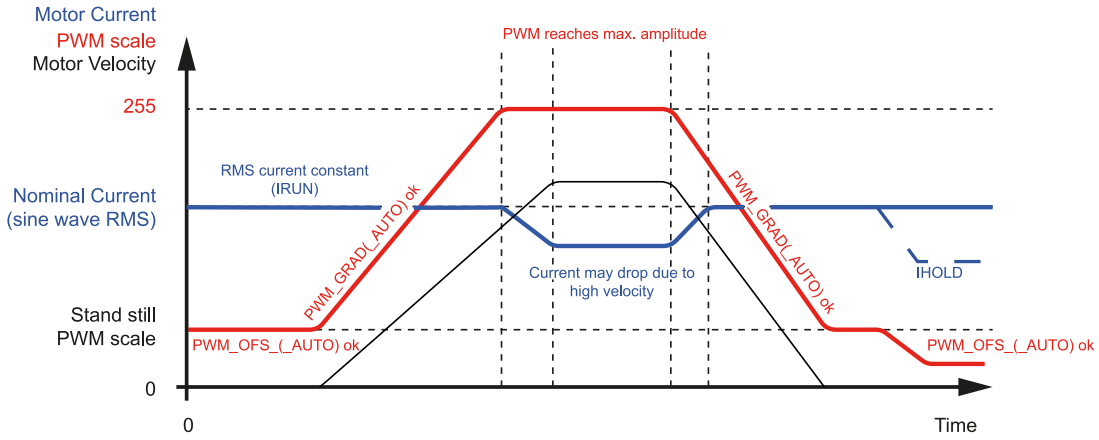
Motor current recording with good setting for PWM_REG



Motor current recording with too small a value for PWM_REG during AT#2



Successfully determined PWM_GRAD(_AUTO) and PWM_OFS(_AUTO)



12.1.6 Lower Current Limit

The voltage PWM mode chopper sets a lower limit for the motor current control. Since the motor current can only be measured during the chopper's switch-on phase, the minimum chopper duty cycle that enables regulation of the coil current is given by the blanking time and the chopper frequency.The motor-specific minimum coil current therefore increases in auto-scaling mode of voltage PWM mode chopper, with the supply voltage and with the chopper frequency. For the correct determination of PWM_OFS_AUTO, it is important that in AT#1 the running current set by the GLOBALSCALER and IRUN is clearly within the control range. Lower currents (e.g. for shutdown when stationary) are implemented automatically on the basis of PWM_OFS_AUTO and PWM_GRAD_AUTO or on the basis of PWM_OFS and PWM_GRAD, with non-automatic current scaling. The free-wheeling option makes it possible to set the motor current to zero.

The lower current limit of the motor coil for automatic tuning of voltage PWM mode chopper is:

$$I_{Lower\ Limit} = t_{BLANK} * f_{PWM} * \frac{V_M}{R_{COIL}}$$

The blanking time t_{BLANK}	is fixed at 1.5 µs.
The PWM frequency f_{PWM}	is fixed at 31.25 kHz.
V_M	is the power supply of the motor output stage (DC link supply).
R_{COIL}	is the winding resistance of the motor.
$I_{Lower\ Limit}$	can be considered as a guideline for the minimum nominal current setting of the IRUN motor.

Example: A motor has a coil resistance of 5 Ω and the supply voltage is +24 V.

$I_{Lower\ Limit}$ = 1,5 µs ∗ 31,25 kHz ∗245 Ω = 24512 ∗ 24 V 5 Ω = 225 mA

This means that the motor target current for automatic tuning must be 225 mA or more, taking into account all relevant settings. This lower current limit also applies to the change of the motor current via the GLOBALSCALER.

A lower motor current limit applies for the automatic tuning. Current settings for IRUN under 8 do not work with automatic tuning. The motor current in the automatic tuning phase AT#1 must exceed the lower limit $I_{Lower\ Limit}$. The $I_{Lower\ Limit}$ must be calculated or measured. After a successful automatic tuning, it is possible to set the motor running current or the holding current below the lower current limit during operation by changing IRUN and IHOLD. The lower current limit also limits the ability of the motor end stage to respond to changes in GLOBALSCALER.

12.1.7 Speed-dependent Scaling

The speed-based scaling scales the voltage PWM mode chopper amplitude based on the time between two steps (T_{STEP}), measured in clock cycles. This concept basically does not require current measuring, since no control loop is necessary. Purely speed-based scaling is only available via programming if pwm_autoscale = 0 is set. The basic idea is a linear approach to the voltage required to drive the target current into the motor. The stepper motor has a certain coil resistance and therefore requires a certain voltage amplitude to generate a target current according to the basic formula I=U/R. With R as the coil resistance and U as the supply voltage, scaled with the PWM value, the current I results.

The initial value for PWM_OFS can be calculated:

$$PWM_OFS = \frac{374 * R_{COIL} * I_{COIL}}{V_M}$$

V_M is the supply voltage of the motor end stage (DC link supply) and I_{COIL} is the target RMS current in the motor winding.

The effective PWM voltage U_{PWM} (1/SQRT(2) x peak value) is calculated as follows, taking into account the 8-bit resolution and 248 sine wave peak values for the current PWM amplitude as PWM_SCALE:

$$U_{PWM} = V_M * \frac{PWM_SCALE}{256} * \frac{248}{256} * \frac{1}{\sqrt{2}} = V_M * \frac{PWM_SCALE}{374}$$

As the motor speed increases, the motor generates an increasing back-EMF voltage. The back-EMF voltage is proportional to the motor speed. It reduces the PWM voltage applied to the inductor, thereby reducing the current. The motor end stage offers a second speed-dependent factor (PWM_GRAD) to compensate for this.

The effective total PWM amplitude (PWM_SCALE_SUM) is automatically calculated in this mode as a function of the microstep frequency as follows:

$$PWM_SCALE_SUM = PWM_OFS * \frac{CS_ACTUAL + 1}{32} + PWM_GRAD * 256 * \frac{f_{STEP}}{f_{CLK}}$$

Where f_{STEP} is the microstep frequency for a resolution of 256 microsteps and f_{CLK} is the internal clock frequency (16 MHz). CS_ACTUAL takes into account the current current scaling as defined by IHOLD and IRUN.

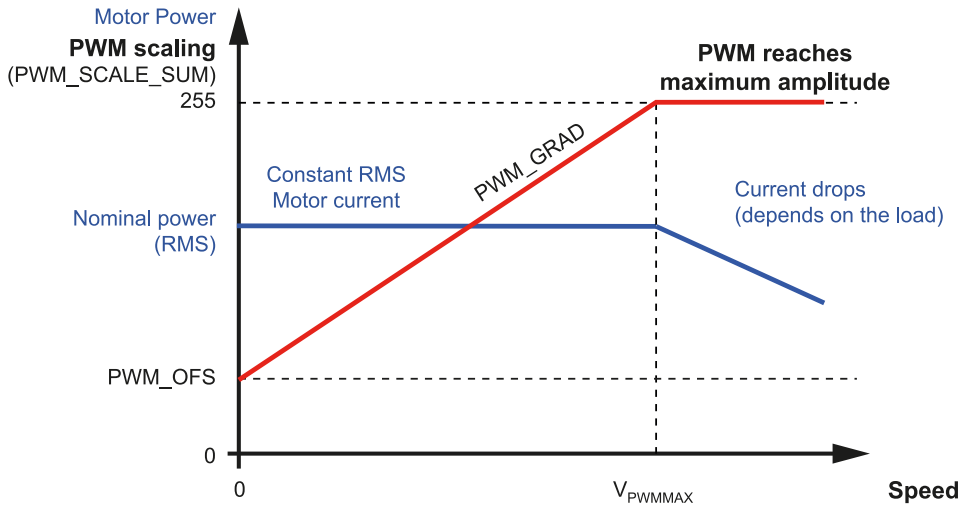
In the first approximation, the back-EMF subtracts from the supply voltage, thus reducing the effective current amplitude. In this way, a first approximation for the setting of PWM_GRAD can be calculated:

$$PWM_GRAD = C_{BEMF}\left[\frac{V}{\frac{rad}{s}}\right] * 2\pi * \frac{f_{CLK} * 1.46}{V_M * MSPR}$$

C_{BEMF} is the back-EMF constant of the motor in volts per radian/second.

MSPR is the number of microsteps per revolution assuming a resolution of 256 microsteps, e.g. 51200 = 256 microsteps multiplied by 200 full steps for a 1.8° motor.

Speed-based PWM scaling (pwm_autoscale=0)



The values for PWM_OFS and PWM_GRAD can easily be optimized by measuring the motor current with a current probe. Alternatively, these values are determined by the automatic tuning and can be read from PWM_OFS_AUTO and PWM_GRAD_AUTO.

Motor back-EMF constant

The back-EMF constant is the voltage generated by a motor when it is turning at a certain speed. Often, motor data sheets do not include this value, as it can be derived from the motor torque and the coil current. In SI units, the numerical value of the back-EMF constant CBEMF has the same numerical value as the numerical value of the torque constant.

For example, a motor with a torque constant of 1 Nm/A has a CBEMF of 1 V/rad/s. If such a motor turns at 1 rpm (1 rpm = 1 revolution per second = 6.28 rads/s), it produces a back-EMF voltage of 6.28 V.

The back-EMF constant can therefore be calculated as follows:

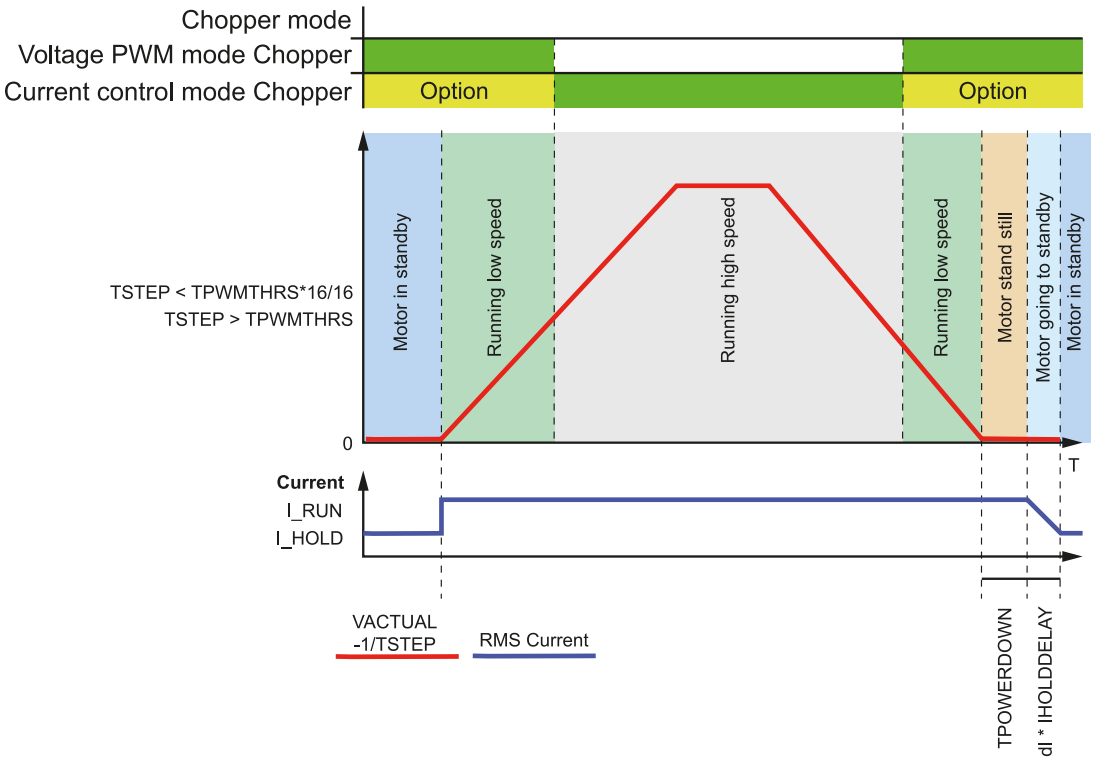
$$C_{BEMF}\left[\frac{V}{rad/s}\right] = \frac{HoldingTorque[Nm]}{2 * I_{COILNOM}[A]}$$

$I_{COILNOM}$ is the rated phase current of the motor for the specified holding torque. HoldingTorque is the motor-specific holding torque, i.e. the torque achieved at $I_{COILNOM}$ on both coils. The torque unit is [Nm], where 1 Nm = 100 Ncm = 1000 mNm. The voltage is the effective voltage per coil, so the rated current is multiplied by 2 in this formula because the rated current assumes a full step position where both coils are in operation.

12.1.8 Combination of Voltage PWM Mode Chopper with Current Control Mode Chopper

For applications that require high-speed movement, the current control mode chopper can provide more stable operation at high speeds. To combine quiet operation with maximum dynamics, the stepper motor output stage allows the combination of voltage PWM mode chopper and current control mode chopper based on a speed threshold. This means that the voltage PWM mode chopper is only active at low speeds.

TPWMTHRS for optional switchover to current control mode chopper



In a first step, both chopper modes are to be individually parameterized and optimized. The next step is to define a switching speed. The voltage PWM mode chopper operation is used, for example, for precise positioning with low speed positioning, while the current control mode chopper is to be used for highly dynamic movements. TPWMTHRS determines the changeover speed. Read T_{STEP} when the motor is moving at the desired speed and write the resulting value to TPWMTHRS. To avoid a jerk at the switching point, a low switching speed should be used.

A jerk occurs when switching at higher speeds because the back-EMF of the motor (which increases with speed) causes a phase shift of up to 90° between motor voltage and motor current. Therefore, when switching at higher speeds, this jerk between the voltage PWM mode chopper and the current control mode chopper occurs with increased intensity. A strong jerk can even lead to a temporary overcurrent (depending on the resistance of the motor winding). At low speeds (e.g. 1 to a few 10 rpm), this can be completely neglected for most motors. The switchover jerk must therefore be taken into account when selecting TPWMTHRS. If you only want to work with the voltage PWM mode chopper, TPWMTHRS must be set to zero.

