BECKHOFF Drive Technology

Operating instructions

Servo Drives AX5000

Version: 2.4

Date: 2009-11-03

BECKHOFF Automation: AX5000 - Digital servo drives

Table of contents

BECKHOFF Automation: Foreword

Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards. It is essential that the following notes and explanations are followed when installing and commissioning these components.

Liability Conditions

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

The documentation has been prepared with care. The products described are, however, constantly under development. For that reason the documentation is not in every case checked for consistency with performance data, standards or other characteristics. None of the statements of this manual represents a guarantee (Garantie) in the meaning of § 443 BGB of the German Civil Code or a statement about the contractually expected fitness for a particular purpose in the meaning of § 434 par. 1 sentence 1 BGB. In the event that it contains technical or editorial errors, we retain the right to make alterations at any time and without warning. No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

Copyright

BECKHOFF Automation: Foreword

Safety Instructions

Safety Rules

Consider the following safety instructions and descriptions!
Product specific safety instructions are to be found on the following pages or in the areas mounting, wiring, commissioning etc.

Disclaimer

All the components are supplied in particular hardware and software configurations appropriate for the application. Modifications to hardware or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH.

Personnel Qualification

This description is only intended for the use of trained specialists in control, automation and drive engineering who are familiar with the applicable national standards.

Description of symbols

The following symbols with a adjoining safety advise or notice are used in this documentation. You have to read the safety advices carefully and adhere them strictly!

DANGER

Acute risk of injury!

If you **do not** adhere the safety advise adjoining this symbol, there is immediate danger to life and health of individuals!

WARNING

Risk of injury!

If you **do not** adhere the safety advise adjoining this symbol, there is danger to life and health of individuals!

CAUTION

Hazard to individuals!

If you **do not** adhere the safety advise adjoining this symbol, there is obvious hazard to individuals!

Attention

Hazard to environment and devices

If you **do not** adhere the notice adjoining this symbol, there is obvious hazard to environment and devices.

Note

Note or pointer

This symbol indicates information that contributes to better understanding.

UL Pointer

This symbol indicates important information about the UL-compliant.

BECKHOFF Automation: Foreword

Special safety instructions for AX5000

The safety instructions are designed to avert danger and must be followed during installation, commissioning, production, troubleshooting, maintenance and trial or test assemblies.

The servo drives of the AX5000 series are not designed for stand-alone operation and must always be installed in a machine or system. After installation the additional documentation and safety instructions provided by the machine manufacturer must be read and followed.

WARNING

Serious risk of injury through high electrical voltage!

- Never open the servo drive when it is live. Wait until the DC link capacitors are discharged. The voltage measured between the DC+ and DC- terminals (X02) must have fallen below 50 V. Opening the device (with the exception of expansion card slots) invalidates all warranty and liability claims against Beckhoff Automation GmbH.
- Negligent, improper handling of the servo drive and bypassing of the safety devices can lead to personal injury or death through electric shock.
- Ensure that the protective conductor is connected properly.
- Disconnect the servo drive from the mains supply and secure it against reconnection before connecting or disconnecting the pluggable terminals.
- Disconnect the servo drive from the mains supply and secure it against reconnection before working on electrical parts with a voltage > 50 V.
- The DC link voltage can exceed 890 V. Wait until the DC link capacitors are discharged before touching live terminals. The voltage measured between the DC+ and DC- terminals (X02) must have fallen below 50 V.

WARNING

Serious risk of injury through hot surfaces!

- The surface temperature may exceed 50 °C, resulting in a risk of burns.
- Avoid touching the case during or shortly after operation.
- Leave the servo drive to cool down for at least 15 minutes after it is switched off.
- Use a thermometer to check whether the surface has cooled down sufficiently.

CAUTION

Danger for persons, the environment or equipment!

- Carefully read this manual before using the servo drive thoroughly, paying particular attention to the safety instructions. In the event of any uncertainties please notify your sales office immediately and refrain from working on the servo drive.
- Only well trained, qualified electricians with sound knowledge of drive equipment may work on the device.
- During installation it is essential to ensure that the specified ventilation clearances and climatic conditions are adhered to. Further information can be found in the "Technical data" and "Mechanical installation" sections.
- If the servo drive is operated in contaminated ambient air, the cooling openings must be checked regularly for blockage. These checks should be carried out several times per day.
- During the electrical installation it is essential to ensure that the correct fuses/protective circuit breakers are used between the mains supply and the servo drive. Further information can be found in the "Electrical installation" section.
- The servo drives contain components at risk from electrostatic discharge caused by improper handling:
  - Please ensure you are electrostatically discharged before touching the servo drive directly.
  - Avoid contact with highly insulating materials (synthetic fibres, plastic film etc.).
  - Place the servo drive on a conductive surface.
- If a servo drive is installed in a machine it must not be commissioned until proof of compliance of the machine with the latest version of the EC Machinery Directive has been provided. This includes all relevant harmonised standards and regulations required for implementation of this Directive in national legislation.

BECKHOFF AX5000: Foreword

Appropriate use

The servo drives of the AX5000 series are exclusively designed for torque, speed and position control of suitable asynchronous and synchronous three-phase current motors. The maximum permissible effective motor voltage must be at least equal the effective mains voltage fed into the servo drive.

The servo drives from the AX5000 series are designed for installation as components in electrical systems or machines and may be operated only as integrated system or machine components.

WARNING

Caution – Risk of injury!

Electronic equipment is not fail-safe. The machine manufacturer is responsible for ensuring that the connected motors and the machine are brought into a safe state in the event of a fault in the drive system.

The servo drives may only be operated in enclosed control cabinets and in accordance with the conditions described in the "Technical data" section.

BECKHOFF AX5000: Foreword

Guidelines and Standards

CE conformity

The servo drives of the AX5000 series comply with the

- • EC Low-Voltage Directive, 2006/95/EC

Applied harmonised standards:

EN 60204-1

EN 50178

CAUTION

Danger for persons, the environment or equipment!

Servo drives are not covered by the EC Machinery Directive. Operation of the servo drives in machines or systems is only permitted once the machine or system manufacturers has provided evidence of CE conformity of the complete machine or system.

Electromagnetic compatibility

The servo drives of the AX5000 series comply with the

- 2004/108/EC EMC Directive

Applied harmonised standards:

IEC / EN 61000-4-2

IEC / EN 61000-4-3

IEC / EN 61000-4-4

IEC / EN 61000-4-5

IEC / EN 61000-4-6

IEC / EN 61000-6-1

IEC / EN 61000-6-2

IEC / EN 61000-6-3

IEC / EN 61000-6-4

IEC / EN 61800-3

UL Listing

The following servo drives from the AX5000 series have a UL-Listing and must bear the UL symbol

LISTED
Ind. Cond. E.q.
41GE

AX5000 with UL-Listing!

AX5101, AX5103; AX5106, AX5112, AX5201, AX5203 and AX5206

on the name plate. If you wish to operate an AX5000 in an economic area that requires a UL-Listing, please check that there is a UL symbol on the name plate.

Below is a list of the relevant chapters that are amended with respect to the UL-Listing. Furthermore, UL-specific remarks are listed. It is essential to observe these specifications.

UL-specific chapter changes

“Mains supply connection (X01)”

AX5000 shall be connected only to a **grounded wye-source** where the maximum voltage does not exceed 277 V to ground.

“Connection of several servo drives to form a drive system”

Drive system with UL-Listing!

Please consult our Application Department with respect to the requirements for a drive system with UL-Listing.

UL-specific chapter

“External protection, UL-compliant”

Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the Manufacture Instructions, National Electrical Code and any additional local codes.

Suitable for use on a circuit capable of delivering not more than 18000 rms symmetrical amperes, 480 V maximum, when protected by RK5 class fuses.

Single-phase:

	AX5101	AX5103	AX5106	AX5201	AX5203	AX5206

AC-supply (max.) *)	6 A	12 A	20 A	12 A	20 A	20 A
24 V-supply (max.)	3 A					
Brake resistor	electronic					

*) Mains fuses according to type “RK5” must be used.

Three-phase:

	AX5101	AX5103	AX5106	AX5112	AX5201	AX5203	AX5206
AC-supply (max.) *)	6 A	12 A	20 A	20 A	12 A	20 A	20 A
24 V-supply (max.)	3 A						
Brake resistor	electronic						

*) Mains fuses according to type “RK5” must be used.

AX5112

When protected by RK5 class fuses: Rated 20 A, min. 480 V

UL-specific notes

Use in a Pollution Degree 2 environment.

Use 75 °C Copper Conductors min..

Control Board rating = 24 V

Drive intended for use over a range of motor sizes. Internal motor overload protection level is adjustable:

The internal motor protection is parameterised via the IDN P-0-0062 “Thermal motor model”, based on the value of the IDN S-0-0111 “Motor continuous stall current”. The IDN P-0-0062 “Time constant” is specified by the motor manufacturer and must be entered here. The IDN P-0-0062 “Warning limit” (Default) is responsible for deciding when a warning is to be generated. The IDN P-0-0062 “Error limit” (Default) is responsible for deciding when the motor is to be switched off. The default values take into account the specific characteristics of the servomotors.

Electrical isolation according to EN 50178 / VDE 0160

The power section (motor connection, DC link connection and mains connection) and the control unit are **doubly** insulated against each other, so that safe protection against accidental contact is ensured at all terminals of the control unit without additional measures. The air and creepage distances also meet the requirements of the above standard.

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BECKHOFF AX5000: Foreword

Documentation issue status

Version	Comment
2.4	**Update:** • Installation --> Electrical installation --> Motor • Installation --> Electrical installation --> Feedback • Product overview --> Type code and Name plates • Accessories --> Cables • Accessories --> Motor cables • Accessories --> Feedback cables for Beckhoff motors • Accessories --> Brake modul AX5021 **New:** • Accessories --> Optional encoder card AX5701 / AX5702 • Accessories --> External Brake Resistor AX2090-BW5x

2.3	Internal version
2.2	Internal version
2.1	**New:** • Commissioning --> Commutation method
2.0	General revision and restructuring; new safety-symbols integrated and chapter about UL-Listing integrated
1.29	**Update:** • Installation --> Electrical installation --> Power supply **New:** • Appendix --> Fault management
1.28	**Update:** • Product overview --> Technical data • Installation --> Electrical installation --> motor • Accessories --> AX-Bridge quick connection system • Accessories --> Feedback cables for Beckhoff motors
1.27	**Update:** • Product overview --> Technical data • Installation --> Electrical installation --> Power supply • Installation --> Electrical installation --> Digital I/Os • Accessories --> AX-Bridge quick connection system **General routine corrections**
1.26	**Update:** • Foreword --> Appropriate use • Foreword --> Guidelines and Standards • Product overview --> Technical data • Product overview --> Multi-feedback interface • Product overview --> Dimensions • Installation --> Mechanical installation --> Mounting • Installation --> Electrical installation --> Power supply • Installation --> Electrical installation --> Digital I/Os • Installation --> Electrical installation --> Feedback • Installation --> Electrical installation --> Motor • Commissioning --> Dive functions • Accessories --> AX-Bridge quick connection system **General routine corrections**
1.25	**Update:** • Installation --> Electrical installation --> Feedback (high-resolution) • Installation --> Mechanical installation --> Mounting
1.24	Internal version
1.23	**Update:** • Product overview --> Technical Data • Installation --> Electrical installation --> Power supply • Electrical installation --> I/O plug connector • Electrical installation --> Feedback (Resolver) **New:** • Foreword --> Guidelines and standards-->Electrical isolation according to EN 50178 / VDE 0160 • Integrated Safety --> Safety-Card AX5801 • Accessories --> Special connection of motors **General routine corrections**
1.22	Not published
1.21	Not published
1.20	First published

Scope of the documentation

The overall documentation package for the AX5000 is comprised of the following manuals:

- User documentation
- Description of drive parameters (IDN)

- Description of diagnostic messages

BECKHOFF AX5000: Product overview

General

Introduction

The AX5000 series is available in single- or multi-channel design and is optimised in terms of function and cost-effectiveness. Integrated control technology supports fast and highly dynamic positioning tasks. EtherCAT as a high-performance system communication enables ideal interfacing with PC-based control technology.

The AX51xx single-channel servo drives are designed for rated motor currents up to 25 A.
The AX52xx two-channel servo drive enables operation of two motors with identical or even with different capacity, up to a total current of 12 A. The multi-axis drives with variable motor output allocation optimise packaging density and the cost per drive channel.

The AX5000 system enables simple and fast connection of several AX5000 devices to form a multi-axis system through the AX-Bridge quick connection system. The pluggable supply and connection module combines power supply, DC link, and control (24 V_{DC}) and braking voltage.

A wide range of motor types can be connected to the AX5000. Motors of different size and type can be connected without additional measures. Examples include synchronous, linear, torque and asynchronous motors. The multi-feedback interface supports all common feedback standards such as BiSS, EnDat, 1 Vss, TTL, resolver.

The AX5000 was developed specifically for the EtherCAT real-time Ethernet system. The outstanding features of EtherCAT are particularly beneficial for drive technology. They include short cycle time, synchronicity and simultaneity. EtherCAT enables very short cycle times, even in networks containing a large number of devices.

Properties

- high-speed EtherCAT system communication
- wide voltage range: 1 x $100_{-10\%}$ V_{AC} - 1 x $240_{+10\%}$ V_{AC} … 3 x $100_{-10\%}$ V_{AC} - 3 x $480_{+10\%}$ V_{AC}
- active DC link and brake energy management (in preparation)
- multi-feedback interface
- flexible motor type selection
- scalable wide range motor current measurement
- high-speed capture inputs
- diagnostic and parameter display
- integrated mains filter
- optional safety functions: restart lock, intelligent TwinSAFE safety functions (in preparation)
- compact design for simple control cabinet installation
- AX-Bridge - the quick connection system for power supply, DC link and control voltage
- variable cooling concept (in preparation)

The integrated, fast AX5000 control technology with a current control cycle of up to 31.25 µs supports fast and highly dynamic positioning tasks. The drives are designed as single- or two-channel servo drives:

- **AX51xx: single-channel servo drive**
  rated motor current: 1 A, 3 A, 6 A, 12 A, 18 A, 25 A
- **AX52xx: two-channel servo drive**
  rated motor current: 2 x 1 A, 2 x 3 A, 2 x 6 A (with flexible allocation of total device current on both axes)

The two-channel servo drives with variable motor output allocation enable operation of two motors with identical or different capacity with the same servo drive. For example, an asynchronous motor with a rated current of 1 A and a linear motor with a rated current of 9 A can be operated with a servo drive with two 6 A channels. The total current is relevant for the device utilisation.

The AX-Bridge enables convenient and fast connection of several servo drives from the AX5000 range to form a drive system. This pluggable supply and connection module combines power supply, DC link and control (24 V_{DC}) and enables fast installation and commissioning.

The AX5000 offers flexible and universal connection options. It supports

- almost all feedback systems, including robust resolvers, sine/cosine encoders with EnDat, Hiperface or BiSS, and
- a wide range of motor types such as asynchronous, synchronous, torque or linear motors.

Wide voltage range

In order to facilitate worldwide application with different voltage systems, the AX5000 features a wide voltage range. Between 1 x 100 V_{AC} and 3 x 480 V_{AC} almost any voltage system can be connected to one and the same device. This reduces stock-keeping and prevents destruction through unsuitable mains voltage. Examples for different mains systems:

- 1 x 100 V_{AC}, 3 x 200 V_{AC} for Asia
- 1 x 115 V_{AC}, 3 x 230 V_{AC}, 3 x 480 V_{AC} for North America
- 1 x 220 V_{AC}, 3 x 380 V_{AC} for China
- 1 x 230 V_{AC}, 3 x 400 V_{AC} for Europe

Variable motor interface

The AX5000 supports the connection of different motor types, ranging from standard asynchronous motors to ironless linear motors:

Motor type	Operating mode and limits
Brushless synchronous motors	• Servo mode with feedback
Torque motors	• Multiple servomotors with high torque and relatively low speed
Linear motors (iron core)	• Servo mode with feedback
Linear motors (ironless)	• Servo mode with feedback
Asynchronous motor	• Frequency converter mode without feedback • High-frequency spindle up to 60,000 rpm • Servo mode with feedback

Multi-feedback interface

AX5000 offers interfaces for all common feedback systems. No additional interface cards are required.
Connection options:

- Sine / cosine 1 V_{pp}
- EnDAT, single- and multi-turn
- Hiperface, single- and multi-turn
- BiSS, single- and multi-turn
- Resolver, 2-pole - 8-pole
- TTL encoder
- Support for electronic motor name plates

BECKHOFF AX5000: Product overview

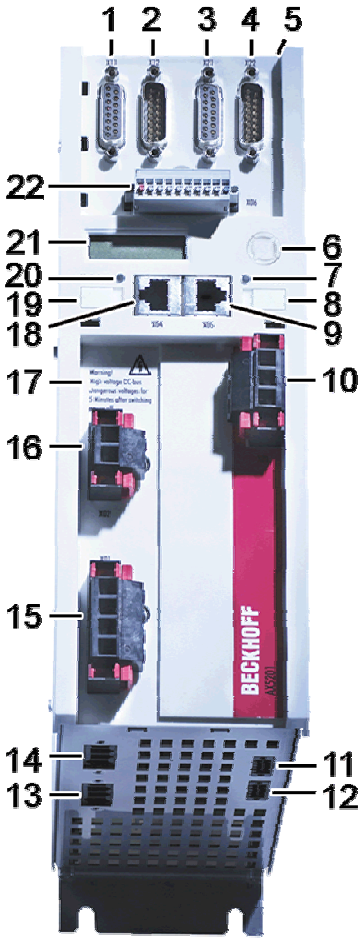
General overview

The servo drive shown below is a two-channel device designed for a maximum current of 12 A. Components that are only available for the second channel are identified in the item description. The 18 A and 25 A units are twice as wide, although the connection diagram is identical.

Item descriptions:

No.	Designation
1	X11 - feedback connection, encoder
2	X12 - feedback connection, resolver
3	X21 - feedback connection, encoder channel B (only for two-channel unit)
4	X22 - feedback connection, resolver channel B (only for two-channel unit)
5	X3x - optional slot for safety card X4x - optional slot for expansion cards
6	Navigation rocker
7	Status LED for EtherCAT output
8	Labelling field
9	X05 - socket for EtherCAT output
10	X03 - power supply 24 V DC input
11	X14 - sensor for motor temperature and brake
12	X24 - sensor for motor temperature and brake

	channel B (only for two-channel unit)
13	X23 - motor connection (U, V, W, PE) channel B (only for two-channel unit)
14	X13 - motor connection (U, V, W, PE)
15	X01 - mains supply 100 – 480 V
16	X02 - DC link output (890 V DC voltage) Connection for the external brake resistor
17	WARNING: 890 V DC voltage at the DC link terminals. Dangerous voltage may be present for at least 3 minutes after the device is switched off.
18	X04 - socket for EtherCAT input
19	Labelling field
20	Status LED for EtherCAT input
21	Display
22	X06 - connection for digital inputs and outputs



BECKHOFF AX5000: Product overview

Technical data

UL Listing

It is essential to observe chapter "Product overview-->Guidelines and Standards-->UL-Listing" if you wish to operate an AX5000 in an economic area that requires a UL-Listing.

Permitted environmental conditions and operating conditions

Technical data	AX5000
Ambient temperature during operation	0 °C to +50 °C
Ambient temperature for transportation / storage	-25 °C to +70 °C
Air humidity	5 % to 95 %, non-condensing
Contamination level	Contamination level 2 according to EN 60204 / EN 50178
Corrosion protection	Under extreme operating conditions, special measures must be agreed with the manufacturer, and implemented by the user.
Operating altitude	up to 1000 m above sea level
Permissible installation position	vertical
Ventilation	Total rated device current ≤3 A: free convection, Total rated device current >3 A: built-in temperature-controlled fan
Protection class	IP20
Vibration test (EN 60068-2-6)	Frequency range: 10 - 500 Hz Amplitude: 10 - 58 Hz = 0,075mm pk-pk 59 - 500 Hz = 1 g
Shock test (EN 60068-2-27)	Half sine wave Amplitude : 5 g Duration: 30 ms Number of shocks: 3 per axis and direction (total. 18 shocks)
Shock test (EN 60068-2-29)	Half sine wave Amplitude : 5 g Duration: 30ms Number of shocks: 1000 per axis and direction (total. 6000 shocks)
EMC / radio interference*	Category C3: standard Category C1, C2: auxiliary filter required
Approvals	CE

Special operating conditions	The usability of Beckhoff servo drives from the AX5000 type series under harsh operating conditions or other unfavourable conditions must be ascertained individually in consultation between the manufacturer and the user.