When using the voltage PWM mode chopper with automatic current control for the first time, the motor must be at a standstill to enable correct current control. When the motor end stage switches to voltage PWM mode chopper at a higher speed, the last current control setting is stored until the motor returns to a lower speed. In this way, the regulation has a known starting point when the motor returns to the lower known starting point at which the voltage PWM mode chopper is activated again. Therefore, neither the speed threshold nor the supply voltage may be changed significantly during the phase in which the chopper is switched to a different mode, as otherwise the motor may lose steps or the motor current may be too high or too low. An motor blockage or a sudden change in motor speed can cause the motor end stage to detect a short circuit or lead to an error condition in the automatic current control. In this case, an error is detected and the motor end stage is switched off. The error must be acknowledged by the user before the end stage can be reactivated.

12.1.9 Configuration/Commissioning Voltage PWM Mode Chopper

In the standard settings, the feature is already prepared to allow for quick activation. The following two steps activate the voltage PWM mode chopper up to a set speed. Since the module performs internal calibrations during the first enable, it is important that these two values are written before the axis is first enabled.

- Setting register GCONF (register index 0x4001, sub-index 0x01) to sub-index 0x04 (bit 2 en_pwm_mode).
- Setting the maximum speed for voltage PWM mode chopper. Writing to register TPWMTHRS (register index 0x4001, sub-index 0x14). The value is given in clock cycles between two 1/256 µsteps. The easiest way to determine the limit value is to read the current value from register TSTEP (register index 0x4001, sub-index 0x13) at a constant desired speed.

With these settings, voltage PWM mode chopper is already used for speeds below this threshold TSTEP ≥ TPWMTHRS.

When using the default settings, the module automatically determines the correct gain and offset to maintain the target current as closely as possible.

In the voltage PWM mode chopper, there may be deviations in the set current setpoint at low speeds due to the principle involved. To prevent the motor from being under- or over-energized, the motor current in the application must be verified using measurement technology for the speed range used.

For a more precise current amplitude when switching on after the automatic tuning process, it is possible to initialize the gain and offset. To do this, the current offset and gain are read out of the PWM_AUTO register (register index 0x4001, sub-index 0x73) in the typical driving situation. These values can then be used as initial values with register PWM_OFS (register index 0x400E, sub-index 0x01) and register PWM_GRAD (register index 0x400E, sub-index 0x02). To determine the offset accurately, it makes sense to bring the axis to a standstill several times before reading the value.

12.2 Sensorless Load Determination

The sensorless load determination allows a statement to be made about the current load and torque reserve of the connected motor. This method is dependent on the existing back-EMF of the motor and can therefore only be used in the speed range in which the back-EMF allows a reliable statement. The calculated value is therefore unusable at very low or very high speeds. The quality of the value is also dependent on the motor type due to the direct dependency on the measurable back-EMF. When using the voltage PWM mode, it is not possible to determine.

The available value scales between 1023 and 0. In this case, 1023 means no load and 0 means a load scenario that could potentially cause the motor to stall.

Index	SubIndex	Name	Meaning
0x4000	0x6D Bit 0:9	POLLING_ STATUS/Sensorless load value (reading)	Current sensorless load value determined by the determination. 1023 corresponds to no load, 0 corresponds to the load scenario in which an motor stall is detected.
0x4001	0x6E Bit 16:23	COOLCONF/Sensorless load scaling factor	Scaling of the sensitivity of the determination of the sensorless load value. The default value is 0. The setting allows a change between -64 and 63. An increase in the value reduces the sensitivity of the sensorless load determination. Typical values range between -10 and 10.

12.2.1 Configuration/Commissioning

The goal is to configure the calculation of the sensorless load value so that at the target current and at the target speed under:

- idle the sensorless load value is in the range of a few hundred units
- full load the sensorless load value is small, without reaching zero before the motor stalls.

The motor must be measured once with a variable load. A variable load can be:

- coupled axis (second stepper motor, servo motor)
- static load with variable load (weights)

Driving at constant speed and increasing the load until the motor stalls. Reducing the load to about 90 % and reading the sensorless load value from bits 0-9 of register index 0x4000, sub-index 0x6D. A value of 0 means that potential stall has been detected.

If current value:

- is 0 -> Increase the sensorless load scaling factor (bit 16:23, register index 0x4001, sub-index 0x6E)
- rarely is 0 -> change of sensorless load scaling factor (bit 16:23, register index 0x4001, sub-index 0x6E) by ±1 and evaluation of whether stability is improved
- never becomes 0 and is still several integers away from 0 -> reduce the sensorless load scaling factor (bit 16:23, register index 0x4001, sub-index 0x6E) until the sensorless load value is close to 0.

12.2.2 Stop on Stall

The module can provide a signal that can be used to stop the motor. Alternatively, the current sensorless load value can be read from bits 0-9 of register index 0x4000, sub-index 0x6D and the stopping without an event of the chip can be executed in the application. In this case, no activation procedure is necessary in the application.

A speed must be selected at which a “Stop on Stall” event is triggered. Select the speed in pps at the VSTALL_LIMIT register (register index 0x4000, sub-index 0x68). A “Stop on Stall” event can only be triggered if |Actual speed (Register Index 0x4000, Subindex 0x23)| > VSTALL_LIMIT.

The following procedure must be followed to operate the feature:

- Activating “Stop on Stall” by setting bit 26 in register index 0x4000, sub-index 0x02.
- The event can be queried by reading register index 0x4000, sub-index 0xF bit 29.
- Resetting the event by writing register index 0x4000, sub-index 0x0F with value 0x20000000.
- Activating “Stop on Stall” by setting bit 27 in register index 0x4000, sub-index 0x02.
- Starting the movement (motor must be in motion)
- Resetting “Drive after Stall”, reset bit 27 in register index 0x4000, sub-index 0x02.

INFORMATION

When using voltage PWM mode, the load is not determined without a sensor. All functionalities that rely on the sensorless determination of the load cannot be used.

12.3 Sensorless Load-dependent Motor Current Control

If the sensorless load dependency is set up correctly, the current amplitude can be controlled directly on this basis. This allows a reduction in power and energy consumption for the module and motor. In general, it is not possible to say whether the vibrations or the volume of the motor are better or worse as a result of changing the current amplitude, since this depends on the motor and the mechanical design.

The following parameters are used to set the sensorless load-dependent motor current setting:

Index	SubIndex	Name	Meaning
0x4001	0x6E Bit 0:3	COOLCONF semin0-semin3/Lower threshold sensorless load value	Output of maximum current when sensorless load value < (lower threshold sensorless load value)*32
0x4001	0x6E Bit 5:6	COOLCONF seup0 – seup1/Rate of change of power increase	Current increase with change in sensorless load value in steps
0x4001	0x6E Bit 8:11	COOLCONF semax0-semax3/Upper threshold for sensorless load value	Output of maximum current when sensorless load value > (lower threshold sensorless load value + upper threshold sensorless load value + 1)*32
0x4001	0x6E Bit 13:14	COOLCONF sedn0-sedn1/Rate of change of power decrease	%00: Current reduction when the sensorless load value is reduced by every 32 units. %01: Current reduction when the sensorless load value is reduced by every 8 units. %10: Current reduction when the sensorless load value is reduced by every 2 units. %11: Current reduction when the sensorless load value is reduced
0x4001	0x6E Bit 15	COOLCONF seimin/Minimum current load-dependent current decrease	0 … minimum current is half the maximum current 1 … minimum current is a quarter of the maximum current
0x4000	0x6D Bit 0:9	POLLING_STATUS SG_ RESULT/Sensorless load value	Current sensorless load value between 0 and 1023. A higher value corresponds to a lower load.

The maximum value at a standstill or the standstill of the sensorless load value depends on the motor and the setting of the sensorless load scaling factor (bit 16:23, register index 0x4000, sub-index 0x6E).

To avoid a delayed reaction (increase in current amplitude), the lower threshold of the sensorless load value must be selected so that the maximum current is already output at high load. Conversely, the sum of the lower and upper threshold of the sensorless load value must be selected so that the minimum current is output. This makes good use of the scaling range.

In addition, the range in which the sensorless load-dependent motor current reduction is to be used must be defined. The limits are defined by two speed values. These speed values are also used to determine the sensorless load value.

Index	SubIndex	Name	Meaning
0x4001	0x15	TCOOLTHRS/Starting speed load-dependent current reduction	Load-dependent current reduction is active if TSTEP register index 0x4001, sub-index 0x13 < setting and if condition from register index 0x4001, sub-index 0x16 is inactive.
0x4001	0x16	THIGH/Ending speed load-dependent current reduction	Load-dependent current reduction is deactivated if TSTEP register index0x4001, sub-index 0x13 < setting.

This means that the operating range of the load-dependent current reduction can be set in the range in which the determination of the sensorless load value works reliably. When set correctly, the current amplitude is regulated so that the axis runs stably at a reduced current.

12.4 Closed Loop Regulator

The module ST 152 has an integrated regulator for closed loop position and speed control.

Closed loop regulation on the module offers advantages for the following applications:

- precise regulation of position
- suppression of vibrations and oscillations
- regulation without step loss and without motor stall
- energy-optimized operation through load-dependent current reduction

These properties make it attractive to use closed loop regulation directly on the module. The module has standard parameters that allow it to be operated in closed loop regulation directly without further tuning. It is not recommended to use this if your own system uses an encoder with low resolution or if the motor is to be operated as quietly as possible at low speeds.

The standard procedure is to adjust the position controller first. The current controller can be set using the current scaling on the basis of a good position setting. In exceptional cases, the compensation speed of the speed controller can then still be set.

12.4.1 Functioning of Closed Loop Regulation

The closed-loop regulation consists of three main components:

1. a position correction in conjunction with a P-regulator for the position deviation. In addition, the position correction has a component that compensates for the effects of the counter-electromotive force.
2. dynamic current level control (dependent on the position deviation). This thus indirectly acts as a current amplitude control, which is load-dependent on the effect of an increasing position deviation.
3. a speed control that adds a component to the set speed in addition to the controlled speed. This makes it possible to adjust the target speed if the stepper motor's rotor lags or leads the current level beyond the extent of the equalization.

The first and second components are the ones that make the more important contribution in the overall concept. The position control must first be set up and, based on this regulation, the current amplitude control is applied.

12.4.1.1 Position Control

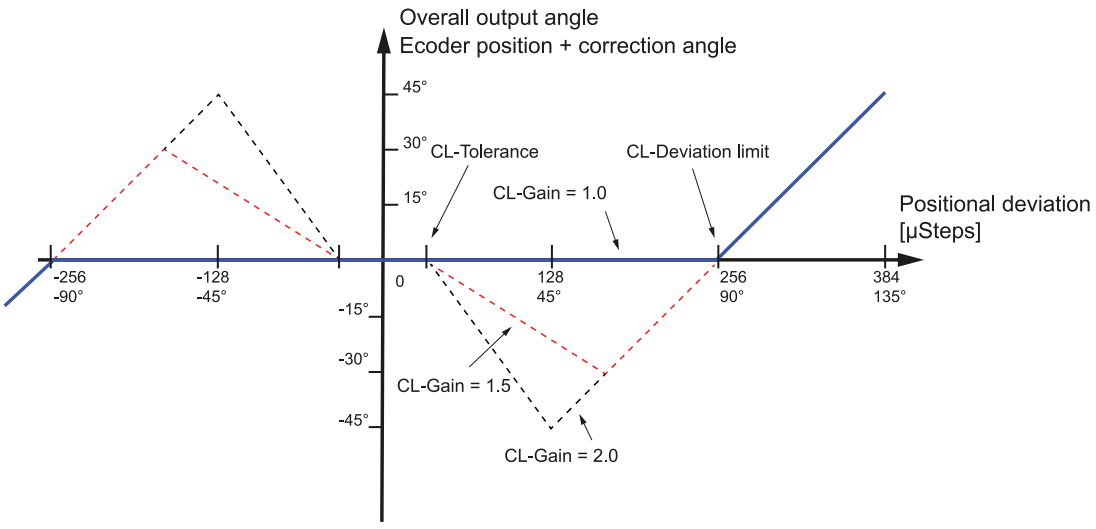
The position control works to the target position within one step, with the position deviation of the encoder. The motor can only be controlled stably if the encoder is within one step of the target position. To compensate for these effects and to maintain full torque for longer, the electrical angle of the current is adjusted to compensate for the current deviation. That is the principle behind the controller. The implementation in the module by shifting the target position works, which corresponds to a shift of the electrical angle via the sine table.

In a simple model without back-EMF, when using the standard parameters, stable regulation is possible up to a deviation of 90° in the electrical angle. Stable regulation is possible as long as the deviation is smaller than this angle. In the event of deviations in the range between -90° and +90°, the electrical field can be shifted so that the regulation can convert the setpoint current into a setpoint torque. If the deviation continues to grow, the electric field can no longer be adjusted (not to mention the case of field weakening; in the case of stepper motors, this is only useful for the most experienced users). An attempt is still being made to compensate for the deviation with the maximum value of 90°. This is possible up to a maximum deviation of 180° with decreasing torque. This is the behavior when using the default parameters.

The module offers the following settings to influence behavior based on the default settings.

Index	SubIndex	Name	Meaning
0x4000	0x5D	CL gain/CL_ DELTA_P	The CL gain is used to make the behavior of the axis stiffer or softer. A stiffer axis follows the input more directly, although disturbances such as oscillations are more strongly excited. A softer axis follows the specification less well, but is more tolerant of oscillations. The default value is 1.0 = 0x10000. The value consists of 16 bit decimal places and 8 bit integer places. 1.25, for example, corresponds to 0x14000. The decimal value is obtained by dividing 0x4000 by 0x10000 = 0.25.
0x4000	0x60	CL tolerance/CL_ TOLERANCE	CL gain is 1.0 if |encoder deviation| < CL_TOLERANCE. This value should always be slightly larger than the scaling of the encoder increment in µsteps so as not to amplify the noise of the encoder. The default value is 20.
0x4000	0x1D Bit 0:8	CL deviation limit/CL_BETA	The CL deviation limit defines the maximum correction value of the electrical angle for the CL position. If there is a larger deviation in real terms, this value is used as the maximum value. The default value is 255.

The position correction can be visualized as follows, depending on the settings. For clarity, the CL deviation limit is shown at the default value of 255.



To compensate for the effects of back-EMF, the output angle can also be corrected by a speed-dependent value. This means that the CL regulator only compensates for the correct deviation that results from the drive, and the increasing effect of the back-EMF with speed does not have to be compensated for.