Electrical data - Single-channel servo drive (AX51xx)

Single-phase connection

Technical data	AX5101	AX5103	AX5106
Rated output current	1.5 A	3 A	4,5 A
Minimum rated motor current at full current resolution	0.35 A	1 A	1 A
Peak output current (1)	4.5 A	7.5 A	13 A
Rated supply voltage	1 x $100_{-10\%}$ - $240_{+10\%}$ V_{AC}		
max. DC link voltage	890 V_{DC}		
Rated apparent power (choices) 120 V 230 V	 0.3 kVA 0.6 kVA	 0.6 kVA 1.2 kVA	 1.2 kVA 2.4 kVA
Power loss (2)	35 W	50 W	85 W
Continuous braking power (internal brake resistor)	50 W	50 W	150 W
Max. braking power (internal brake resistor)	14 kW		
Min. brake resistor (**external** brake resistor)	47 Ω		
Max. braking power (**external** brake resistor)	15 kW		

(1) I_{rms} for max. 7 s

(2) S1 mode incl. power supply, without braking chopper

Electrical data - Single-channel servo drive (AX51xx)

Three-phase connection

Technical data	AX5101	AX5103	AX5106	AX5112	AX5118	AX5125
Rated output current	1.5 A	3 A	6 A	12 A	18 A	25 A
Minimum rated motor current at full current resolution	0.35 A	1 A	1 A	6 A	12 A	12 A
Peak output current (1)	4.5 A	7.5 A	13 A	26 A	36 A	50 A
Rated supply voltage	3 x $100_{-10\%}$ - $480_{+10\%}$ V_{AC}					
max. DC link voltage	890 V_{DC}					
Rated apparent power (choices) 120 V 230 V 400 V 480 V	 0.3 kVA 0.6 kVA 1.0 kVA 1.2 kVA	 0.6 kVA 1.2 kVA 2.1 kVA 2.5 kVA	 1.2 kVA 2.4 kVA 4.2 kVA 5.0 kVA	 2.5 kVA 4.8 kVA 8.3 kVA 10,0 kVA	 3,4 kVA 7,2 kVA 12,5 kVA 15 kVA	 4,8 kVA 10 kVA 17,3 kVA 20,8 kVA
Power loss (2)	35 W	50 W	85 W	160 W	255 W	340 W
Continuous braking power (internal brake resistor)	50 W	50 W	150 W	90 W	200 W	200 W
Max. braking power (internal brake resistor)	14 kW				26 kW	26 kW
Min. brake resistor (**external** brake resistor)	47 Ω	47 Ω	47 Ω	30 Ω	22 Ω	22 Ω
Max. braking power (**external** brake resistor)	15 kW	15 kW	15 kW	23,5 kW	32 kW	32 kW

(1) I_{rms} for max. 7 s

(2) S1 mode incl. power supply, without braking chopper

Electrical data - Two-channel servo drive (AX52xx)

Single-phase connection

Technical data	AX5201	AX5203	AX5206
Rated output current / channel	1.5 A	3 A	6 A
Minimum rated channel current at full current resolution	0.35 A	1 A	1 A
Maximum rated channel current at full current resolution	3 A	4.5 A	9 A
Total rated output current at full current resolution	3 A	4.5 A	9 A
Maximum Peak output current (1) / channel	5 A	10 A	13 A
Peak output current (1) total device current	10 A	20 A	26 A
Rated supply voltage	1 x $100_{-10\%}$ - $240_{+10\%}$ V_{AC}		

max. DC link voltage	890 V_{DC}		
Rated apparent power (choices) 120 V 230 V	 0.6 kVA 1.2 kVA	 1.2 kVA 2.4 kVA	 2.5 kVA 4.8 kVA
Power loss (2)	55 W	85 W	160 W
Continuous braking power (internal brake resistor)	50 W	150 W	90 W
Max. braking power (internal brake resistor)	14 kW		
Min. brake resistor (**external** brake resistor)	47 Ω		
Max. braking power (**external** brake resistor)	15 kW		

(1) I_{rms} for max. 7 s

(2) S1 mode incl. power supply, without braking chopper

Electrical data - Two-channel servo drive (AX52xx)

Three-phase connection

Technical data	AX5201	AX5203	AX5206
Rated output current / channel	1.5 A	3 A	6 A
Minimum rated channel current at full current resolution	0.35 A	1 A	1 A
Maximum rated channel current at full current resolution	3 A	6 A	9 A
Total rated output current at full current resolution	3 A	6 A	12 A
Maximum Peak output current (1) / channel	5 A	10 A	13 A
Peak output current (1) total device current	10 A	20 A	26 A
Rated supply voltage	3 x $100_{-10\%}$ - $480_{+10\%}$ V_{AC}		
max. DC link voltage	890 V_{DC}		
Rated apparent power (choices) 120 V 230 V 400 V 480 V	 0,6 kVA 1,2 kVA 2,1 kVA 2,5 kVA	 1,2 kVA 2,4 kVA 4,2 kVA 5,0 kVA	 2,5 kVA 4,8 kVA 8,3 kVA 10,0 kVA
Power loss (2)	55 W	85 W	160 W
Continuous braking power (internal brake resistor)	50 W	150 W	90 W
Max. braking power (internal brake resistor)	14 kW		
Min. brake resistor (**external** brake resistor)	47 Ω		
Max. braking power (**external** brake resistor)	15 kW		

(1) I_{rms} for max. 7 s

(2) S1 mode incl. power supply, without braking chopper

Mechanical data - Single-channel servo drive (AX51xx)

Technical data	AX5101	AX5103	AX5106	AX5112	AX5118	AX5125
Weight	approx. 4 kg	approx. 4 kg	approx. 5 kg	approx. 5 kg	approx. 11 kg	approx. 11 kg
Width	92 mm				185 mm	185 mm
Height without plugs	274 mm					
Depth without plugs	232 mm					

Mechanical data - Two-channel servo drive (AX52xx)

Technical data	AX5201	AX5203	AX5206
Weight	approx. 5 kg	approx. 6 kg	approx. 6 kg
Height without plugs	274 mm		
Width	92 mm		
Depth without plugs	232 mm		

BECKHOFF AX5000: Product overview

Type code and Name plates

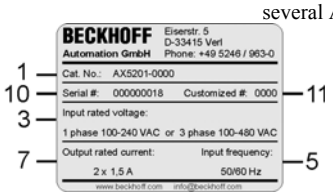
Type code

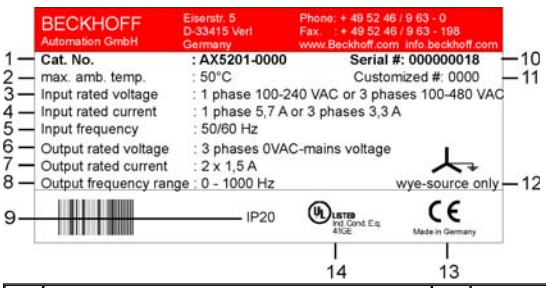
AX5xyz-a b c d	
AX	Beckhoff product line: Servo drive
5	Type series: 5000
X	No. of channels: 1 = single-channel 2 = two-channel
YZ	Nominal current per channel: Single-channel devices 01, 03, 06, 12, 18, 25, 40, 60, 72, 90 **or:** 91 = 110 A 92 = 143 A 93 = 170 A Two-channel devices: 01, 03, 06
-a	---
bc	Hardware features: 00 = Standard 01 = Cold plate design with enclosed housing 02 = Auxiliary fan for devices that are normally supplied without fan (e.g. AX5201)
d	Version: 0 = Standard version 1 = Custom version (see key)

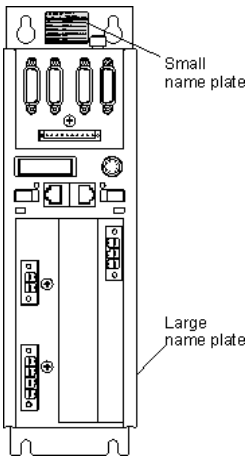
Name plates

The servo drive features two name plates.

- Large name plate: The large name plate attached at the side of the servo drive and includes the following information.
- Small name plate: The second name plate is attached to the upper mounting flange mounted and is designed to show the main, even if several AX5000 are installed directly side by side. The small name plate contains the following information.







1	Catalog number	6	Output rated voltage	11	Customer-specific
2	Max. ambient temperature	7	Output rated current	12	wye-source only
3	Input rated voltage	8	Output frequency range	13	CE - Conform
4	Input rated current	9	Protection class	14	UL - Listed
5	Input frequency	10	Serial number		

BECKHOFF AX5000: Product overview

Equipment

Scope of delivery

The AX5000 is supplied as follows:

- AX5000 in the performance class according to the order
- Plug connector
  X01: for mains input

X02: for DC link
X03: for DC power supply (24 V)
X06: for digital inputs and outputs

- Short description (Startup)
- Documentation on CD-ROM

Note

Connectors

The D-Sub connectors X11, X12, X21, X22 (for feedback cable and resolver/Hall) and the motor and sensor connectors X13, X14, X23, X24 are not part of the scope of delivery of the servo drive.
However, they are included with pre-assembled motor and feedback cables.

Accessories

Accessories with UL-Listing!

If you wish to operate an AX5000 in an economic area that requires a UL-Listing, please make sure that the accessories also have a UL-Listing.