The characteristic curve of the back-EMF and the compensation by the regulator depend on the motor type. The starting speed should be selected in the range in which the encoder deviation increases and is already noticeably compensated by the CL controller. Since the back-EMF correction ideally compensates for the effect, the encoder deviation remains constant from this speed up to the final speed.

Index	SubIndex	Name	Meaning
0x4000	0x61	Back-EMK correction start speed/FS_ VEL/CL_VMIN_ EMF	Starting speed from which the back-EMF correction starts in pps. The default value is 250000 pps.
0x4000	0x62	Back-EMK correction speed range/CL_ VADD_EMF	The back-EMF is linearly interpolated. The correction is 0 at the back-EMF correction start speed and maximum (CL max. back-EMF correction) at (back-EMF correction start speed + back-EMF correction speed range).
0x4000	0x1D Bit 16:23	CL max. back-EMK correction/CL_ GAMMA	The CL deviation limit defines the maximum correction value of the electrical angle for the CL position. If there is a larger deviation in real terms, this value is used as the maximum value.

12.4.1.2 Current Controller

The current controller is used purely for the regulation of the current amplitude and, depending on the encoder deviation, allows it to be increased or decreased.

The current amplitude is scaled between the minimum value if the deviation is less than 50 µsteps and the maximum value if the encoder deviation has reached or exceeded the value of CL deviation limit.

The module uses default values for the minimum deviation at which the current is increased (50 µSteps) and for the rate of change of the current when increasing (0.0625 ms) and decreasing (6.25 ms). The user is not intended to make any changes.

12.4.1.3 Speed Regulator

The idea of the speed controller can be compared to the approach with the position controller. An additional speed is determined, which is added to the target speed. The total speed is the sum of the control speed and the additional speed.

The regulation of this variable is done by a PI regulator with a maximum limit on the additional speed.

Index	SubIndex	Name	Meaning
0x4000	0x5B	P-gain PI regulator additional speed	P-gain of the PI regulator of the additional speed. The default value is 200.
0x4000	0x5C	I-amplification PI regulator additional speed	I-amplification of the PI regulator of the additional speed. The default value is 50.
0x4000	0x5F	Maximum additional speed	The maximum additional speed that is added to the current speed. The default value is 100000.

The maximum additional speed is not applied in the standard settings because the use of a maximum additional speed is highly dependent on the application.

To activate the limitation of the additional speed, bit 27 of ENC_IN_CONF index 0x4000, sub-index 0x08 must be set.

12.4.1.4 Closed Loop Tuning Procedure

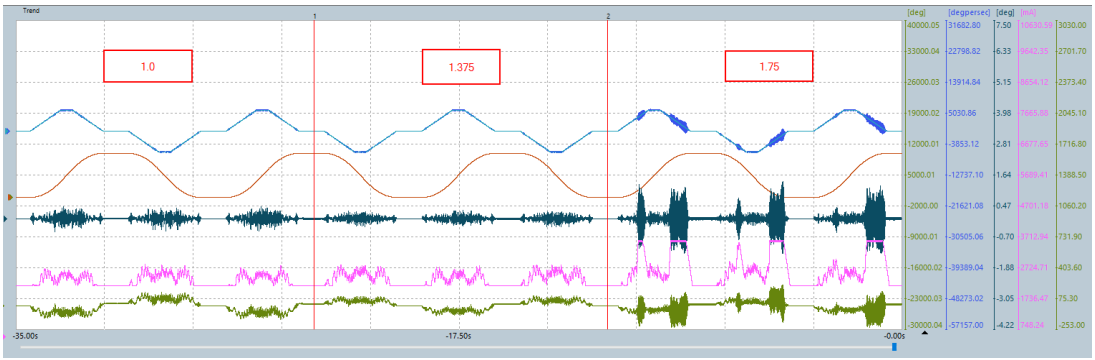
If the analysis of the controller quality shows that the standard settings of the module are not satisfactory, the closed loop controller can be tuned.

The most important tuning factor for the CL regulator has typically already been set during commissioning, by defining “minimum current” and “maximum current”. This setting typically has the greatest effect on stimulating oscillations. The default setting of the position controller is set gently with a gain of 1.0 and therefore does not actively excite oscillation under normal circumstances. Before proceeding, it is necessary to ensure that the “minimum current” and “maximum current” have already been selected.

As a first step in the closed loop regulator tuning, the position control is set. The CL tolerance should be checked at the start. If the CL gain is not equal to 1.0, this value has an effect (with a standard gain of 1.0, nothing changes in the entire range up to the CL deviation limit). The CL tolerance should be selected so that the value is slightly larger than the “scaling of the encoder increment to µSteps”. This scaling value can be read out of the module via ENC_CONST index 0x4000, sub-index 0x55. The value consists of 16 decimal places and 15 integer places. The CL tolerance should be set slightly higher than the scaling value in order to prevent encoder noise from being included in the CL regulation.

After that, the CL gain can be set. The procedure is similar to that for servo drives. If the encoder deviation increases significantly with increasing speed or the axis shows a superimposed oscillation, the axis can be made stiffer by increasing the CL gain. The regulator thus increases the position's compensation angle earlier and thus compensates for the encoder deviation to a greater extent. Constant oscillations can also be the result of a maximum current that is too low to correct these oscillations. Generally, a balance must be struck here between the CL gain and the current amplitude in order to achieve the best control quality.

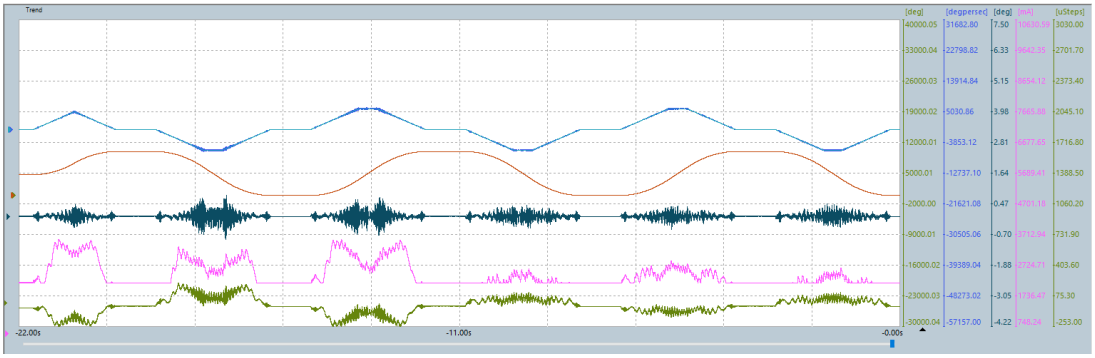
Conversely, if the axis is already oscillating at the default setting, the axis can be softened. In this case, it makes sense to also reduce the value of CL deviation limit by x% when reducing the gain by x%. A real deviation of 255 µSteps should already correspond to the maximum of CL deviation limit for good regulation. The effect of CL amplification on a real axis is shown in the following figure. It starts with the default values of the module, then the gain is gradually increased to 1.375 and 1.75. At 1,375, you can see that the stiffer axis can partially suppress the oscillations. With a further increase to 1.75, the oscillations are actively stimulated.



The next step is to set the back-EMF correction. To do this, it is best to accelerate the axis slowly (if possible without exciting resonant frequencies). From the speed of back-EMF correction start speed (default = 250000 pps), a reduction in encoder deviation should be visible or no further increase. The value of the back-EMF correction speed range should be selected so that the encoder deviation is kept approximately constant.

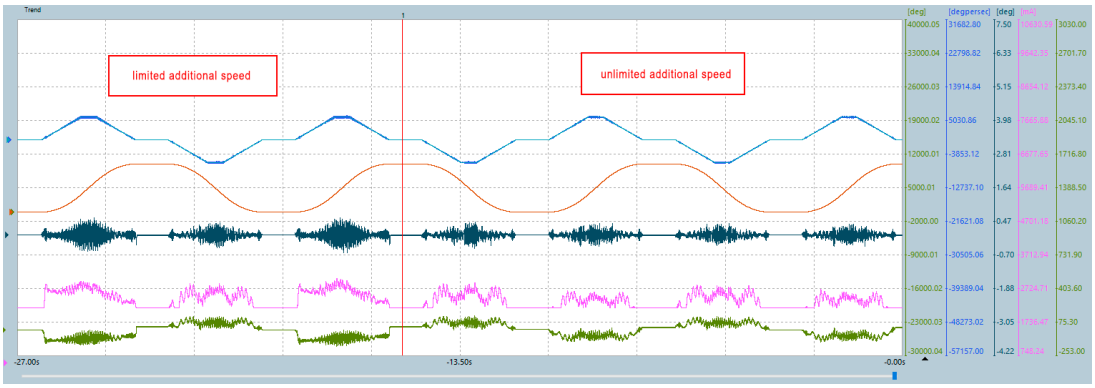
Following is a comparison between two settings of the back-EMF correction start speed. At first, 400000 pps are used (a value that still allows stable driving), after three cycles the value is switched to 200000 pps (a good value for this motor). The maximum speed is 850000 pps. In the first part, you can see the effect as soon as the back-EMF correction takes effect. Before that, however, a large encoder deviation has already built up. When the back-EMF correction is started in the second half, the active encoder deviation remains approximately constant. The indirect effect on the current is clearly visible, as the axis vibrates less at the same load. With well-adjusted back-EMF compensation, a lower current is required.

The indirect effect on the current is also clearly visible, since the axis with well-adjusted back-EMF compensation runs more smoothly with fewer oscillations and with the same load, with less current.



In the case of the current controller, the user only has access to the minimum and maximum current. As with open loop mode, there is no general rule for how the current amplitude should be changed to influence vibrations and oscillations. As a rough rule, vibrations tend to decrease at higher currents, while oscillations increase. However, it is also true that a higher current can reduce the excitation of the resonance, especially during oscillations at low speeds. In this case, it is necessary for the user to set the current amplitudes for the minimum and maximum currents for the specific application. As a starting value, 100% can be used for the maximum current and 50% for the minimum current in closed loop regulation. Between the starting value of 50 µSteps and the value of the CL deviation limit, the current is scaled linearly from the minimum current to the maximum current. The way in which the current scaling works can be seen in the figures above.

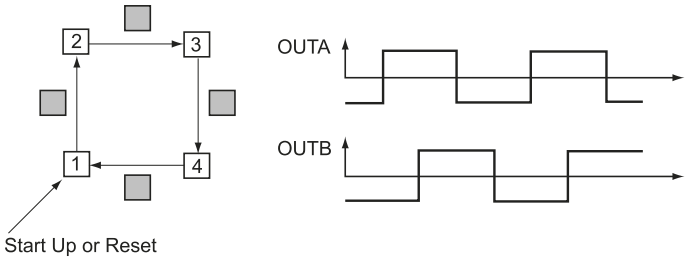
The additional speed determined by the PI regulator of the speed controller is added to the target speed in order to follow the changes in position and to be able to catch up or fall back. This speed therefore has the least influence on the overall performance of the CL regulator. When using the default settings, the additional speed directly follows the position changes and is not limited. The following figure shows a comparison between operation with and without limitation. The limitation is calculated with P-gain PI regulator additional speed = 30000 and I-gain PI regulator additional speed = 400 and the high limitation Maximum additional speed = 2000 pps. Since the load is not symmetrical, the effect of the limitation is only visible in one direction of movement.



12.5 Supported Step Operation Modes

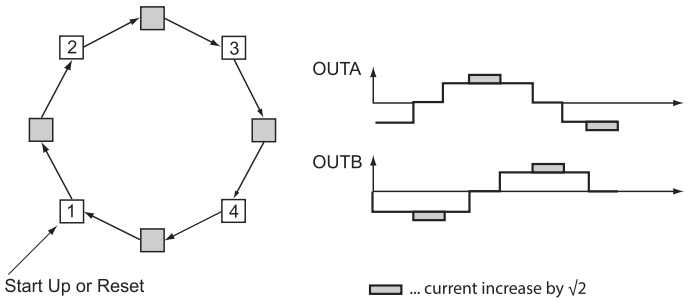
12.5.1 Full step mode

In full step mode, Current is applied to the winding as shown below. The motor rotates in full steps only. It therefore executes the nominal number of steps of the motor in one revolution. The step mode selection with full step, half step, 4-/8-/16-/32-/64-/128-/256-fold microstep is done automatically.



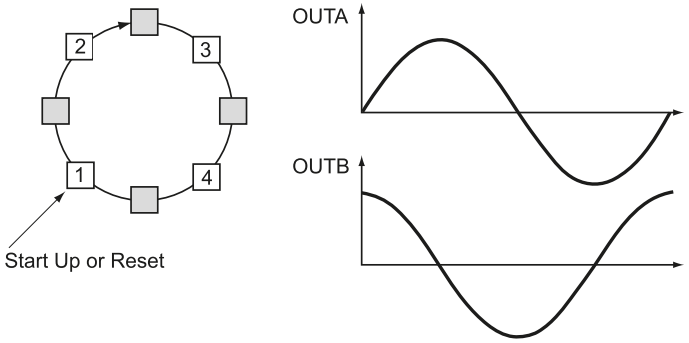
12.5.2 Half step mode

In half step mode, Current is applied to the winding as shown below. Between each full step, an intermediate step is taken. The resolution per turn is thereby doubled.



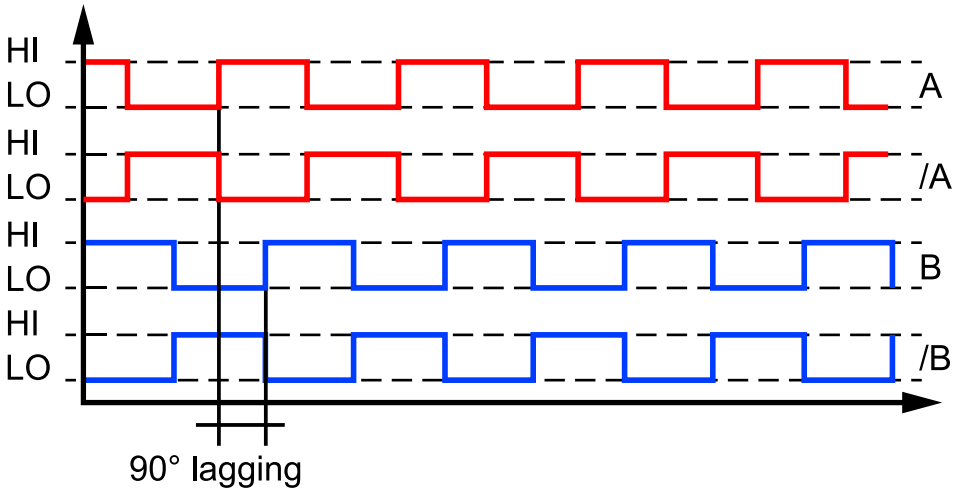
12.5.3 Micro Step Mode

In micro step mode, a nearly sine wave formed current is applied to the individual windings. With the ST 152, the resolution of the sine oscillation is 1024 steps. 256 micro steps per full step are thereby produced.

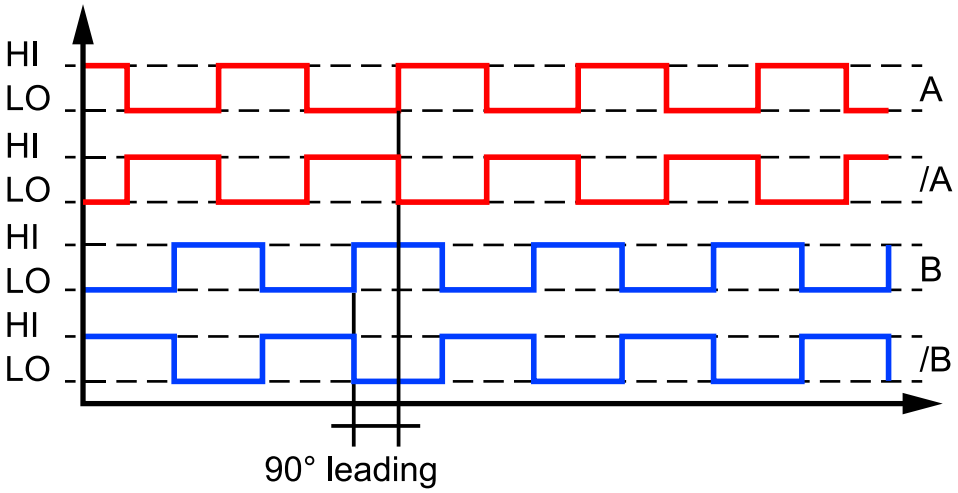


12.6 Incremental encoder

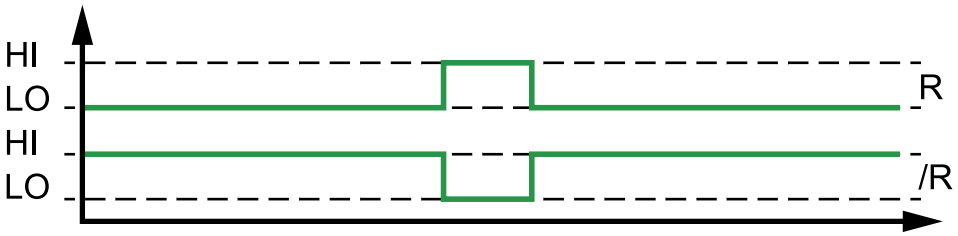
12.6.1 Signal Process “Count UP”



12.6.2 Signal Process “Count DOWN”



12.6.3 Signal Process “Reference Pulse (Zero Position)”



12.6.4 Latch Function

This function is primarily used for the reference motion.

The incremental encoder data and frequency counter values can be stored (latched) in a selected input at the time of an event. The event source (input) and event type (edge) can be set via latch registers.

12.7 Object Directory Overview

Index	SubIndex	Name
0x1001	0x00	Error Register
0x100A	0x00	FW Version
0x2001	0x00	FW Status
0x1600	0x00	RPDO Mapping
0x1600	0x01-0x0A	Mapping Entry 1-10
0x1A00	0x00	TPDO Mapping
0x1A00	0x01-0x0A	Mapping Entry 1-10
0x4000	0x00	Motion Controller Parameter
0x4000	0x02	REFERENCE_CONF
0x4000	0x08	ENC_IN_CONF

Index	SubIndex	Name
0x4000	0x0F	EVENTS
0x4000	0x1D	CL_BETA/CL_GAMMA
0x4000	0x22	XACTUAL
0x4000	0x23	VACTUAL
0x4000	0x34	VIRT_STOP_LEFT
0x4000	0x35	VIRT_STOP_RIGHT
0x4000	0x51	ENC_POS
0x4000	0x53	ENC_POS_DEV/CL_TR_ TOLERANCE
0x4000	0x54	ENC_POS_DEV_TOL
0x4000	0x55	ENC_CONST
0x4000	0x5B	CL_VMAX_CALC_P
0x4000	0x5C	CL_VMAX_CALC_I
0x4000	0x5D	CL_DELTA_P
0x4000	0x60	CL_TOLERANCE
0x4000	0x61	FS_VEL/CL_VMIN_EMF
0x4000	0x62	CL_VADD_EMF

Index	SubIndex	Name
0x4000	0x67	V_ENC_MEAN
0x4000	0x68	VSTALL_LIMIT
0x4000	0x7D	SCALE_PARAM
0x4001	0x00	Motor Controller Parameter
0x4001	0x01	GCONF
0x4001	0x0C	GLOBALSCALER
0x4001	0x11	IHOLD_IRUN
0x4001	0x13	TSTEP
0x4001	0x14	TPWMTHRS
0x4001	0x15	TCOOLTHRS
0x4001	0x16	THIGH
0x4001	0x6E	COOLCONF
0x4001	0x72	PWM_SCALE
0x4001	0x73	PWM_AUTO
0x4002	0x00	Controller Mode
0x4003	0x00	Set Device State
0x4004	0x00	Act Device State
0x4005	0x00	Position Mode
0x4006	0x00	Chopper Config
0x4006	0x01	Chopper Enable
0x4006	0x02	Chopper Resistor
0x4006	0x03	Power of Resistor
0x4006	0x04	Time Constant of Resistor
0x4006	0x05	Utilisation Resistor
0x4006	0x06	Maximum On Time

Index	SubIndex	Name
0x4006	0x07	Blocking Time
0x4006	0x08	Upper Voltage Limit
0x4006	0x09	Lower Voltage Limit
0x4006	0x0A	Warning Threshold Utilisation
0x4007	0x00	Motion Profile
0x400A	0x00	Analog Values
0x400A	0x01	Motor Supply Voltage
0x400A	0x02	Temperature
0x400B	0x00	Latch Position
0x400B	0x01-0x02	Latch Position Input 1/2
0x4008	0x00	Position Latch Config
0x4008	0x01-0x02	Latch Config Input 1/2
0x400C	0x00	Chopper Values
0x400C	0x06	Utilisation Value
0x400C	0x09	Chopper Enabled
0x400D	0x00	Chop Conf Values
0x400D	0x02	HSTRT
0x400D	0x03	HEND
0x400D	0x04	VHIGHFS
0x400E	0x01	PWM_OFS
0x400E	0x02	PWM_GRAD
0x400E	0x03	PWM_AUTOSCALE
0x400E	0x04	PWM_AUTOGRAD
0x400E	0x06	PWM_LIM

Index	SubIndex	Name
0x400F	0x00	Scale Value
0x400F	0x01	OL DRV1_SCALE_VAL / CL CL_IMAX
0x400F	0x02	OL HOLD_SCALE_VAL / CL CL_IMIN
0x400F	0x03	OL DRV2_SCALE_VAL / CL_START_UP
0x400F	0x04	OL BOOST_SCALE_VAL / CL_START_DOWN
0x4009	0x00	Digital Inputs
0x4010	0x00	Error Info Detail
0x4011	0x00	Warning Register
0x4012	0x00	Warning Info Detail
0x4018	0x00	Motion Controller Infos
0x4018	0x01	Motion Controller Status
0x4018	0x02	Motor Controller Status
0x4018	0x03	Motion Controller Events
0x4018	0x04	Motion Controller SPI STATUS Flags
0x4019	0x00	PDO Info
0x4019	0x01	RPDO Mapping Size
0x4019	0x02	TPDO Mapping Size
0x4019	0x03	RPDO Motion Controller Para
0x4019	0x04	TPDO Motion Controller Para
0x401A	0x00	Closed Loop Settings
0x401A	0x01	EMF Enable
0x401A	0x02	VLIMIT Enable
0x401B	0x00	Motor Current
0x401B	0x01	Global Scaler

Index	SubIndex	Name
0x401B	0x02	IRUN
0x401B	0x03	IHOLD
0x6041	0x00	Status Word
0x6061	0x00	Modes of Operation Display
0x6064	0x00	Actual Position
0x606C	0x00	Actual Speed
0x6040	0x00	Control Word
0x6073	0x00	Max Motor Current
0x6060	0x00	Modes of Operation
0x607A	0x00	Target Position
0x60FF	0x00	Target Speed

Index	SubIndex	Name
0x6080	0x00	Motor Max Speed
0x60C5	0x00	Motor Max Acceleration
0x60C6	0x00	Motor Max Deceleration
0x6083	0x00	Motor Profile Acceleration
0x6084	0x00	Motor Profile Deceleration
0x6410	0x00	Motor Data
0x6410	0x01	Full Steps One Turn
0x6410	0x02	Encoder Resolution
0x6410	0x03	Encoder Direction
0x6410	0x04	Encoder Signal Mode

12.8 Detailed Object Directory

Name	**Error Register**	Index	**0x1001**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows error bits in a bit field from 0-31.					
Bit 0-1: Reserved.					
Bit 2: Voltage error (see chapter Stepper Motor Output Specifications).					
Bit 3: Temperature error (see chapter Stepper Motor Output Specifications).					
Bit 4: Switch to OP error (invalid configuration).					
Bit 5-7: Reserved.					
Bit 8: Safety STO input off.					
Bit 9: Safety error.					
Bit 10: Open or closed loop calibration not OK.					
Bit 11: Chopper initialization not OK.					
Bit 12: Latch initialization not OK.					
Bit 13: Chopper not OK.					
Bit 14: Bridge short error.					
Bit 15: Chopper short error.					
Bit 16: Encoder short error.					
Bit 17: Flash calibration data error.					
Bit 18: S-DIAS bus time or sync error.					
Bit 19: Motor current calibration error (invalid "MaxMotorCurrent").					
Bit 20: Encoder failure on motion controller.					
Bit 21: Temperature error on Motor Controller.					
Bit 22: Stall error recognized.					
Bit 23: Error recognized on Motor Controller.					
Bit 24: Communication Error to Motor or Motion Controller					
Bit 25: Communication Error to CPLD					
Bit 26-31: Reserved.					

Name	**FW Version**	Index	**0x100A**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**2**
Shows the FW version in xx.yy. E.g.: 0x0100 = version 1.0					

Name	**FW Status**	Index	**0x2001**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**2**
Shows the FW status in bits.					
Bit 0: DC not OK (not used).					
Bit 1: Not synchronized (no sync).					
Bit 2: Flash error (normalization data invalid).					
Bit 3: RAM error (cyclic RAM check detected errors).					
Bit 4: Flash unsafe (normalization data unsafe).					
Bit 5: S-DIAS bus time error (invalid SDIAS bus time).					
Bits 6-15: Reserved for later use.					

Name	**RPDO Mapping**	Index	**0x1600**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**1**
Number of sub-indices 0-10 allowed. Configures the PDOs received by the ST 152. A maximum of 5 PDOs can be configured directly to the motion controller.					

Name	**Mapping Entry 1-10**	Index	**0x1600**	Sub-index	**0x01-0x0A**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
uint16_t index: Specifies the mapping index uint8_t sub-index: Specifies the mapping sub-index uint8_t len: Specifies the length of the mapping parameter					

Name	**TPDO Mapping**	Index	**0x1A00**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**1**
Number of sub-indices 0-10 allowed. Configures the PDOs sent by the ST 152. A maximum of 4 PDOs can be configured directly to the motion controller.					

Name	**Mapping Entry 1-10**	Index	**0x1A00**	Sub-index	**0x01-0x0A**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
uint16_t index: Specifies the mapping index uint8_t sub-index: Specifies the mapping sub-index uint8_t len: Specifies the length of the mapping parameter [bytes]					

Name	**Motion Controller Parameter**	Index	**0x4000**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Sub-index 1-128 Parameter Motion Controller. Important! Only the listed sub-indices may be used.					

Name	**REFERENCE_ CONF**	Index	**0x4000**	Sub-index	**0x02**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Application user: STOP_ON_STALL (Bit 26) drive_after_stall (Bit 27) Activate virtual stop limits (Bit 6, Bit 7) The reference switch configuration register (REFERENCE_CONF 0x01) contains several control bits for managing reference switches and stop events when controlling the motor. Below you will find a breakdown of the bits and their meaning:					
Bits 0-5: Default value = 0 -> must not be changed					
Bit 6: virtual_left_limit_en 0: Deactivates the virtual left position limit (VIRT_STOP_LEFT). 1: Activates the virtual left position limit. Default value = 0					
Bit 7: virtual_right_limit_en 0: Deactivates the virtual right position limit (VIRT_STOP_RIGHT). 1: Activates the virtual right position limit. Default value = 0					
Bits 8-9: virt_stop_mode 0: Reserved. 1: Hard stop; sets the speed to 0 at a virtual stop event. 2: Smooth stop with a linear ramp to 0. 3: Reserved. Default value = 0					
Bits 10-20: Default value = 0 -> must not be changed					
Bit 21: clr_pos_at_target 0: Ramp stops when XTARGET is reached. 1: Sets XACTUAL to 0 after reaching XTARGET so that the next ramp can begin immediately. Default value = 0					
Bit 22: circular_movement_en 0: XACTUAL is not limited (ranges from -2^{31} to $2^{31}-1$). 1: XACTUAL is limited by the defined range (X_RANGE). Default value = 0					
Bits 23-24: pos_comp_output 0: TARGET_REACHED is triggered by the TARGET_REACHED flag. 1: TARGET_REACHED is triggered by the VELOCITY_REACHED flag. 2: TARGET_REACHED is triggered by the ENC_FAIL flag. 3: TARGET_REACHED is triggered by the POSCOMP_REACHED flag. Default value = 0					
Bit 25: pos_comp_source 0: Compares POS_COMP with the internal position (XACTUAL). 1: Compares POS_COMP with an external position (ENC_POS). Default value = 0					
Bit 26: stop_on_stall 0: SPI and S/D output interface remain active during a “stall” event. 1: SPI and S/D output interface stop the movement during a stall event (hard stop). Default value = 0					
Bit 27: drv_after_stall 0: No further movement after a “stall” event. 1: Allows movement after resetting a stop-on-stall event. Default value = 0					
Bits 28-29: modified_pos_compare 0: The POS_COMP_REACHED_F event is based on the comparison between XACTUAL and POS_COMP.					