The following optional accessories are available (see Beckhoff main catalog or www.beckhoff.de):

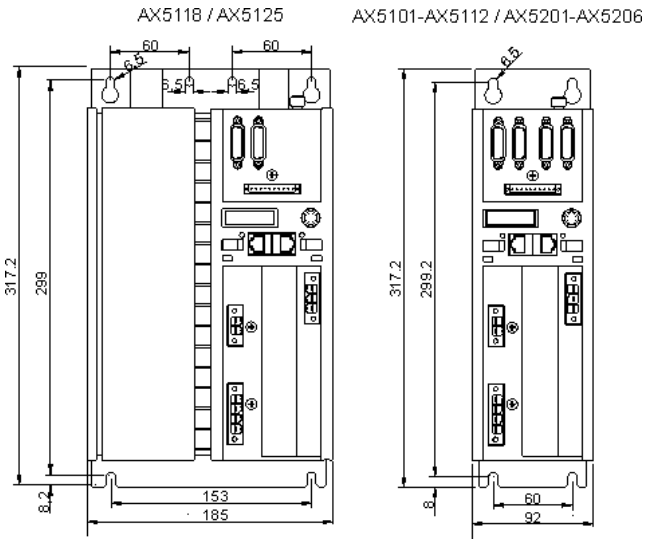
- Motor and feedback cable (ready-made)
- Motor and feedback cable sold by the metre
- D-Sub connector X11, X12, X21, X22 individual (for feedback cable and resolver/Hall)
- Motor and sensor connector X13, X14, X23, X24
- EtherCAT bus cable, ready-made or sold by the metre
- Synchronous servomotors (linear or rotational)
- External ballast resistor
- Expansion cards
- Additional modules

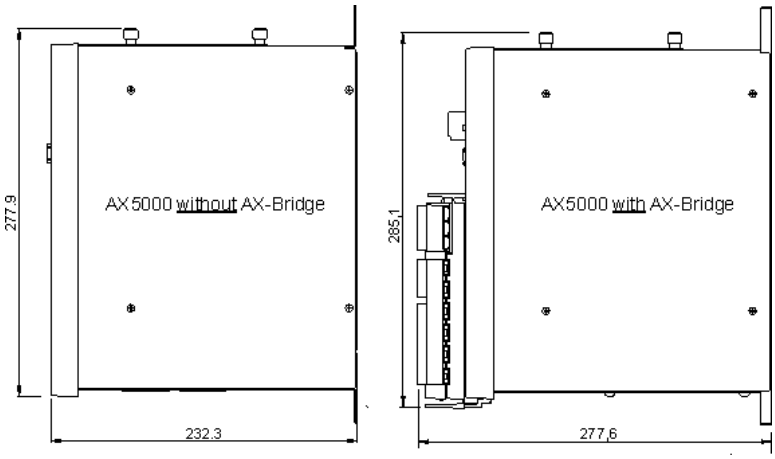
BECKHOFF AX5000: Product overview

Dimensions

AX5000 as single device

All dimensions in millimeters.





BECKHOFF AX5000: Installation

Transport and storage

Transport

- Only by qualified personnel
- Only in recyclable original manufacturer's packaging
- Avoid sharp impacts
- Temperature: -40...+70°C, varying no faster than 20K / hour
- Air humidity: relative humidity max. 95%, non-condensing
- The servo drives contain components at risk from electrostatic discharge caused by improper handling.
  - Please ensure you are electrostatically discharged before touching the servo drive directly.
  - Avoid contact with highly insulating materials (synthetic fibres, plastic film etc.).
  - Place the servo drive on a conductive surface.
- If the packaging is damaged check the AX5000 and any accessories for visible damage. Inform the transport company and, if necessary, the manufacturer.

Packaging

- Recyclable carton with inserts
- Dimensions:
  AX5000 (H x W x D) 348 x 324 x 175 mm
  Identification: Device name plate on the outside of the carton

Storage

- The AX5000 and its accessories must not be stored outdoors. The storage space must be adequately ventilated and dry.
- The devices must be stored in the recyclable original manufacturer's packaging.
- The servo drives contain components at risk from electrostatic discharge caused by improper handling.
  - Please ensure you are electrostatically discharged before touching the servo drive directly.
  - Avoid contact with highly insulating materials (synthetic fibres, plastic film etc.).
  - Place the servo drive on a conductive surface.
- Max. stack height 8 cartons
- Storage temperature: - 40...+ 55° C, varying no faster than 20 K / hour
- Atmospheric humidity: relative humidity max. 95%, non-condensing
- Duration of storage:
  < 5 years: without limitation

CAUTION

Destruction of the devices!

On no account must the device be connected to 400 V if the DC link capacitors have lost their **forming**.
The capacitors must be reformed (see below).

> 5 years: The dielectric (an oxidation layer with a thickness of approx. 1 µ) in the DC link capacitors degrades over time, and the capacitors lose their **forming**.
Prior to commissioning of the servo drive the capacitors must be **reformed**. Release all electrical connections and feed the servo drive for about 30 minutes with 230 V_{AC} (single-phase) at terminals L1/L2 or L2/L3.

BECKHOFF AX5000: Installation

Mechanical installation

WARNING

Caution – Risk of injury!

- The servo drives may only be installed by trained, qualified personnel. The qualified personnel must know and comply with the national accident prevention regulations.
- Safety boots must be worn.

WARNING

Caution - Risk of injury through electric shock!

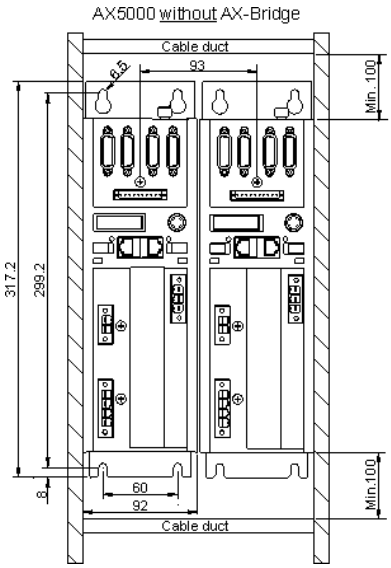
De-energise all electrical components (servo drive, control cabinet, etc.) before commencing the installation or deinstallation.

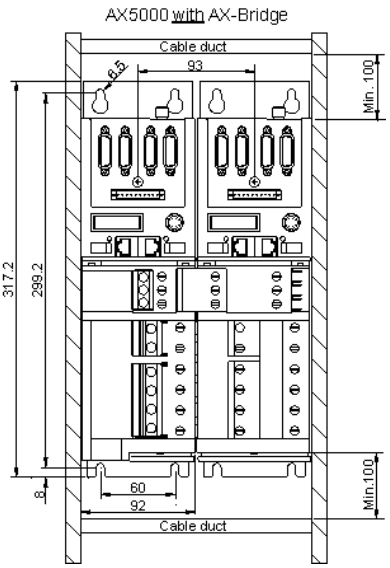
CAUTION

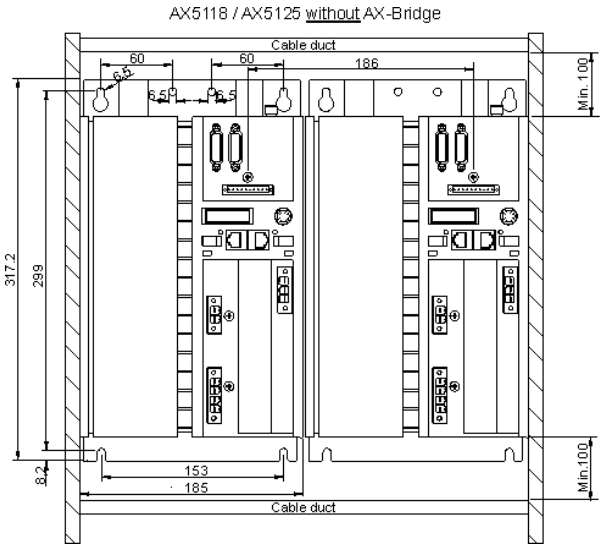
Destruction of the servo drive!

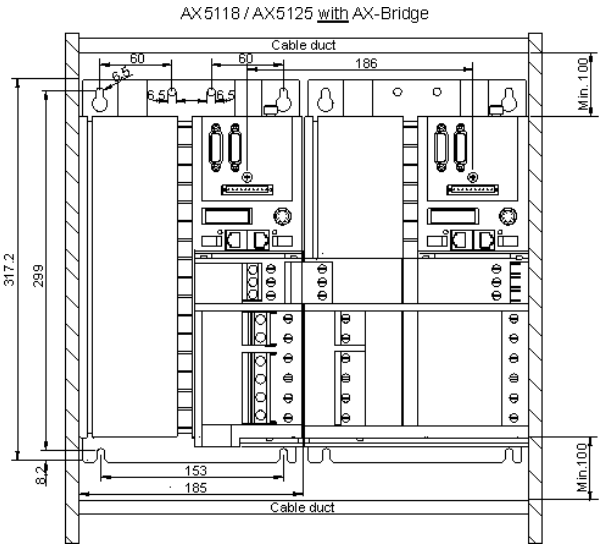
- Always install the servo drive vertically
- Provide adequate ventilation for the servo drive. The permissible ambient conditions are specified in the "Technical data" section.
- It is essential to adhere to the required distances (see diagrams below).

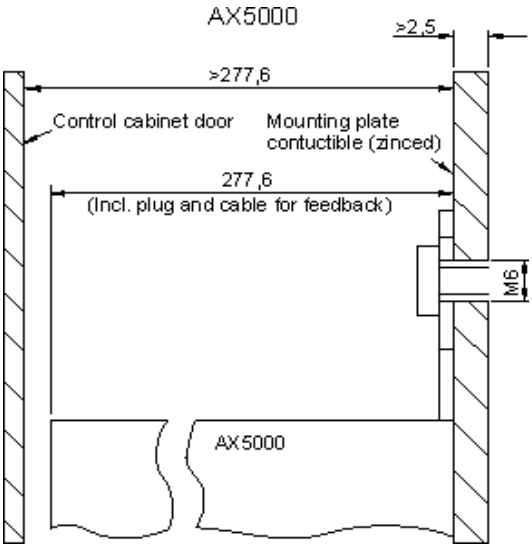
Installation examples











WARNING

Caution - Risk of injury through electric shock!

Take care that the mounting plate is earthed (grounded) properly.

BECKHOFF AX5000: Installation

Electrical installation

UL Listing

It is essential to observe chapter "Product overview-->Guidelines and Standards-->UL-Listing" if you wish to operate an AX5000 in an economic area that requires a UL-Listing.

WARNING

Caution – Risk of injury!

- The servo drives may only be installed by trained, qualified personnel. The qualified personnel must know and comply with the national accident prevention regulations.
- Safety boots must be worn.

WARNING

Caution - Risk of injury through electric shock!

De-energise all electrical components (servo drive, control cabinet, etc.) before commencing the installation or deinstallation.

DANGER

Serious risk of injury through electric shock!

Due to the DC link capacitors dangerous voltage may persist at the DC link contacts "X02" after the servo drive has been disconnected from the mains supply. After disconnecting the servo drive wait at least 3 minutes and measure the voltage at the DC link contacts DC+ and DC-. The device is safe once the voltage has fallen below 50 V.

WARNING

Caution - Risk of injury through electric shock!

- Before installation, wiring and commissioning it is essential to read the section on "Safety".
- Before installing, uninstalling or connecting the servo drive and the motors please note the following:
  - Remove all relevant mains fuses.
  - Switch off the main system switch and secure it with a lock.
  - Put up a warning sign.
- The control and power connections for the motors may be live, even if the motor is prevented from rotating by the internal brake.

CAUTION

Destruction of the AX5000!