1: The POS_COMP_REACHED_F event is based on a comparison with X_HOME. 2: The POS_COMP_REACHED_F event is based on a comparison with X_LATCH or ENC_LATCH. 3: The POS_COMP_REACHED_F event is based on a comparison with REV_CNT. Default value = 0
Bit 30: Default value = 0 -> must not be changed
Bit 31: circular_enc_en 0: ENC_POS is not limited (ranges from -2^{31} to $2^{31}-1$). 1: ENC_POS is limited by X_RANGE (ranges from -X_RANGE to X_RANGE - 1). Default value = 0

Name	**ENC_IN_CONF**	Index	**0x4000**	Sub-index	**0x08**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Encoder signal configuration inversion encoders are covered by 0x6410. Bit 0: enc_sel_decimal 0: The encoder constant represents a binary number. 1: Encoder constant is a decimal number (for ABN encoders only). Default value = 0					
Bit 1: clear_on_n 0: ENC_POS is not set to ENC_RESET_VAL. 1: ENC_POS is set to ENC_RESET_VAL at every N-event if clr_latch_cont_on_n = 1 or at the next N-event if clr_latch_once_on_n = 1. **Note:** This setting must not be used in normal operation. Default value = 0					
Bit 2: clr_latch_cont_on_n 0: ENC_POS is not deleted/blocked at each N-event. 1: ENC_POS is deleted/blocked at each N-event. Default value = 0					
Bit 3: clr_latch_once_on_n 0: ENC_POS is not deleted/stored at the next N event. 1: ENC_POS is deleted/stored at the next N event. This bit is reset to 0 after a single occurrence. Default value = 0					
Bit 4: pol_n 0: Active polarity for N event is low active. 1: Active polarity for N event is high active. Default value = 0					
Bits 5-6: n_chan_sensitivity 0: N event is active as long as N is equal to the active polarity. 1: N event is triggered when N switches to active polarity. 2: N event is triggered when N switches to inactive polarity. 3: N event is triggered on both rising and falling edges (change between active and inactive polarity). Default value = 0					
Bit 7: pol_a_für_n 0: For a valid N event, a polarity must be low. 1: For a valid N event, a polarity must be high. Default value = 0					
Bit 8: pol_b_für_n 0: The B polarity must be low for a valid N event. 1: The B polarity must be high for a valid N event. Default value = 0					
Bit 9: ignore_ab 0: A and B polarities are considered for a valid N event. 1: The polarity of A and B signals is ignored for a valid N event. Default value = 0					

Bit 10: latch_enc_on_n 0: ENC_POS is not cached. 1: ENC_POS is cached in ENC_LATCH on every N event if clr_latch_cont_on_n = 1 or on the next N event if clr_latch_once_on_n = 1. Default value = 0
Bit 11: latch_x_on_n 0: XACTUAL is not latched. 1: XACTUAL is cached in X_LATCH on every N event if clr_latch_cont_on_n = 1 or on the next N event if clr_latch_once_on_n = 1. Default value = 0
Bit 12: Default value = 0 -> must not be changed
Bit 13: Default value = 0 -> must not be changed
Bit 14: Default value = 0 -> must not be changed
Bit 15: use_usteps_instead_of_xrange 0: X_RANGE is valid when circular motion is activated for encoders. 1: USTEPS_PER_REV is valid when circular motion is activated for encoders. Default value = 0
Bits 16-21: Default value = 0 -> must not be changed
Bits 22-23: Internal use -> must not be changed
Bit 24: Default value = 0 -> must not be changed
Bit 25: cl_emf_en (only in closed loop operation) 0: Back-EMF compensation is deactivated in control mode. 1: Back-EMF compensation is activated when |VACTUAL| > CL_VMIN. Default value = 1
Bit 26: cl_clr_xact (only for operation in a closed loop) 0: XACTUAL is not reset to ENC_POS during closed loop operation. 1: XACTUAL is set to ENC_POS_DEV if |ENC_POS_DEV| exceeds ENC_POS_DEV_TOL in normal operation. **Note:** Only use this function if you fully understand how it works. Default value = 0
Bit 27: cl_vlimit_en (only in controlled operation) 0: No limit on the catch-up speed during normal operation. 1: The internal PI regulator limits the catch-up speed during normal operation. Default value = 0
Bit 28: cl_velocity_mode_en (only for operation in a closed loop) 0: The speed mode is switched off. 1: The speed mode activated. If |ENC_POS_DEV| > 768, XACTUAL is adjusted accordingly. Default value = 0
Bit 29: invert_enc_dir 0: The direction of the encoder is not inverted. 1: The direction of the encoder is inverted. Default value = 1
Bit 30: Default value = 0 -> must not be changed
Bit 31: no_enc_vel_preproc (incremental ABN encoder) 0: AB signal is preprocessed for internal encoder speed calculation. 1: No preprocessing of the AB signal is performed. **Note:** Preprocessing is recommended to filter out encoder resonances. Default value = 0

Name	**EVENTS**	Index	**0x4000**	Sub-index	**0x0F**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**

Implementation of Stop on Stall using User Bit description:

0: TARGET_REACHED: The movement target was reached. Default value = 0

1: POS_COMP_REACHED: Position comparator has been triggered. Default value = 0

2: VEL_REACHED: Desired speed was reached. Default value = 0

3: VEL_STATE = b'00: speed is zero (VACTUAL = 0). Default value = 0

4: VEL_STATE = b'01: speed is positive (VACTUAL > 0). Default value = 0

5: VEL_STATE = b'10: speed is negative (VACTUAL < 0). Default value = 0

6: RAMP_STATE = b'00: Ramp status is constant speed (AACTUAL = 0, VACTUAL is constant). Default value = 0

7: RAMP_STATE = b'01: Ramp status increasing speed. Default value = 0

8: RAMP_STATE = b'10: Ramp status decreasing speed. Default value = 0

9: MAX_PHASE_TRAP: The trapezoidal ramp has reached its maximum speed. Default value = 0

10: FROZEN: Freezing of movement detected, NFREEZE has switched to low. A reset is required for further movement. Default value = 0

11-12: Default value = 0 -> must not be changed

13: VSTOPL_ACTIVE: Virtual stop on the left has been activated. No further movement in the negative direction until the event is cleared. Default value = 0

14: VSTOPR_ACTIVE: Virtual stop on the right has been activated. No further movement in the positive direction until the event is cleared. Default value = 0

15: Default value = 0 -> must not be changed

16: XLATCH_DONE: X-position lock completed or reference run completed. Default value = 0

17: FS_ACTIVE: The full step movement has been activated. Default value = 0

18: ENC_FAIL: A discrepancy between XACTUAL and ENC_POS exceeded the specified limit. Default value = 0

19: N_ACTIVE: N event triggered (only activated if clr_latch_cont_on_n or clr_latch_once_on_n is activated in ENC_IN_CONF register 0x07). Default value = 0

20: ENC_DONE: Shows that ENC_LATCH has been rewritten. Default value = 0

21: Default value = 0 -> must not be changed

22: Reserved. Default value = 0

23-24: Default value = 0 -> must not be changed

25: COVER_DONE: SPI datagram sent to the motor driver. Default value = 0

26: ENC_VEL0: Encoder speed has reached zero. Default value = 0

27: CL_MAX: The commutation angle in the closed control loop has reached the maximum value. Default value = 0

28: CL_FIT: The control loop deviation has reached the inner limit. Default value = 0

29: STOP_ON_STALL: Motor standstill detected and motor ramp has been stopped. Default value = 0

30: MOTOR_EV: One of the selected motor driver flags was triggered. Default value = 0

31: RST_EV: Reset was triggered Default value = 0

Name	**CL_BETA / CL_ GAMMA**	Index	**0x4000**	Sub-index	**0x1D**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
CL_BETA and CL_GAMMA configuration Bits 0-8 - CL_BETA: 0x0FF: Defines the maximum commutation angle for the regulation. **Note:** A value of 255 (0x0FF) is recommended for best performance. The setting of CL_BETA above 255 should be done with caution, especially if cl_vlimit_en is activated. Bits 16-23 - CL_GAMMA (Preset: 0xFF): Defines the maximum equalization angle for compensating back-EMF at higher speeds during regulation. Preset: 0xFF (255)					

Name	**XACTUAL**	Index	**0x4000**	Sub-index	**0x22**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Current internal motor position in [µSteps]. Is mapped to parameter 0x6064 when the mode of operation = open loop.					

Name	**VACTUAL**	Index	**0x4000**	Sub-index	**0x23**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Current internal ramp generator speed [µsteps per second].					

Name	**VIRT_STOP_ LEFT**	Index	**0x4000**	Sub-index	**0x34**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Virtual left stop position in [µSteps].					

Name	**VIRT_STOP_ RIGHT**	Index	**0x4000**	Sub-index	**0x35**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Virtual right stop position in [µSteps].					

Name	**ENC_POS**	Index	**0x4000**	Sub-index	**0x51**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Current encoder motor position in [µSteps]. Is mapped to parameter 0x6064 when the mode of operation = closed loop.					

Name	**ENC_POS_DEV / CL_TR_ TOLERANCE**	Index	**0x4000**	Sub-index	**0x53**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
ENC_POS_DEV and CL_TR_TOLERANCE configuration: Bits 0-31 - ENC_POS_DEV (Preset: 0x00000000) read only (R): This represents the deviation between the current XACTUAL position and the encoder position ENC_POS. For open loop operation: ENC_POS_DEV = ENC_POS - XACTUAL. For closed loop or PID operation: ENC_POS_DEV = ENC_POS - XACTUAL - CL_OFFSET. The deviation is calculated differently depending on whether regulation or control is active. Bits 0-31 - CL_TR_TOLERANZ (Preset: 0x00000100) write only (W): Defines the tolerated absolute difference between XACTUAL and ENC_POS that triggers the TARGET_ REACHED condition, including setting the TARGET_REACHED_FLAG and triggering an event.					

Name	**ENC_POS_DEV_TOL**	Index	**0x4000**	Sub-index	**0x54**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
ENC_POS_DEV_TOL (default setting: 0x000FFFFF). Maximum tolerated value of ENC_POS_DEV that is not flagged as an error.					

Name	**ENC_CONST**	Index	**0x4000**	Sub-index	**0x55**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Encoder constant Bit 0-30 Value representation: 15 digits and 16 decimal places.					

Name	**CL_VMAX_CALC_P**	Index	**0x4000**	Sub-index	**0x5B**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
PID configuration, default value = 0xC8 Bits 0-23 - PID_P (preset: 0x000000). write only (W): Parameter P of the PID regulator. Proportional term = PID_E · PID_P/256. Bits 0-31 - CL_VMAX_CALC_P write only (W): Parameter P of the PI regulator, which controls the limitation of the maximum catch-up speed in closed loop operation. Bits 0-31 - PID_VEL read only (R): Actual PID output speed in pulses per second (pps).					

Name	**CL_VMAX_CALC_I**	Index	**0x4000**	Sub-index	**0x5C**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
PID integral configuration, default value = 0x32 Bits 0-23 - PID_I write only (W): Parameter I of the PID regulator. Integral value = (PID_ISUM / 256) × (PID_I/256). Bits 0-31 - CL_VMAX_CALC_I write only (W): Parameter I of the PI controller, which controls the maximum limitation of the catch-up speed in control operation. Bits 0-31 - PID_ISUM_RD read only (R): Current PID integrator sum. Refresh rate = f_CLK/128.					

Name	**CL_DELTA_P**	Index	**0x4000**	Sub-index	**0x5D**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**
Configuration of the PID derivative, default value = 0x10000 Bits 0-23 - PID_D write only (W): Parameter D of the PID regulator. The derivative part is calculated as follows: derivational term = (PID_E_LAST - PID_E_ACTUAL) × PID_D. PID_E is scanned with f_CLK / 128 / PID_D_CLKDIV. Bits 0-31 - CL_DELTA_P write only (W): Gain parameter multiplied by the actual position difference to calculate the commutation angle for position maintenance stiffness. The value is truncated at CL_BETA. Real value = CL_DELTA_P/2^{16} (e.g. 65536 -> 1.0, gain = 1). Value representation: 8 digits and 16 decimal places.					

Name	**CL_TOLERANCE**	Index	**0x4000**	Sub-index	**0x60**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**
PID and closed loop tolerance configuration, tuning user, if encoder resolution is less than 2560 CPR/640 PPR, it can also be reduced for high-resolution encoders. Bits 0-19 - PID_TOLERANZ (preset: 0x00000) write only (W): tolerated position deviation. PID_E = 0, if |PID_E| < PID_TOLERANCE. Bits 0-7 - CL_TOLERANZ (preset: 0x14) write only (W): tolerated position deviation. CL_DELTA_P = 65536 (gain = 1), if |ENC_POS_DEV| < CL_TOLERANCE.					

Name	**FS_VEL / CL_ VMIN_EMF**	Index	**0x4000**	Sub-index	**0x61**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**
Closed loop minimum encoder speed configuration CL_VMIN_EMF (preset: 0x0003D090) read/write (U): Encoder speed at which back-EMF compensation begins.					

Name	**CL_VADD_EMF**	Index	**0x4000**	Sub-index	**0x62**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**
Closed loop additional velocity configuration CL_VADD_EMF (default: 0x0006DDD0) read/write (U): Additional speed value for calculating the encoder speed at which the back-EMF compensation reaches the maximum angle CL_GAMMA.					

Name	**V_ENC_MEAN**	Index	**0x4000**	Sub-index	**0x67**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
V_ENC_MEAN (standard:0x00000000). Filtered encoder speed [pps]. Mapped to 0x606C, if position comes from encoder, readable for users.					

Name	**VSTALL_LIMIT**	Index	**0x4000**	Sub-index	**0x68**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Stall velocity configuration VSTALL_LIMIT (default value: 0x0000C800) raed/write (U): Stop on stall speed limit in pulses per second (pps). Only when the actual speed exceeds this limit will an active stall cause the helicopter to stop at the stall, if activated.					

Name	**SCALE_PARAM**	Index	**0x4000**	Sub-index	**0x7D**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Configuration of scale parameters SCALE_PARAM read Bit 0-8: Currently used scale parameter. write Bit 0-31: Also used as CIRCULAR_DEC for write access. Default value = 0x00000000					

Name	**Motor Controller Parameter**	Index	**0x4001**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Sub-index 1-128 Parameter motor controller. **Important!** Only the listed sub-indices may be used.					

Name	**GCONF**	Index	**0x4001**	Sub-index	**0x01**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**

GCONF register, default vert = 0x00010000
Bit description:
Bit 0: Recalibrate
1: Zero-crossing recalibration at driver disable (via DRV_ENN or TOFF setting).
Default value = 0

Bit 1: faststandstill
Timeout for step execution until standstill is detected:
1: Short time: 2^{18} pulses
0: Normal time: 2^{20} pulses
Default value = 0

Bit 2: en_pwm_mode
1: Current control mode chopper voltage PWM mode activated (depending on speed threshold). Switching from off to on only possible at standstill and when IHOLD = nominal current IRUN.
Default value = 0

Bit 3: - multistep_filt: Default value = 0 -> must not be changed

Bit 4: Wave
1: Inverse motor rotation.
Default value = 0

Bit 5: - diag0_error: Default value = 0 -> must not be changed

Bit 6: - diag0_otpw: Default value = 0 -> must not be changed

Bits 7-15: Default value = 0 -> must not be changed

Bit 16: direct_mode
0: Normal operation.
1: The currents and polarity of the motor coils are programmed directly via the serial interface:
The XDIRECT register (0x2D) indicates the signed current of coil A (bits 0-8) and the current of coil B (bits 16-24). In this mode, the current is scaled by the IHOLD setting. The speed-based current control of the current control mode chopper is not available in this mode. The automatic current control mode chopper current control only works at low stepper motor speeds.
Default value = 1

Bit 17: Default value = 0 -> must not be changed

Name	**GLOBALSCALER**	Index	**0x4001**	Sub-index	**0x0C**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

GLOBALSCALER register, default value = 0x00000000
write (W): Global scaling of the motor current. This value is multiplied by the current scaling to adapt a drive to a specific motor type. This value should be selected before tuning other settings, as it also affects the chopper hysteresis.
Bit description:
Bits 0-7:
0: Scale end value (or write 256).
1-31: Not permitted for operation.
32-255: 32/256 ... 255/256 of the maximum current.
Note: Values > 128 are recommended for best results.

Name	**IHOLD_IRUN**	Index	**0x4001**	Sub-index	**0x11**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

IHOLD and IRUN configuration, default value = 0x00071003
IHOLD:
Bits 0-4:
This setting specifies the standstill current. It can be between 0 and 31, where 0 corresponds to 1/32 of the maximum current and 31 to 32/32 (full current). In combination with the current control mode chopper mode, setting IHOLD to 0 allows the user to choose between freewheeling or coil shorting for motor standstill.
IRUN:
Bits 8-12:
This parameter is used to set the motor running current, also in the range from 0 to 31. Similar to IHOLD, 0 corresponds to 1/32 of the maximum current, while 31 corresponds to the full current (32/32).
Note: It is advisable to select the measuring resistors so that the normal IRUN is between 16 and 31 for optimal microstep performance.
IHOLDDELAY:
Bits 16-19:
This field controls the number of clock cycles for motor shutdown after motion is detected (when stst=1) and the TPOWERDOWN time has expired. This smooth transition helps to avoid jerking the motor during shutdown.
Options:
0: Immediate shut down.
1-15: Delay per current reduction step, in multiples of 2^{18} clock cycles.

Name	**TSTEP**	Index	**0x4001**	Sub-index	**0x13**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**

TSTEP register, default value = 0x0000000A
Actual time measured between two 1/256 microsteps, derived from the step frequency in units of 1/fCLK. The measured value is (2^{20})-1 when overflowing or at a standstill.
All TSTEP-related thresholds use a hysteresis of 1/16 of the reference value.
Comparison value to compensate for jitter in the clock or step frequency.
Frequency to compensate. The small_hysteresis flag changes the hysteresis to a smaller value of 1/32.
(Txxx*15/16)-1 or
(Txxx*31/32)-1 is used as the second comparison value for each comparison value.This means that the lower switching speed is equal to the calculated setting, but the upper switching speed is higher than the hysteresis setting defined by the hysteresis setting.

Name	**TPWMTHRS**	Index	**0x4001**	Sub-index	**0x14**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

TPWMTHRS register, default value = 0x00061A80
This is the upper speed for the current control mode chopper voltage PWM mode.
TSTEP ≥ TPWMTHRS
- Current control mode chopper PWM mode is activated if configured.

Name	**TCOOLTHRS**	Index	**0x4001**	Sub-index	**0x15**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

TCOOLTHRS register, default value = 0x000000C8
This is the lower limit speed for switching on the smart energy, sensorless load-dependent motor current setting and sensorless load value. Set this parameter to deactivate sensorless load-dependent motor current control at low speeds where it cannot operate reliably. The stall output signal is activated when this speed is exceeded.
TCOOLTHRS ≥ TSTEP ≥ THIGH:
- The sensorless load-dependent motor current control is activated if configured.
- The current control mode chopper voltage PWM mode is deactivated.

Name	**THIGH**	Index	**0x4001**	Sub-index	**0x16**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

THIGH register, default value = 0x00000032
This speed setting enables speed-dependent switching to a different chopper mode and full stepping to maximize torque (unsigned).
The stall detection is disabled for 2-3 electrical cycles when the THIGH threshold is exceeded to compensate for the effect of switching.
TSTEP ≤ THIGH:
- The sensorless load-dependent motor current control is deactivated (motor runs at normal current scale).
- The current control mode chopper voltage PWM mode is deactivated.
- When vhighchm is set, the chopper switches to chm=1 with TFD=0 (only constant off time with slow decay).

Name	**COOLCONF**	Index	**0x4001**	Sub-index	**0x6E**
Device State	**OP**	RW	**WO**	Size [bytes]	**4**

COOLCONF register, default value = 0x0100A220
Bits 0-3: semin0, semin1, semin2, semin3
Function: Minimum sensorless load value for Smart Current Control and Smart Current Enable.
Note: When the sensorless load value result falls below SEMIN * 32, the motor current is increased to reduce the motor load angle.
%0000: Intelligent current control of sensorless motor current control from %0001... %1111: 1 ... 15
Default value = 0

Bit 4: Reserved.
Function: Reserved, set to 0.
Default value = 0

Bits 5-6: seup0, seup1
Function: Current upward step size.
Note: Current upward step size per measured sensorless load value.
%00 ... %11: 1, 2, 4, 8
Bit 5: Default value = 1
Bit 6: Default value = 0

Bit 7: Reserved. Default value = 0

Bits 8-11: semax0, semax1, semax2, semax3
Function: Sensorless load value hysteresis value for intelligent current control.
Note: If the sensorless load value result is equal to or greater than (SEMIN + SEMAX + 1) * 32, the motor current is reduced to save energy. Range: %0000 ... %1111: 0 ... 15
Bit 8: Default value = 0
Bit 9: Default value = 1
Bits 10-11: Default value = 0

Bit 12: Reserved. Default value = 0

Bits 13-14: sedn0, sedn1
Function: Current downward step speed.
Note:
%00: Current reduction when the sensorless load value is reduced by every 32 units.
%01: Current reduction when the sensorless load value is reduced by every 8 units.
%01: Current reduction when the sensorless load value is reduced by every 2 units.
%01: Current reduction when the sensorless load value is reduced.
Bit 13: Default value = 1
Bit 14: Default value = 0

Bit 15: seimin
Function: Minimum current for intelligent current control.
Note:
0: 1/2 of the set current (IRUN).
1: 1/4 of the set current (IRUN).
Default value = 1

Bits 16-22: sgt0, sgt1, sgt2, sgt3, sgt4, sgt5, sgt6

Function: Sensorless load value threshold.
Note: This signed value controls the sensorless load value level for the stall output and sets the optimal measuring range for the readout. A smaller value results in higher sensitivity. Zero is the start value that works with most motors.
Range: -64 to +63
A higher value makes the sensorless load value less sensitive and requires more torque to show a stall.
Default value = 0

Bit 23: Reserved.
Function: Reserved, set to 0.
Default value = 0

Bit 24: sfilt
Function: Sensorless load value filter release.
Note:
0: Standard mode, high time resolution for sensorless load value.
1: Filtered mode, sensorless load value signal is only updated for every four full steps (or six full steps for 3-phase motors) to compensate for motor pole tolerances.
Default value = 1

Bits 25-31: Reserved.
Function: Reserved, set to 0.
Default value = 0

Name	**PWM_SCALE**	Index	**0x4001**	Sub-index	**0x72**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**

Analysis of current control mode chopper by current scaling.
This section shows the results of the current control mode chopper amplitude controller. The values can be used to monitor the automatic PWM amplitude scaling, where 255 represents the maximum voltage.
PWM_SCALE_SUMME:
Bits 0-7:
This value represents the actual PWM pulse control factor. It is used to scale the values of CUR_A and CUR_B read from the sine wave table.
Range: 0-255
PWM_SCALE_AUTO:

Bits 16-24: This is a 9-bit signed offset that is added to the calculated PWM pulse control factor. It reflects the result of the automatic amplitude control based on the current measurement. Range: -255 to +255

Name	**PWM_AUTO**	Index	**0x4001**	Sub-index	**0x73**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**

These are automatically generated values that can be read to determine default or power-on settings for PWM_GRAD and PWM_OFS.
PWM_OFS_AUTO:
Bits 0-7:
This is the automatically determined offset value.
Range: 0-255
PWM_GRAD_AUTO:

Bits 16-23:
This is the automatically determined gradient value. Range: 0 to 255

Name	**Controller Mode**	Index	**0x4002**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**

Specifies the controller mode.
0: Open Loop
1: Closed Loop

Name	**Set Device State**	Index	**0x4003**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Changes the device state by writing to the parameter. 2: Change to PreOp 3: Change to Operational					

Name	**Act Device State**	Index	**0x4004**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Returns the current device state of the module. 0: BootUp 1: Init 2: PreOP 8: Operational					

Name	**Position Mode**	Index	**0x4005**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Determines whether the internal counter or the incremental encoder should be used. 0: Internal step counter 1: Encoder					

Name	**Chopper Config**	Index	**0x4006**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices 10 for the braking resistor configuration.					

Name	**Chopper Enable**	Index	**0x4006**	Sub-index	**0x01**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Settings for chopper enable 0: Braking resistor ist deactivated 1: Braking resistor is activated					

Name	**Chopper Resistor**	Index	**0x4006**	Sub-index	**0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Setting of braking resistor in Ω/10 Value range: 150-100000 Default: 250					

Name	**Power of Resistor**	Index	**0x4006**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Setting braking resistor power W/10 Value range: 1-100000 Default: 750					

Name	**Time Constant of Resistor**	Index	**0x4006**	Sub-index	**0x04**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Time constant for brake resistor [ms] Value range: 1-100000 Default: 1000					

Name	**Utilisation Resistor**	Index	**0x4006**	Sub-index	**0x05**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Utilization of braking resistor [‰] Value range: 1-1000 When the set value is reached, the error flag is set in the status word and the drive is switched off. Default: 1000					

Name	**Maximum On Time**	Index	**0x4006**	Sub-index	**0x06**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Maximum continuous switch-on time of braking resistor [ms] Value range: 1-100000 Default: 3000					

Name	**Blocking Time**	Index	**0x4006**	Sub-index	**0x07**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Description	Switch-off time after the maximum switch-on time of the braking resistor is reached [ms] Value range: 1-100000 Default: 1000				

Name	**Upper Voltage Limit**	Index	**0x4006**	Sub-index	**0x08**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Switch-on threshold for braking resistor [mV] Value range: 1-65000 Default: 60000					

Name	**Lower Voltage Limit**	Index	**0x4006**	Sub-index	**0x09**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Switch-off threshold for braking resistor [mV] Value range: 1-60000 Default: 55000					

Name	**Warning Threshold Utilisation**	Index	**0x4006**	Sub-index	**0x0A**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Warning threshold braking resistor [‰] Value range: 1-1000 When the value is reached, the warning flag is set in StateWord. Default: 980					

Name	**Motion Profile**	Index	**0x4007**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Setting for motion profiles. (Motion Controller 0x20 Bit 0-1) 0: None ramp 1: Trapezoid ramp (default) 2: S-shaped ramp					

Name	**Analog Values**	Index	**0x400A**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 2					

Name	**Motor Supply Voltage**	Index	**0x400A**	Sub-index	**0x01**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the motor supply voltage in [mV]					

Name	**Temperature**	Index	**0x400A**	Sub-index	**0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the temperature in [C°/10]					

Name	**Position Latch Config**	Index	**0x4008**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 2					

Name	**Latch Config Input 1/2**	Index	**0x4008**	Sub-index	**0x01-0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Specifies the behavior for the position latch trigger of input 1/2. 0: Deactivated 1: With rising edge 2: With falling edge 3: With rising and falling edge					

Name	**Latch Position**	Index	**0x400B**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 2					

Name	**Latch Position Input 1/2**	Index	**0x400B**	Sub-index	**0x01-0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Returns the position of the last latch event that occurred at input 1 or 2. The time at which the position is latched is specified via “Position Latch Config.”					