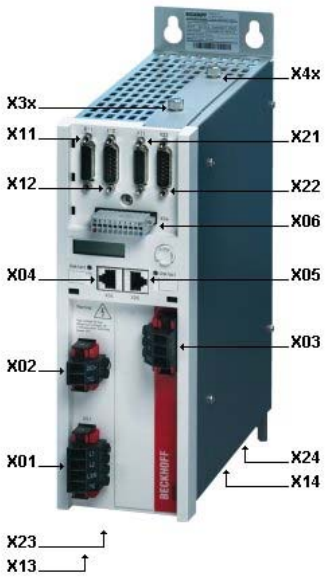
- Check the rated voltage and current of the servo drive and the connected motors.
- When the AX5000 is disconnected from the mains supply (emergency stop, mains contactor etc.), wait at least 3 minutes before starting again or query the status of the IDN "P-0-0205" (see documentation of the “IDN-Description”).

Overview of ports and identifiers

Function	Connection
Optional safety bay	X3x
Feedback port, high-resolution for axis 1	X11

Connection	Function
X4x	General optional bay
X21	Feedback port, high-resolution for axis 2

Feedback port, resolver for axis 1	X12
Incoming EtherCAT port	X04
DC link (high voltage)	X02
Mains voltage connection 100-480 V	X01
Motor circuit Axis 2	X23
Motor circuit Axis 1	X13



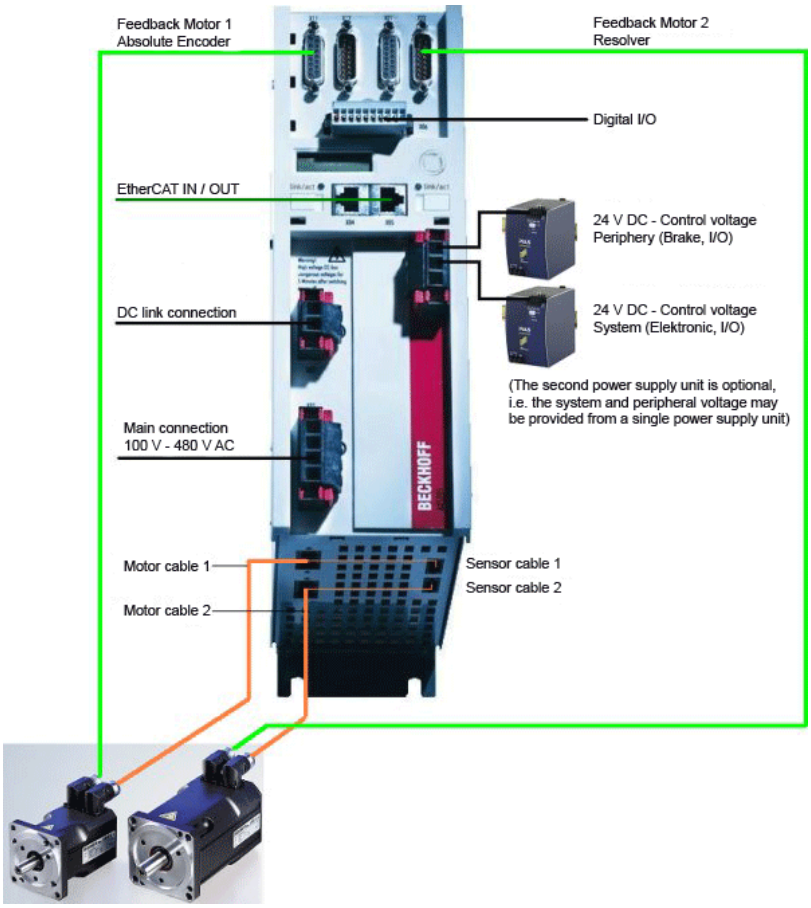
X22	Feedback port, resolver for axis 2
X06	Connector for digital I/Os
X05	Outgoing EtherCAT port
X03	Power supply 24 V_{DC}
X24	Sensor for motor temperature and brake, axis 2
X14	Sensor for motor temperature and brake, axis 1

Tightening torques

Plug	Tightening torque
X01; X02; X03; X13; X23	0.5 - 0.6 Nm

Connection example

The following diagram shows a typical connection diagram for a two-axis device. Motor 1 features an absolute encoder, motor 2 a resolver:



BECKHOFF AX5000: Installation

Power supply

WARNING

Risk of injury!

The electrical installation must be carried out by a qualified electrician.

Before installing and commissioning AX5000 servo drives please read the safety notes in the foreword of this documentation.

CAUTION

Destruction of the AX5000!

The connection sequence of the devices is not arbitrary. The total rated current of the device must decrease from the power supply. The order "AX5112-AX5106-AX5201-AX5103" is **correct** the order "AX5201-AX5112-AX5203" is **wrong**.

CAUTION

Danger for persons and equipment!

Note the total current of the connected devices.

According to CE the current carrying capacity of power busbars is limited to 100 A.

CAUTION

Danger for persons and equipment!
Please ensure that the connection line for the AX5901 supply module is adequately dimensioned. The dimensioning depends on the total rated current and must comply with EN 60204-1. The connector plugs are designed for a maximum conductor cross-section of 25 mm^2.

A 3-phase connection must be used if the total rated current exceeds 9 A.

CAUTION

Danger for persons and equipment!
To set up a drive system without AX5901 supply module and AX bridge please note the following:

The connector plugs of the wide voltage input are designed for a maximum current of 41 A and a maximum conductor cross-section of 6 mm^2. The cable configuration must comply with the requirements specified in DIN VDE 0298 Part 4 / 2003-08 and EN 60204-1.

Avoid phase reversal between the devices!

X01: Main supply connection

UL Listing

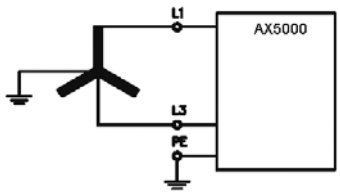
It is essential to observe chapter "Product overview-->Guidelines and Standards-->UL-Listing" if you wish to operate an AX5000 in an economic area that requires a UL-Listing.

Voltage systems ranging from single-phase 100 V_{AC} to three-phase 480 V_{AC} can be connected to the wide voltage input of the AX5000. In single-phase systems the mains phase is connected to terminal point L1 and the neutral conductor to terminal point L3/N.

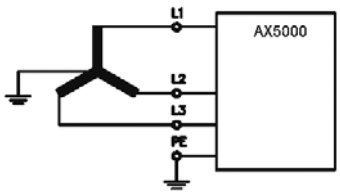
Terminal point	Connection	
	3-phase	1-phase
L1	Phase L1	Phase L1
L2	Phase L2	not used
L3/ N	Phase L3	Neutral conductor
PE	Protective conductor	Protective conductor

Connection to the standard mains supply (TT / TN) with earthed centre

Single phase 100 $_{-10\%}$.- 240 $_{+10\%}$ V_{AC}, 50/60 Hz



Three phase 100 $_{-10\%}$.- 480 $_{+10\%}$ V_{AC}, 50/60 Hz

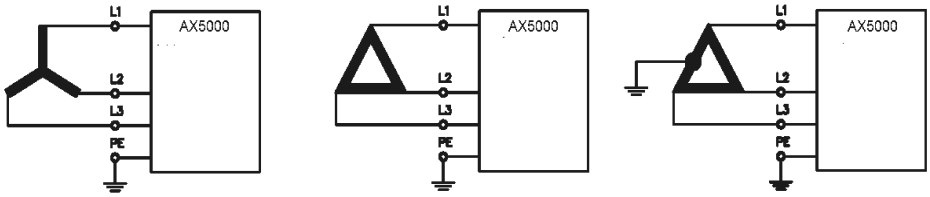


Connection to a IT-mains supply (100 - 240 V) without isolating transformer

EMC Act in europe!

Due to electromagnetic emission, in Europe the AX5000 must be operated in conjunction with an isolating transformer

CAUTION



Connection to other mains types (100 - 240 V) without isolating transformer

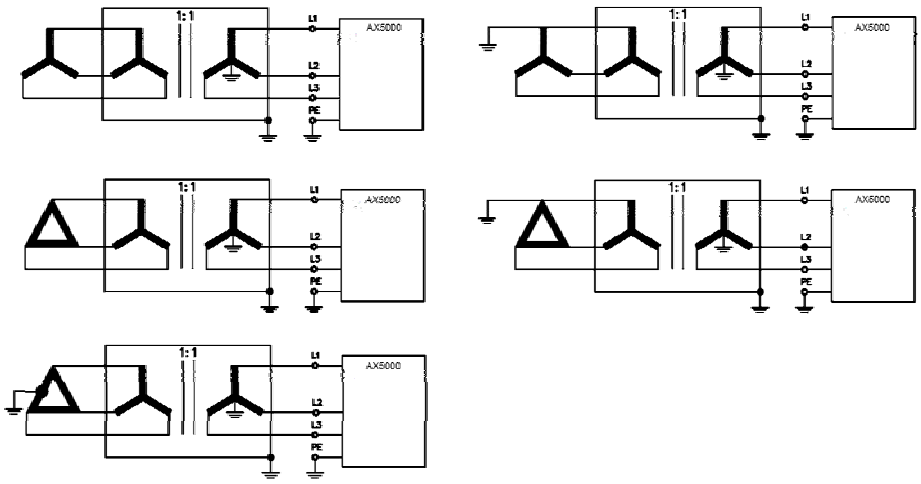
Connection to other mains types (100 - 240 V) with isolating transformer

CAUTION

Destruction of the AX5000!

For asymmetrically earthed or non-earthed 100...480 V mains an isolating transformer must be used.

100 - 480 V Isolating transformer 240 - 480 V Isolating transformer



Fusing

WARNING

Fire hazard through cable overload!

- The following data refer to stand-alone devices. Please note the total current of all connected devices in a multi-axis system.
- The recommended fuses are designed for line protection. The servo drives feature integrated self-protection.

External protection, CE-compliant

Single-phase:

	AX5101	AX5103	AX5106	AX5201	AX5203	AX5206
AC supply *)	10 AT	10 AT	16 AT	10 AT	16 AT	20 AT
24 V supply	3 AT					
Brake resistor	electronic					

*) Application class "gG" mains fuses according to IEC 60269 or "D" type automatic circuit-breakers must be used.

Three-phase:

	AX5101	AX5103	AX5106	AX5112	AX5118	AX5125	AX5201	AX5203	AX5206
AC supply *)	6 A	6 A	10 A	20 A	35 A	35 A	10 A	10 A	20 A
24 V supply	3 AT								
Brake resistor	electronic								

*) Application class "gG / gL" mains fuses according to IEC 60269 or "D" type automatic circuit-breakers must be used.

Internal protection, CE-compliant

Circuit	Fuse
24 V system voltage	3.4 AF
24 V peripheral voltage	electronic
Brake resistor	electronic

External protection, UL-compliant

Integral solid state short circuit protection does not provide branch circuit protection. Branch circuit protection must be provided in accordance with the Manufacture Instructions, National Electrical Code and any additional local codes.

Suitable for use on a circuit capable of delivering not more than 18000 rms symmetrical amperes, 480 V maximum, when protected by RK5 class fuses.

Single-phase:

	AX5101	AX5103	AX5106	AX5201	AX5203	AX5206
AC-supply (max.) *)	6 A	12 A	20 A	12 A	20 A	20 A
24 V-supply (max.)	3 A					
Brake resistor	electronic					

*) Mains fuses according to type “RK5” must be used.

Three-phase:

	AX5101	AX5103	AX5106	AX5112	AX5201	AX5203	AX5206
AC-supply (max.) *)	6 A	12 A	20 A	20 A	12 A	20 A	20 A
24 V-supply (max.)	3 A						
Brake resistor	electronic						

*) Mains fuses according to type “RK5” must be used.

AX5112

When protected by RK5 class fuses: Rated 20 A, min. 480 V

Internal protection, UL-compliant

Circuit	Fuse
24 V system voltage	3.4 AF
24 V peripheral voltage	electronic
Brake resistor	electronic

Residual current circuit breaker

Servo drives with built-in mains filters generate a small leakage current (fault current) due to the capacitors in the filter. This fault current is responsible for malfunctions in standard residual current circuit breakers. For this reason so-called AC/DC sensitive residual current circuit breakers must be used, which also take into account DC currents.

X02: DC link

DC link coupling or DC supply via an external DC source is possible via terminal X2.

Terminal point	Signal
DC+	DC link +
DC-	DC link -

X03: 24 V_{DC} supply

System and peripheral voltage for the servo drive is supplied via connector X3. The supply is based on two channels in order to offer an option to

separate between motor stopping brakes and control electronics. Both channels are connected via a bridge as standard.

CAUTION

Safe operation!

The voltage tolerances must be taken into account when connecting motors with stopping brake.

Terminal point	Signal	current consumption
Up	24 $V_{DC \pm 10\%}$ - Periphery (e.g. separate brake supply)	variable (see X06 and X14, X24)
Us	24 $V_{DC -15\% + 20\%}$ - system supply / control voltage	0,4 A - 0,8 A
GND	GND	

Safe system stop in the event of power failure

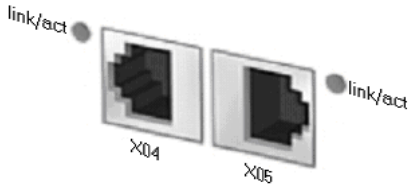
A power failure can lead to uncontrolled run-out of drive axes, which means that linear axes or lifting axes would hit the limit stop unbraked. The 24 V_{DC} supply of the AX5000 has two channels, so that separate power supplies can be used for the control electronics and the brake control. This enables the supply voltage for the control electronics to be buffered via the UPS of the Industrial PCs until all axes were stopped safely.

BECKHOFF AX5000: Installation

EtherCAT

X04, X05: EtherCAT connection

The AX5000 is integrated in EtherCAT via the X04 and X05 RJ45 sockets.



RJ45	Signal
X04 (IN)	incoming EtherCAT line
X05 (OUT)	outgoing EtherCAT line

BECKHOFF AX5000: Installation

X06: Digital I/Os

CAUTION

Destruction of the AX5000!

This connector is <u>not</u> designed for external power supply. It is supplied via the 24 V supply (periphery) of connector X03.

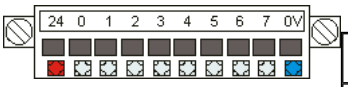
Note

Output current

The specified output currents are maximum values. The actual values depend on your current configuration.

I/O plug connector without LEDs

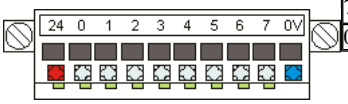
ZS4500-2006



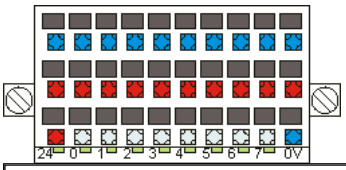
Terminal point	Signal	output current
24	Output voltage (U_p 24 V_{DC} +)	max. 1 A
0	Input 0	
1	Input 1	
2	Input 2	
3	Input 3	
4	Input 4	
5	Input 5	
6	Input 6	
7	Input 7 or output (configurable) (U_p 24 V_{DC} +)	max. 0,5 A
0V	Output voltage GND (-)	

I/O plug connector with LEDs

ZS4500-2007 (optional)



ZS4500-2008 (optional)



Voltage level	State
-3 V ... 5 V	"0" signal voltage
15 V ... 30 V	"1" signal voltage

The signal inputs of the connectors can be assigned the following functions, which are configured through IDNs.

IDN	Name
	Hardware enable
P-0-0400	**Hardware enable configuration**
	Configuration (BitSize 2, OffSet 0)
	Input number (BitSize 5, OffSet 3)
	Position limit switches
P-0-0401	**Position limit switch configuration**
	Positive limit switch (BitSize 16, OffSet 0)
	Input number (BitSize 8, OffSet 8)
	Negative limit switch (BitSize 16, OffSet 16)
	Input number (BitSize 8, OffSet 8)
	Ready to operate
P-0-0402	**Ready to operate configuration**
	Ready to operate output (BitSize 8, OffSet 0)
	Output number (BitSize 5, OffSet 3)
	Ready to operate input (BitSize 8, OffSet 8)
	Configuration number (BitSize 3, OffSet 0)
	Input number (BitSize 5, OffSet 3)
	General I/O
P-0-0800	**Digital output control word**
	reserved (BitSize 7, OffSet 0)
	Digital I/O (BitSize 7, OffSet 1)
	reserved (BitSize 8, OffSet 8)
P0-0801	**Digital inputs, state**
	Digital Input 0 (BitSize 1, OffSet 0)
	Digital Input 1 (BitSize 1, OffSet 1)
	Digital Input 2 (BitSize 1, OffSet 2)
	Digital Input 3 (BitSize 1, OffSet 3)
	Digital Input 4 (BitSize 1, OffSet 4)
	Digital Input 5 (BitSize 1, OffSet 5)
	Digital Input 6 (BitSize 1, OffSet 6)
	Digital Input 7 (BitSize 1, OffSet 7)
	reserved (BitSize 8, OffSet 8)
P-0-0802	**Digital outputs**
	reserved (BitSize 7, OffSet 0)
	Digital Output 7 (BitSize 1, OffSet 7)
	reserved (BitSize 8, OffSet 8)
	Latch-unit
P-0-0251	**Probe 1 logic configuration**
	Mux 1 (BitSize 16, OffSet 0)
	Signal selection (BitSize 15, OffSet 0)
	Output negation (BitSize 1, OffSet 15)
	Mux 2 (BitSize 16, OffSet 16)
	Signal selection (BitSize 15, OffSet 0)
	Output negation (BitSize 1, OffSet 15)
	Logic (BitSize 16, OffSet 32)
	Latch ctrl (BitSize 16, OffSet 48)

BECKHOFF Drive Technology: Product overview

ZS4500 - I/O plug connector

Technical data

Technical data	ZS4500-2006	ZS4500-2007	ZS4500-2008
Number of terminal points	10	10	30
Signal LEDs	no	yes	yes
Nominal voltage	24 V_{DC}	24 V_{DC}	24 V_{DC}
Rated current	2 A		
Wire cross section	0.5 mm^2 ... 1.5 mm^2		
Length of stripped conductor	10 mm		
Dimensions (W x H x D)	approx. 42mm x 10.3mm x 26.9mm	approx. 42mm x 12.7mm x 26.9mm	approx. 42mm x 20.8mm x 26.9mm
Weight	approx. 10 g	approx. 10 g	approx. 20 g
Operating temperature	0°C... + 55°C		
Storage temperature	-25°C... + 85°C		
Relative humidity	95%, no condensation		
Vibration / shock resistance	conforms to EN 60068-2-6 / EN 60068-2-27, EN 60068-2-29		
EMC resistance burst / ESD	conforms to EN 61000-6-2 / EN 61000-6-4		
Protection class	IP 20		
Installation position	variable		
Approval	CE, UL, CSA		

Ordering information for I/O plug connectors

Order designation	Signal LEDs	Supports the following connection types		
		Single-conductor	Two-conductor	Three-conductor
ZS4500-2006	no	yes	no	no
ZS4500-2007	yes	yes	no	no
ZS4500-2008	yes	yes	yes	yes

Connection of digital sensors/actuators

ZS4500-2006 (standard) and ZS4500-2007 (optional)

The connection type (single-conductor) in the two connectors ZS4500-2006 and ZS4500-2007 is identical. The ZS4500-2007 is additionally equipped with LEDs.The following diagram shows the ZS4500-2006.

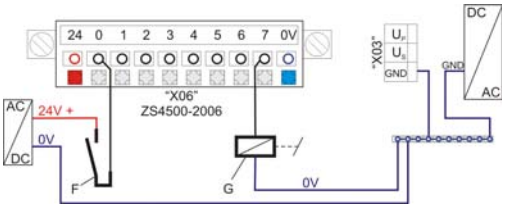
A sensor (F) is connected at terminal point "0" via a single-conductor connection. The 24 V supply for the sensor is connected externally. The 24 V supply for the sensor (F) could be taken directly from terminal point "24", although this would preclude further connections since only one 24 V connection can be connected at terminal point "24".

In this case terminal point "7" is configured as an output. The configuration is implemented on the software side. At this point a relay (G) is connected via a single-conductor connection. The 0 V connection is established externally. Terminal point "0V" can only be used once.

Note

Ground potential

- If sensor (F) or further initiators are supplied through a separate power supply unit, the ground potential of the separate power supply unit must be connected with the ground potential of terminal point "GND" of connector "X03" (24 V supply).
- The ground potential (0 V) of the relay (G) must be connected with the ground potential of terminal point "GND" of connector "X03" (24 V supply).



ZS4500-2008 (optional)

A single-, two- or three-conductor connection may be used for this connector. The diagram shows the two- and three-conductor type. The single-conductor type matches the diagram for connector ZS4500-2006.

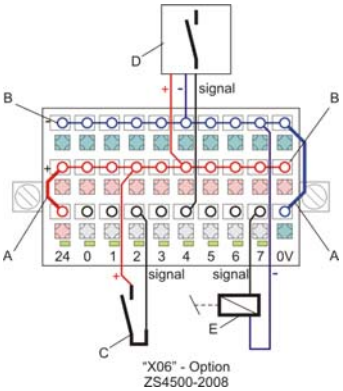
The terminal points at (B) are internally bridged. The two bridges (A) must be established externally on the connector in order to ensure the required function.