Name	**Chopper Values**	Index	**0x400C**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 9					

Name	**Utilisation Value**	Index	**0x400C**	Sub-index	**0x06**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the current load of the braking resistor [‰] Value range: 0-1000					

Name	**Chopper Enabled**	Index	**0x400C**	Sub-index	**0x09**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the current state of the braking resistor. 0: Switched off 1: Switched on					

Name	**Chop Conf Values**	Index	**0x400D**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 5. Changes values in the motor controller 0x6D					

Name	**HSTRT**	Index	**0x400D**	Sub-index	**0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Value range: 0-7 HSTRT (2:0): These three bits define the hysteresis start value, which is added to the hysteresis end value (HEND) when chm (chopper mode) = 0. Hysteresis setting: The values from %000 to %111 correspond to the addition of 1 to 8 to HEND. This set value contributes to the control of the driving current. Effective range: Make sure that the sum of HEND + HSTRT does not exceed 16 for proper operation. Default: 2					

Name	**HEND**	Index	**0x400D**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Value range: 0-15 HEND (3:0): These four bits define the lower hysteresis value (HEND). Hysteresis values: The setting ranges from -3 to 12 (0-15) and allows fine-tuning of the current control by adjusting the hysteresis window. Hysteresis functionality: This hysteresis value is used by the chopper for current control. The value influences how much the drive current fluctuates during operation. Default: 4					

Name	**VHIGHFS**	Index	**0x400D**	Sub-index	**0x04**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
vhighfs high velocity fullstep selection Value range: 0-1 This bit enables switching to full step when VHIGH is exceeded. Switching only occurs at the 45° position. The full-step nominal current uses the current value from the microstep table at the 45° position. Default: 0					

Name	**PWM_OFS**	Index	**0x400E**	Sub-index	**0x01**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
PWM_OFS User-defined amplitude (offset) Value range: 0-255 User-defined PWM amplitude offset (0-255) relative to the full motor current (CS_ACTUAL=31) at a standstill (reset default=30). Use PWM_OFS as the initial value for automatic scaling to speed up the automatic tuning process. To do this, set PWM_OFS to the determined application-specific value with pwm_autoscale=0 and only then to pwm_autoscale=1. Activate the current control mode chopper when you are finished. PWM_OFS = 0 disables scaling down of the motor current below a motor-specific lower measurement threshold. This setting should only be used under certain conditions, i.e. when the supply voltage can fluctuate by a factor of two or more. It prevents the motor from getting out of regulation, but also prevents the current from falling below the regulation limit. PWM_OFS > 0 enables automatic scaling to low PWM duty cycles even below the lower control threshold. This allows low (standstill) current settings based on the current (hold) current scale (IHOLD_IRUN). Default: 0x1E					

Name	**PWM_GRAD**	Index	**0x400E**	Sub-index	**0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
PWM_ GRAD User-defined amplitude gradient Value range: 0-255 Speed-dependent gradient for the PWM amplitude: PWM_GRAD * 256 / TSTEP This value is added to PWM_OFS to compensate for the speed-dependent motor back-EMF. Use PWM_GRAD as the initial value for automatic scaling to speed up the automatic tuning process. To do this, set PWM_GRAD to the determined application-specific value using pwm_autoscale=0 and only then set pwm_autoscale=1. Activate the current control mode chopper when you are finished. Tip: After the initial adjustment, the desired initial value can be read from PWM_GRAD_AUTO. Default: 0x0F					

Name	**PWM_ AUTOSCALE**	Index	**0x400E**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
pwm_ autoscale PWM automatic amplitude scaling Value range: 0-1 0: User-defined forward PWM amplitude. The current settings IRUN and IHOLD are not enforced by the regulation, but only scale the PWM amplitude! The resulting PWM amplitude (limited to 0-255) is: PWM_OFS * ((CS_ACTUAL+1) / 32) + PWM_GRAD * 256 / TSTEP 1: Release of the automatic current regulation (preset) Default: 1					

Name	**PWM_ AUTOGRAD**	Index	**0x400E**	Sub-index	**0x04**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
pwm_ autograd PWM automatic gradient adjustment Value range: 0-1 0: Fixed value for PWM_GRAD (PWM_GRAD_AUTO = PWM_GRAD) 1: Automatic tuning (only with pwm_autoscale=1) (reset standard) PWM_GRAD_AUTO is initialized with PWM_GRAD during pwm_autograd=0 and is automatically optimized during the movement. Prerequisites 1. PWM_OFS_AUTO was initialized automatically. This requires standstill at IRUN for > 130 ms to a) recognize the standstill b) wait for > 128 chopper cycles at IRUN and c) regulate PWM_OFS_AUTO so that -1 < PWM_SCALE_AUTO < 1 2. Motor runs and PWM_SCALE_SUM < 255 and 1.5 * PWM_OFS_AUTO * (IRUN+1)/32 < PWM_SCALE_SUM < 4* PWM_OFS_AUTO * (IRUN+1)/32. Time required for tuning PWM_GRAD_AUTO approximately 8 full steps per change of ±1. Also allows the use of a reduced chopper frequency for tuning PWM_OFS_AUTO. Default: 1					

Name	**PWM_LIM**	Index	**0x400E**	Sub-index	**0x06**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
PWM_LIM PWM automatic scale amplitude limitation when switching on. Value range: 0-15 Default: 0x0C Limit for PWM_SCALE_AUTO when switching back from voltage PWM mode chopper to current control mode chopper. This value defines the upper limit for bits 3 to 0 of the automatic current control when switching back. It can be set to reduce the current jump during mode change back to current control mode chopper. It does not limit the offset of PWM_GRAD or PWM_GRAD_AUTO. (default = 12)					

Name	**Scale Value**	Index	**0x400F**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 4 Changes the values in motion controller 0x06 for current scaling. Has a different meaning depending on the controller mode.					

Name	**OL DRV1_ SCALE_VAL / CL CL_IMAX**	Index	**0x400F**	Sub-index	**0x01**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Scaling in [‰] with use depending on the selected “Controller Mode” (Index 0x4002). Value range: 0-1000 Controller Mode Open Loop: OL DRV1_SCALE_VAL * first drive scaling value Controller mode closed loop: CL CL_IMAX * maximum scaling value					

Name	**OL HOLD_ SCALE_VAL / CL CL_IMIN**	Index	**0x400F**	Sub-index	**0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Scaling in [‰] with use depending on the selected “Controller Mode” (Index 0x4002). Value range: 0-1000 Controller Mode Open Loop: OL HOLD_SCALE_VAL * standstill scaling value Controller mode closed loop: CL CL_IMIN * minimum scaling value					

Name	**OL DRV2_ SCALE_VAL / CL_START_UP**	Index	**0x400F**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Scaling depending on the selected “Controller Mode” (Index 0x4002). Value range: 0-255 Controller Mode Open Loop: OL DRV2_SCALE_VAL * first drive scaling value Controller mode closed loop: CL_START_UP * |ENC_POS_DEV | Value at which the closed loop scaling raises the current scaling value above CL_IMIN.					

Name	**OL BOOST_ SCALE_VAL / CL_START_ DOWN**	Index	**0x400F**	Sub-index	**0x04**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Scaling depending on the selected “Controller Mode” (Index 0x4002). Value range: 0-255 Controller Mode Open Loop: OL BOOST_SCALE_VAL * increase the scaling value. Controller mode closed loop: CL_START_DOWN * |ENC_POS_DEV | Value at which the closed loop scaling lowers the current scaling value under CL_IMAX. Recommended: Set to 0 to automatically assign CL_BETA.					

Name	**Digital Inputs**	Index	**0x4009**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**2**
Shows the state of the inputs in a bit field. Bit 0: Enable input 1 Bit 1: Enable input 2 Bit 2: Latch input 1 Bit 3: Latch input 2 Bit 4-7: Reserved Bit 8: Motor supply OK Bit 9: Motor controller supply OK Bit10: Encoder supply OK Bits 11-15: Reserved					

Name	**Error Info Detail**	Index	**0x4010**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Returns detailed error information if an error is set in the error.					

Name	**Warning Register**	Index	**0x4011**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows warning bits in a bit field from 0-31. The current bits set are reset by reading the register. Bit 0: Temperature has reached the warning limit (103 °C). Bit 1: Braking resistor utilization has reached warning level. Bit 2: Motor controller chip has reached temperature warning threshold. Bit 3-31: Reserved.					

Name	**Warning Info Detail**	Index	**0x4012**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Returns a detailed warning info if a warning flag is set in the warning.					

Name	**Motion Controller Infos**	Index	**0x4018**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 4					

Name	**Motion Controller Status**	Index	**0x4018**	Sub-index	**0x01**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Specifies the status information of the motion controller in a 32-bit variable. Bit 0: TARGET_REACHED_F - XACTUAL = XTARGET (target reached). Default value = 0 Bit 1: POS_COMP_REACHED_F - XACTUAL = POS_COMP (Position comparison reached). Default value = 0 Bit 2: VEL_REACHED_F - VACTUAL = |VMAX| (speed reached). Default value = 0 Bits 3-4: VEL_STATE_F - status of current speed (VACTUAL). Default value = 0					

Bits 5-6: RAMP_STATE_F - status of the current acceleration (AACTUAL). Default value = 0

Bits 7-8: Default value = 0 -> must not be changed

Bit 9: VSTOPL_ACTIVE_F - left virtual end switch active. Default value = 0

Bit 10: VSTOPR_ACTIVE_F - right virtual end switch active. Default value = 0

Bit 11: ACTIVE_STALL_F - Motor failure (stall) detected. Default value = 0

Bit 12: Default value = 0 -> must not be changed

Bit 13: FS_ACTIVE_F - Full step mode active. Default value = 0

Bit 14: ENC_FAIL_F - Difference between XACTUAL and ENC_POS (encoder error). Default value = 0

Bit 15: N_ACTIVE_F - N-event active. Default value = 0

Bit 16: ENC_LATCH_F - ENC_LATCH was overwritten. Default value = 0

Bit 17: MULTI_CYCLE_FAIL_F - Error in the evaluation of multi-cycle data. Default value = 0

Bit 18: Reserved. Default value = 0

Bit 19: CL_FIT_F - ENC_POS_DEV < CL_TOLERANCE (Closed loop fit). Default value = 0

Bits 20-23: Default value = 0 -> must not be changed

Bit 24: SG_UV_SF - Sensorless load value status or undervoltage flag. Default value = 0

Bit 25: OT - Overtemperature cut-off. Default value = 0

Bit 26: OTPW - Overtemperature warning. Default value = 0

Bit 27: S2GA_OCA - Short circuit or overcurrent on bridge A. Default value = 0

Bit 28: S2GB_OCB - Short circuit or overcurrent on bridge B. Default value = 0

Bit 29: OLA - Openload display for coil A. Default value = 0

Bit 30: OLB - Openload display for coil B. Default value = 0

Bit 31: STST_OCHS - Standstill display or overcurrent on the high side. Default value = 0

Name	**Motor Controller Status**	Index	**0x4018**	Sub-index	**0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**

In a 32-bit variable, indicates the status information of the motor controller.

Bits 0-19: LOST_STEPS - Number of skipped steps due to load.
After 2^{20} steps, the counter restarts.

Bits 20-27: PWM_SCALE - Result of the current control mode chopper amplitude controller. Actual PWM duty cycle (0-255) used to scale CUR_A and CUR_B.

Bits 28-31: GSTAT - Global status flags that show the status of the driver and the IC.

Bit 28: RESET - IC reset flag. (1: IC has been reset, all reset to factory settings).

Bit 29: DRV_ERR - Driver shutdown due to overtemperature or short circuit. Read details in DRV_STATUS.

Bit 30: UV_CP - Charge pump undervoltage. The driver is disabled during undervoltage, this flag remains set.

Name	**Motion Controller Events**	Index	**0x4018**	Sub-index	**0x03**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**

Is only being prepared for future applications and is not yet in use.

Name	**Motion Controller SPI STATUS Flags**	Index	**0x4018**	Sub-index	**0x04**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Contains 8 bits mapped from the motion controller event. The flags except for bit 6 are reset by reading the event register (index 0x4000, sub-index 0x0F). Bit 0: target_reached - is set to 1 when the target position is reached. Bit 1: pos_comp_reached - is set to 1 when the position comparison threshold is reached. Bit 2: vel_reached - is set to 1 when the target speed is reached. Bit 3: frozen - is set to 1 when the motor or controller is in a frozen state. Bit 4: enc_fail - is set to 1 when an encoder error is detected. Bit 5: cover_done - is set to 1 when the cover command is complete. Bit 6: stop_on_stall - is set to 1 when the motor stops due to stall detection. Bit 7: motor_ev - is set to 1 when a motor event occurs.					

Name	**PDO Info**	Index	**0x4019**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 4					

Name	**RPDO Mapping Size**	Index	**0x4019**	Sub-index	**0x01**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Size of RPDO data (from ST 152 perspective) in [byte]					

Name	**TPDO Mapping Size**	Index	**0x4019**	Sub-index	**0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Size of TPDO data (from ST 152 perspective) in [byte]					

Name	**RPDO Motion Controller Para**	Index	**0x4019**	Sub-index	**0x03**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Number of parameters written to the motion controller (maximum of 5 is possible).					

Name	**TPDO Motion Controller Para**	Index	**0x4019**	Sub-index	**0x04**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Number of parameters read by the motion controller (maximum of 4 is possible).					

Name	**Closed Loop Settings**	Index	**0x401A**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 2					

Name	**EMF Enable**	Index	**0x401A**	Sub-index	**0x01**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Setting the back-EMF compensation: 0: Back-EMF compensation is deactivated during normal operation. 1: Back-EMF compensation is activated during normal operation. In this mode, the controlled operation compensates for the back-EMF when the absolute value of VACTUAL is greater than CL_VMIN.					

Name	**VLIMIT Enable**	Index	**0x401A**	Sub-index	**0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Setting the speed limit for catching up. 0: No catch-up speed limit is applied during regulation. 1: The internal PI regulator limits the speed of catch-up during normal operation.					

Name	**Motor Current**	Index	**0x401B**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 3					

Name	**Global Scaler**	Index	**0x401B**	Sub-index	**0x01**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Value for global scaler (0-255) can only be read. Is calculated from “Max Motor Current” index 0x6073 when changing from PreOp to OP.					

Name	**IRUN**	Index	**0x401B**	Sub-index	**0x02**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Value for IRUN (0-31) Is calculated from “Max Motor Current” index 0x6073 when changing from PreOp to OP.					

Name	**IHOLD**	Index	**0x401B**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Value for IHOLD Writing: in PreOp 0-30: Value must be smaller than IRUN Taken over in OP if the value is smaller than IRUN when changing from PreOp. Writing: in OP 0-30: Value has been excepted 255: Value was invalid (> IRUN)					

Name	**Status Word**	Index	**0x6041**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**2**
Shows the DS402 status word in a 16-bit bit field. Bit 0: ready_to_switch_on. Bit 1: switched_on. Bit 2: operation_enabled. Bit 3: fault. Bit 4: voltage_enabled. Bit 5: quick_stop. Bit 6: switch_on_disabled. Bit 7: warning. Bit 8: stoOK - Safety flag for the status of the safety input. Bit 9: remote - remote control active. Bit 10: target_reached. Bit 11: internal_limit_active. Bit 12: opSpecific1 - operating mode specific: Target mode = set point acknowledge flag. Bit 13: opSpecific2 - operating mode specific Bit 14: latchInput1 - latch input 1. Bit 15: latchInput2 - latch input 2.					