A sensor (C) is connected at terminal point "2" via a two-conductor connection.

A sensor (D) is connected at terminal point "4" via a three-conductor connection.

In this case terminal point "7" is configured as an output. The configuration is implemented on the software side. At this point a relay (E) is connected

via a two-conductor connection.



BECKHOFF AX5000: Installation

Feedback

Information about commutation you will find in the Chapter "Commissioning-->Commutation methods".

Information on the limit frequencies can be found further below, in the descriptions of the interfaces.

Note

Absolute encoder

When using an absolute encoder, it must be verified before moving the axis that the feedback system supplies the expected position data at the distinctive positions in the traversing range - 'START' and 'MID' and 'END' – and that these positions are retained after the restart (Bootstrap -> OP) of the AX5000.

Encoder

Tested and released encoder for AX5000

Rotational encoders

Heidenhain:

The Heidenhain company supplies feedback systems with the 'EnDat 2.2' interface in 2 versions. One version is without the provision of the analog signal and the other version provides the analog signal '1Vss'. To date, Beckhoff supports only EnDat 2.1 with analog signal. Since the EnDat 2.2 interface supports all of the commands of EnDat 2.1, attention only needs to be paid to the provision of the analog signal 1Vss on the Heidenhain feedback systems with EnDat 2.2; i.e. the Heidenhain order designation 'EnDat02' must be stated.

Type	System	Lines / sine cosine periods per revolution	Supply voltage	Interface	Scanning
ECI 1118	Singleturn	16	5 V	EnDat 2.1	Inductive
ECI 1319	Singleturn	32	5 V or 7 - 10 V	EnDat 2.1	Inductive
ECN 413	Singleturn	512	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
ECN 413	Singleturn	2048	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
ECN 1113	Singleturn	512	5 V	EnDat 2.1 + 1 Vpp	Optical
ECN 1313	Singleturn	2048	5 V	EnDat 2.1 + 1 Vpp	Optical
EQI 1130	Multiturn	16	5 V	EnDat 2.1	Inductive
EQI 1331	Multiturn	32	5 V or 7 - 10 V	EnDat 2.1	Inductive
EQN 425	Multiturn	512	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
EQN 425	Multiturn	2048	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
EQN 1125	Multiturn	512	5 V	EnDat 2.1 + 1 Vpp	Optical
EQN 1325	Multiturn	512	5 V	EnDat 2.1 + 1 Vpp	Optical
EQN 1325	Multiturn	2048	5 V	EnDat 2.1 + 1 Vpp	Optical
RCN 829	Singleturn	32768	3,6 V - 5,25 V	EnDat 2.2 + 1 Vpp	Optical
ROQ 425	Multiturn	512	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
ROQ 425	Multiturn	2048	3,6 V - 14 V	EnDat 2.1 + 1 Vpp	Optical
ERN 180	Incremental	1024	5 V	1 Vpp	Optical
ERN 180	Incremental	2048	5 V	1 Vpp	Optical
ERN 180	Incremental	5000	5 V	1 Vpp	Optical
ERN 480	Incremental	2048	5 V	1 Vpp	Optical
ERM 280	Incremental	1200	5 V	1 Vpp	Magnetic

Hengstler:

Type	System	Lines / sine cosine periods per revolution	Supply voltage	Interface	Scanning
AD 34	Singleturn	2048	5 V	BiSS + 1 Vpp	Optical
AD 36	Singleturn	2048	5 V	BiSS + 1 Vpp	Optical
AD 36	Multiturn	2048	5 V	BiSS + 1 Vpp	Optical
AD 58	Singleturn	2048	5 V	BiSS + 1 Vpp	Optical
AD 58	Multiturn	2048	5 V	BiSS + 1 Vpp	Optical

Kübler:

Type	System	Lines / sine cosine periods per revolution	Supply voltage	Interface	Scanning
8.5853	Singleturn	2048	5 V	BiSS + 1 Vpp	Optical

Sick Stegmann:

Type	System	Lines / sine cosine periods per revolution	Supply voltage	Interface	Scanning
SEK 37	Singleturn	16	7 V - 12 V	HIPERFACE	Capacitive
SEK 52	Singleturn	16	7 V - 12 V	HIPERFACE	Capacitive
SRS 50	Singleturn	512	7 V - 12 V	HIPERFACE + 1 Vpp	Optical
SRM 50	Multiturn	512	7 V - 12 V	HIPERFACE + 1 Vpp	Optical

Universal rotational encoders:

Type	System	Lines / sine cosine periods per revolution	Supply voltage	Interface	Scanning
1		512	5 V	1 Vpp	

Linear encoders

Heidenhain:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
LS 388C	Incremental	20 µm	5 V	1 Vpp	Optical
LS 486	Incremental	20 µm	5 V	1 Vpp	Optical
LS 487	Incremental	20 µm	5 V	1 Vpp	Optical
LC 483	Incremental	20 µm	3,6 V - 5,25 V	Endat 2.1 + 1 Vpp	Optical
LIDA 483	Incremental	20 µm	5 V	1 Vpp	Optical
LIDA 287	Incremental	200 µm	5 V	1 Vpp	Optical

HIWIN:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
Magic	Incremental	1 mm	5 V	1 Vpp	Magnetic

lika:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
SMS	Incremental	1 mm	5 V	1 Vpp	Magnetic

Numerik Jena:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
LIA20	Incremental	20 µm	5 V	1 Vpp	Optical

Siko:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
LE100/1	Incremental	1 mm	5 V	1 Vpp	Magnetic

Universal linear encoders:

Type	System	Measuring steps	Supply voltage	Interface	Scanning
1	Incremental	20 µm	5 V	1 Vpp	
2	Incremental	1 mm	5 V	1 Vpp	
3	Incremental	20 µm	5 V - uncontrolled	1 Vpp	
4	Incremental	1 mm	5 V - uncontrolled	1 Vpp	

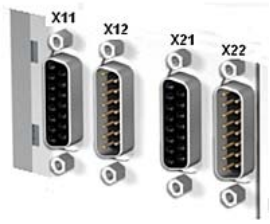
Note

Motor feedback database

If your feedback system is not listed here, please follow the link to the Beckhoff download area. By downloading and installing the 'AX5000 setup' you will obtain the TwinCAT Drive Manager, the latest firmware and the latest motor feedback database.

X11 and X21: Feedback, high-resolution

The X11 and X21 D-SUB sockets are available for connecting high-resolution feedback systems. In delivery state X11 is assigned to axis 1, X21 to axis 2.



Pin	EnDAT / BiSS	Hiperface	Sine / Cosine 1Vpp	TTL	output current
1	SIN	SIN	SIN	n.c.	
2	GND_5 V	GND_9 V	GND_5 V	GND_5 V	
3	COS	COS	COS	n.c.	
4	U_s–5 V	n.c.	U_s–5 V	U_s–5 V	
5	DX+ (Data)	DX+ (Data)	n.c.	B+	
6	n.c.	U_s–9V	n.c.	n.c.	
7	n.c.	n.c.	REF Z	REF Z	
8	CLK+ (Clock)	n.c.	n.c.	A+	
9	REFSIN	REFSIN	REFSIN	n.c.	
10	GND_Sense	n.c.	GND_Sense	GND_Sense	
11	REFCOS	REFCOS	REFCOS	n.c.	
12	U_s–5 V_Sense	n.c.	U_s–5 V_Sense	U_s–5 V_Sense	
13	DX- (Data)	DX- (Data)	n.c.	B-	
14	n.c.	n.c.	Z	Z	
15	CLK- (Clock)	n.c.	n.c.	A-	max. 250 mA

Limit frequency:

1Vpp = 270 kHz
TTL = 10 MHz
MES = 300 Hz

Resolver

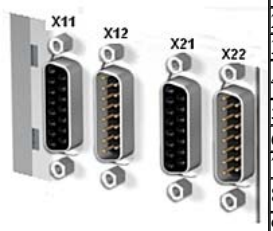
Universal Resolver:

Typ	Number of poles	Frequency	Speed ratio	Phase difference
1	2	8 kHz	0,5 phi	0 °
2	6	8 kHz	0,5 phi	0 °
3	8	8 kHz	0,5 phi	0 °

X12 and X22: Feedback, Resolver / Hall

The X12 and X22 D-SUB sockets are available for connecting resolvers or Hall sensors for commutation. X12 is assigned to axis 1 in the factory, X22 to axis 2.

Resolver specification:



Pin	Resolver	Analog hall sensor
1	Temperature (only PTC, Klixon or bimetal!) Switchpoint 1178 Ω	n.c.
2	AGND	n.c.
3	COS - (S3)	n.c.
4	SIN - (S4)	n.c.
5	REF - (R2)	n.c.
6	n.c.	SIN 1 Vpp
7	n.c.	-120° or -90° 1 Vpp *
8	n.c.	U_s–9 V (supply)
9	Temp. _ GND	n.c.
10	COS + (S1)	n.c.
11	SIN + (S2)	n.c.

12	REF + (R1)	n.c.
13	n.c.	REFSIN 1 Vpp
14	n.c.	REF -120° or -90° 1 Vpp *
15	n.c.	GND (supply)

*) The angle must be configured

Limit frequency:

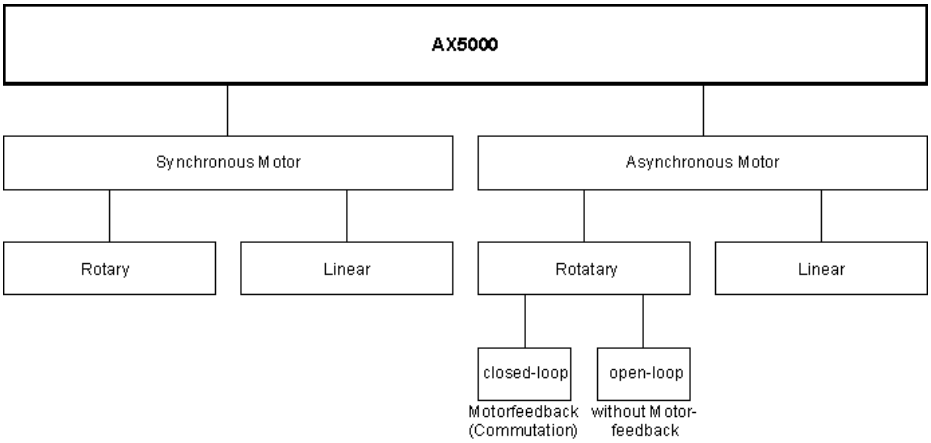
Resolver = 300 Hz

BECKHOFF AX5000: Installation

Motors

Concept

Both three-phase synchronous motors and three-phase asynchronous motors can be driven with the servo drives from the AX5000 series. Due to this flexibility it is possible to implement inexpensive drive solutions with asynchronous motors in addition to demanding positioning tasks in the shortest possible time. The operation of asynchronous motors with the AX5000 is useful if, in the configuration of the drive system, a channel is still freely available and more asynchronous motors are used that are to be operated with open-loop control. In the case of the use of asynchronous motors intended for closed-loop operation, the AX5000 series is a good alternative regardless of the configuration of the drive system.