Name	**Modes of Operation Display**	Index	**0x6061**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the current mode of operation. -1: Target Mode -8: Position Mode -9: Speed Mode					

Name	**Actual Position**	Index	**0x6064**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the current position depending on the selected “Controller Mode” (Index 0x4002). Controller Mode Open Loop: internal counter in [µSteps] Controller Mode Closed Loop: Encoder in [µSteps]					

Name	**Actual Speed**	Index	**0x606C**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**4**
Shows the current speed depending on the selected “Controller Mode” (Index 0x4002). Controller Mode Open Loop: internal counter in [µSteps/s] Controller Mode Closed Loop: Encoder in [µSteps/s]					

Name	**Control Word**	Index	**0x6040**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Shows the DS402 control word in a 16-bit bit field. Bit 0: switch_on - Turn on. Bit 1: enable_voltage - Enable voltage. Bit 2: quick_stop - Quick stop. Bit 3: enable_operation - Enable operation. Bit 4: opSpecific1 - Operating mode specific: Target mode = New setpoint specification. Bit 5: opSpecific2 - Operating mode specific. Bit 6: opSpecific3 - Operating mode specific. Bit 7: fault_reset - Reset error. Bit 8: halt - Halt (is not implemented). Bits 9-15: reserved2. - Reserved.					

Name	**Max Motor Current**	Index	**0x6073**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Specifies the maximum output current for the motor in [mA]. Minimum value = 1 mA Maximum value: = 5000 mA					

Name	**Modes of Operation**	Index	**0x6060**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Sets the current mode of operation. -1: Target Mode -8: Position Mode -9: Speed Mode					

Name	**Target Position**	Index	**0x607A**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Specifies the target position in [µSteps].					

Name	**Target Speed**	Index	**0x60FF**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Specifies the target speed in [µsteps/s].					

Name	**Motor Max Speed**	Index	**0x6080**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Specifies the maximum speed in [µSteps] for the motor. Is only active when modes of operation is "-1 .. Target Mode".					

Name	**Motor Max Acceleration**	Index	**0x60C5**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Specifies the maximum acceleration in [µSteps*s²].					

Name	**Motor Max Deceleration**	Index	**0x60C6**	Sub-index	**0x00**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Defines the maximum negative acceleration (deceleration) in [µSteps*s²].					

Name	**Motor Profile Acceleration**	Index	**0x6083**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Specifies the maximum acceleration in [µSteps*s²]. Is intended for cyclic modification as a PDO in the operational state.					

Name	**Motor Profile Deceleration**	Index	**0x6084**	Sub-index	**0x00**
Device State	**OP**	RW	**RW**	Size [bytes]	**4**
Defines the maximum negative acceleration (deceleration) in [µSteps*s²]. Is intended for cyclic modification as a PDO in the operational state.					

Name	**Motor Data**	Index	**0x6410**	Sub-index	**0x00**
Device State	**OP**	RW	**RO**	Size [bytes]	**1**
Number of sub-indices = 4					

Name	**Full Steps One Turn**	Index	**0x6410**	Sub-index	**0x01**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Number of full steps of the motor for one revolution. Value range: 1-100000 Default: 200					

Name	**Encoder Resolution**	Index	**0x6410**	Sub-index	**0x02**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Resolution of the encoder for one revolution. Value range: 0-4,294,967,295 Default: 0					

Name	**Encoder Direction**	Index	**0x6410**	Sub-index	**0x03**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Specifies the direction of rotation for the encoder. Value range: 0-1 Default: 0					

Name	**Encoder Signal Mode**	Index	**0x6410**	Sub-index	**0x04**
Device State	**PreOP**	RW	**RW**	Size [bytes]	**4**
Specifies the encoder mode. Value range: 0-1 0: TTL mode 1: RS422 mode Default: 0					

12.9 Asynchronous Parameters - Error Codes

Error code	Description	SDO Abort Code
0x00000000	No error occurred or error was reset	SDO_ERROR_RESET_NO_ERROR
0x05040000	Internal timeout when creating the response to an SDO	SDO_ABORT_SDOTIMEOUT
0x06010000	Unsupported access to object	SDO_ABORT_UNSUPPORTED
0x06010001	Object cannot be read	SDO_ABORT_WRITEONLY
0x06010002	Object cannot be written	SDO_ABORT_READONLY
0x06010003	Attempt to write SDO in the wrong DeviceState	SDO_ABORT_NMT_STATE
0x06010004	Error in RPDO mapping	SDO_ABORT_RPDO_MAPPING
0x06010005	Error in TPDO mapping	SDO_ABORT_TPDO_MAPPING
0x06010010	Read error for motion controller	SDO_ABORT_RD_TMC4361
0x06010011	Write error for motion controller	SDO_ABORT_WR_TMC4361
0x06010012	Data for motion controller does not match when writing	SDO_ABORT_WR_TMC4361_DM
0x06010020	Read error for motor controller	SDO_ABORT_RD_TMC2160
0x06010021	Write error for motor controller	SDO_ABORT_WR_TMC2160
0x06010022	Data for motor controller does not match when writing	SDO_ABORT_WR_TMC2160_DM
0x06020000	Object does not exist in the object directory.	SDO_ABORT_NOT_EXISTS
0x06090011	Sub-index does not exist	SDO_ABORT_UNKNOWNSUB
0x06090031	Value of parameter violates upper limit	SDO_ABORT_VALUE_HIGH
0x06090032	Value of parameter violates lower limit	SDO_ABORT_VALUE_LOW
0x08000000	General error	SDO_ABORT_GENERIC_ERROR

13 Assembly/Installation

13.1 Check Contents of Delivery

Ensure that the contents of the delivery are complete and intact. See chapter 1.3 Contents of Delivery.

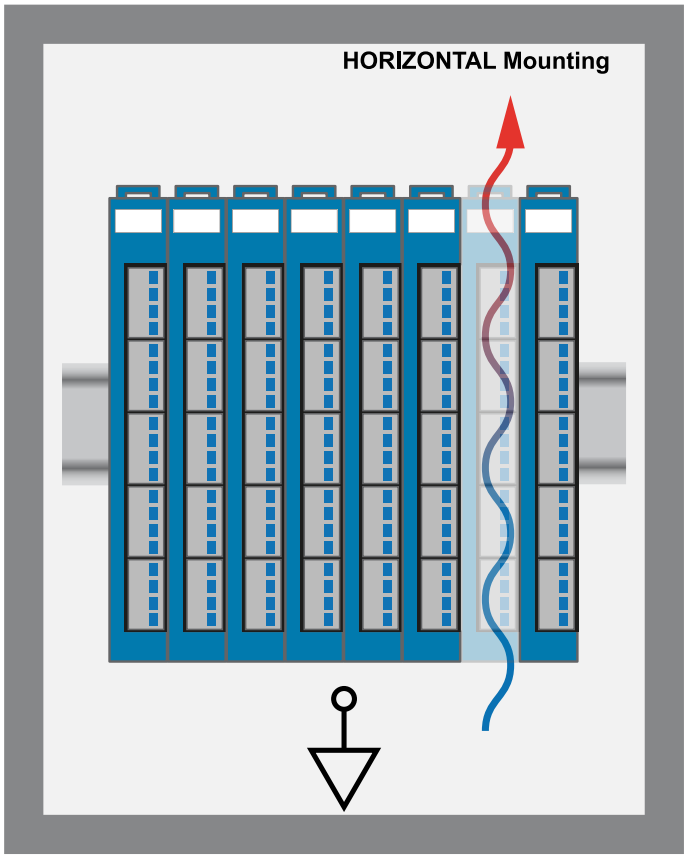
INFORMATION

On receipt and before initial use, check the device for damage. If the device is damaged, contact our customer service and do not install the device in your system.

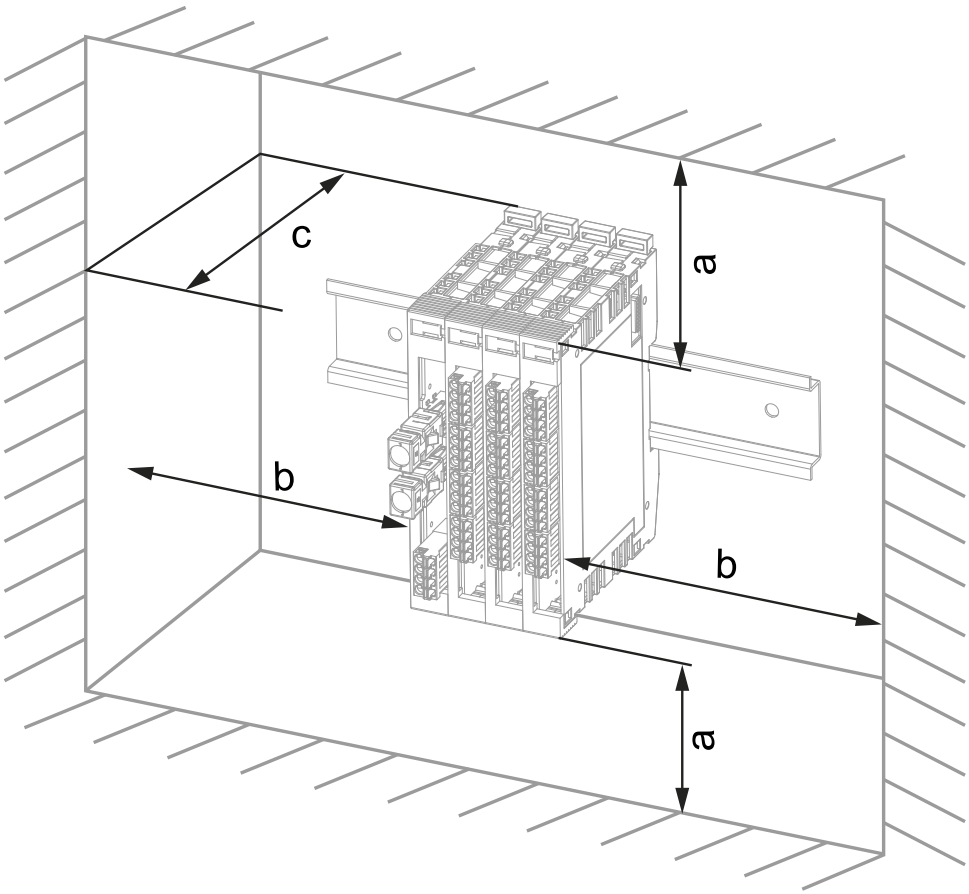
Damaged components can disrupt or damage the system.

13.2 Mounting

The S-DIAS modules are designed for installation into the control cabinet. To mount the modules, a DIN-rail is required. The DIN rail must establish a conductive connection with the back wall of the control cabinet. The individual S-DIAS modules are mounted on the DIN rail as a block and secured with latches. The functional ground connection from the module to the DIN rai is made via the grounding lug on the back of the S-DIAS modules. The modules must be mounted horizontally (module label up) with sufficient clearance between the ventilation slots of the S-DIAS module blocks and nearby components and/or the control cabinet wall. This is necessary for optimal cooling and air circulation to ensure proper function up to the maximum operating temperature.



Recommended minimum distances between the S-DIAS modules and the surrounding components or control cabinet wall:



a	b	c
30 mm (1.18″)	**30 mm** (1.18″)	**100 mm** (3.94″)

a, b, c … distances in mm (inches)

14 Transport/Storage

This device contains sensitive electronics. During transport and storage, high mechanical stress must therefore be avoided.

For storage and transport, the same values for humidity and vibration as for operation must be maintained!

Temperature and humidity fluctuations may occur during transport. Ensure that no moisture condenses in or on the device, by allowing the device to acclimate to the room temperature while turned off.

When sent, the device should be transported in the original packaging if possible. Otherwise, packaging should be selected that sufficiently protects the product from external mechanical influences. Such as cardboard filled with air cushioning.

15 Storage

When not in use, store the device according to the storage conditions. See chapter 14 Transport/Storage.

INFORMATION

During storage, ensure that all protective covers (if available) are placed correctly, so that no contamination, foreign bodies or fluids enter the device.

16 Maintenance

During maintenance as well as servicing, observe the safety instructions from chapter 2 Basic Safety Directives.

16.1 Service

This product was constructed for low-maintenance operation.

16.2 Repair

In the event of a defect/repair, send the device with a detailed error description to the address listed at the beginning of this document.
For transport conditions, see chapter 14 Transport/Storage.

17 Disposal

INFORMATION

Should you need to dispose of the device, the national regulations for disposal must be followed.

The device appliance must not be disposed of as household waste.

Changes Chart

Change date	Affected page(s)	Chapter	Note
24.10.2024	17	6.4 Latch/Digital Inputs Specifications	Signal level values changed
	11	3 IT Security	Chapter added
25.10.2024	40	12 Description of Functions	Separated in different chapters
	40	12.1 Current Regulator Modes	Chapter added
	55	12.4 Closed Loop Regulator	
	60	12.5 Supported Step Operation Modes	
	61	12.6 Incremental encoder	
	65	12.8 Detailed Object Directory	
28.10.2024	15	6.1 Stepper Motor Output Specification	Resolution of stepper motor added
	60	12.5 Supported Step Operation Modes	
04.11.2024	62	12.7 Object Directory Overview	Chapter added
	27	9.2 Note	Info regarding cable length updated
06.11.2024	14	5 Type Plate	new type plate added
21.11.2024		Document	Formal additions and summaries
17.12.2024		Document	EN IEC 61508 added
20.12.2024	27	9.2 Note	ESD note added
19.03.2025		Document	Layout
01.04.2025	21	6.7 Miscellaneous	yes, EG-type-examined
18.02.2026	62	12.7 Object Directory Overview	Object directory expanded
	65	12.8 Detailed Object Directory	
15.05.2026	28	10 Additional Safety Information	Info cable changed
11.08.2026	13	4.4 Safety-Relevant Parameters	Safety parameters: Decimal places removed
23.10.2026	28	10 Additional Safety Information	Chapter Function Test deleted