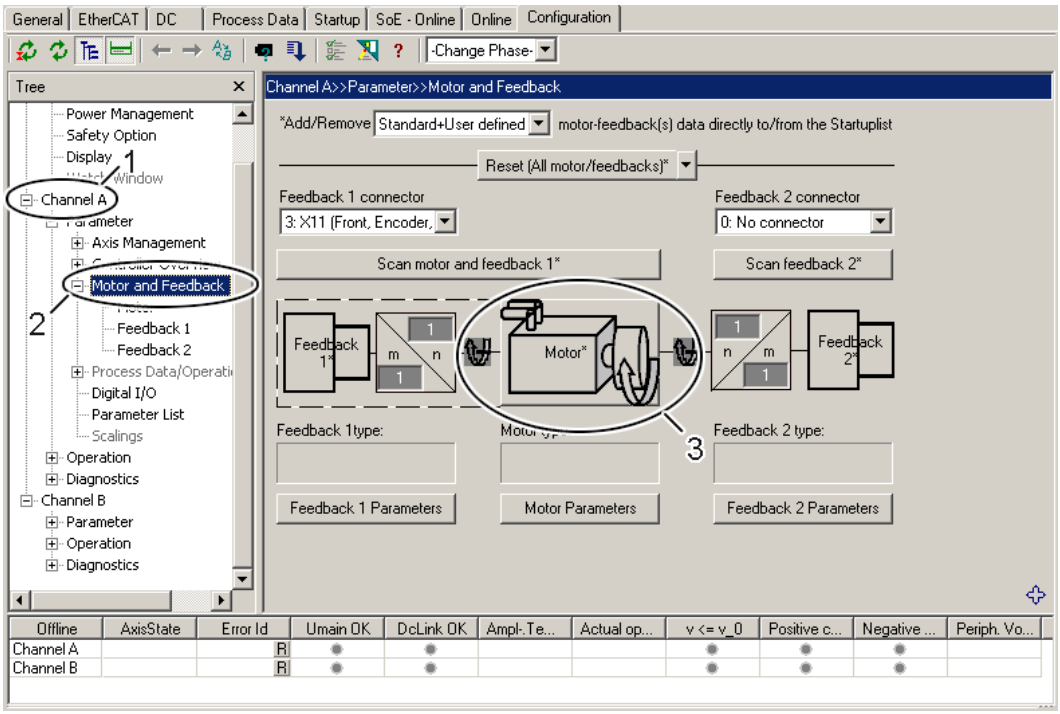
Motor data set

A motor data set contains the motor data required by the AX5000 in order to operate the motor. Motor data sets are saved in a so-called motor database. Beckhoff is continually expanding the pool of available motor data sets and makes the latest motor database available automatically when the TwinCAT Drive Manager is updated.
If you create motor data sets yourself, you create a separate structure and remain independent of the motor database. This means that your motor data sets are retained even if the motor database is expanded by Beckhoff.

TwinCAT Drive Manager

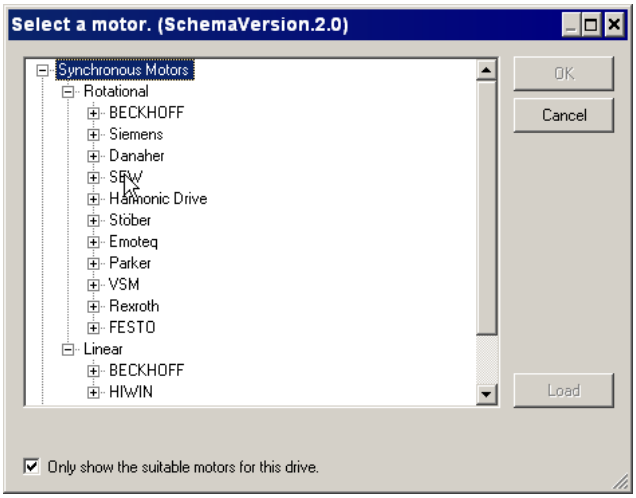
The selection of motors or the input of the parameters for new motors takes place via the TwinCAT Drive Manager (TCDM). The screen masks required for the parameterisation will be explained at this point. If you need basic information about the TCDM, please read the complete documentation, which is available on our website for download.

Start the TCDM and click the entry (2) under the relevant channel (1) in the tree; the motor/feedback configuration appears in the TCDM working area. Click on the field (3) in order to open the ‘Motor selection window’. In the ‘Motor selection window’ you can display all of the available motors, or enter your own motors including motor parameters (asynchronous motors only).



Synchronous motors

In the case of synchronous motors, you can only select an existing motor; it is not possible to register your own motors. If your motor is not listed, please contact our support department.



Asynchronous motors

With the AX5000 you have the possibility to implement a good positioning drive with an inexpensive standard motor in combination with a low-cost incremental encoder.

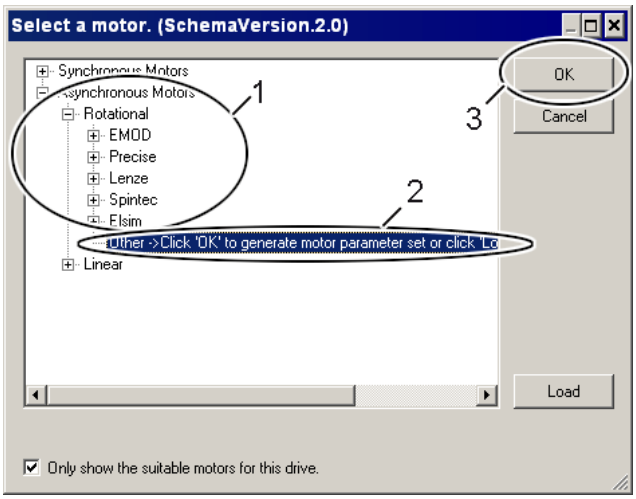
Linear

Linear asynchronous motors are not supported at present.

Rotary

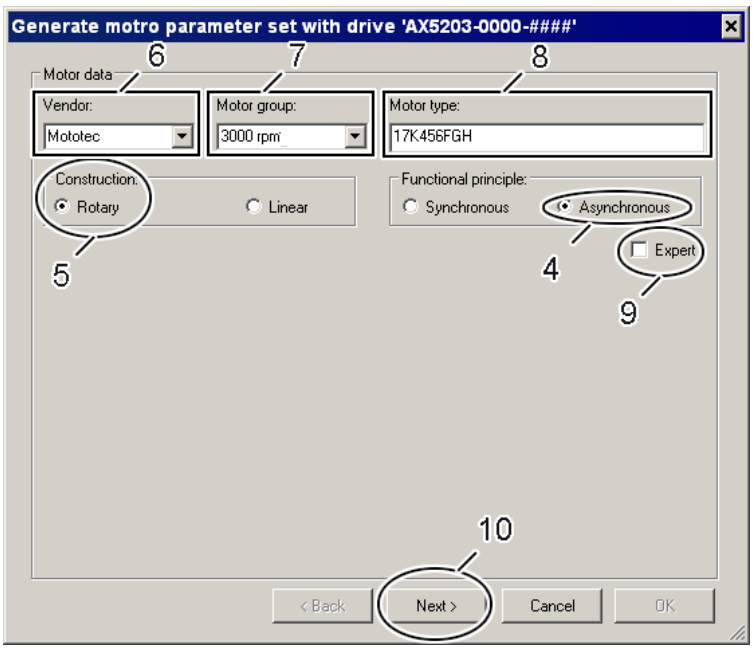
1. Motor selection

You can either choose an existing motor (1) or generate parameters for a new motor (2). After selection, click ‘OK’ (3) to move to the next menu.



2. Identifying motor data

Identifying motor data are entered or selected in the next menu. Expert mode (9) is not currently supported. Parameters (4) and (5) are preset; you do not need to change them. You can enter a new motor manufacturer or select an existing motor manufacturer in parameter (6). A new group is generated in parameter (7) to suit the motor. If you wish to conform to the structure of the motor database, name the group according to the nominal speed of the motor. Enter the exact type designation of the motor in parameter (8). Check your entries and then click 'Next' (10) to move to the next menu.



3. Basic motor data

The basic data are subdivided into three categories: 'Basic' (1); 'Temperature:' (2) and 'Brake' (3).

Basic (1):

a) Type of connection: Star or delta connection. If you wire and operate the motor in a star or delta configuration, please note that the rated motor current changes along with the rated motor voltage and that the AX5000 can supply a maximum rated voltage of 480 V. Please refer to the motor documentation or name plate for the permissible motor voltages and currents for star and delta connection.

b) The derating is dependent upon your application. Derating is the difference between the effective rated channel current and the rated motor current in %. Example: rated motor current = 4 A; effective rated channel current = 3 A -> derating = 25 %.

c) The ratio of Ip to In (overload factor) is set to 1.5 as standard and must be checked against the motor documentation or name plate.

d) The rated current must be adjusted in accordance with the type of connection and checked against the motor documentation or name plate.

e) The maximum motor speed is dependent upon the mechanical properties and the maximum rotary field frequency of the AX5000. Please observe the M / f curve and the field weakening according to the motor documentation.

f) The rated voltage must be adjusted in accordance with the type of connection and checked against the motor documentation or name plate.

g) The nominal speed is dependent upon the number of pole pairs and the nominal frequency and must be checked against the motor documentation or name plate.

h) The nominal frequency is set to 50 Hz as standard and must be checked against the motor documentation or name plate.

i) The power factor (cos ψ) is set to 0.8 as standard and must be checked against the motor documentation or name plate.

Temperature (2):

k) The type of motor temperature monitoring used and the AX5000 input used must be selected:
0 = switch to X14 or X24
1 = KTY 83-110 to X14 or X24
2 = switch to X12 or X22
3 = KTY84-130 to X14 or X24
If the combination you have used is not included in the list, please contact our support department.

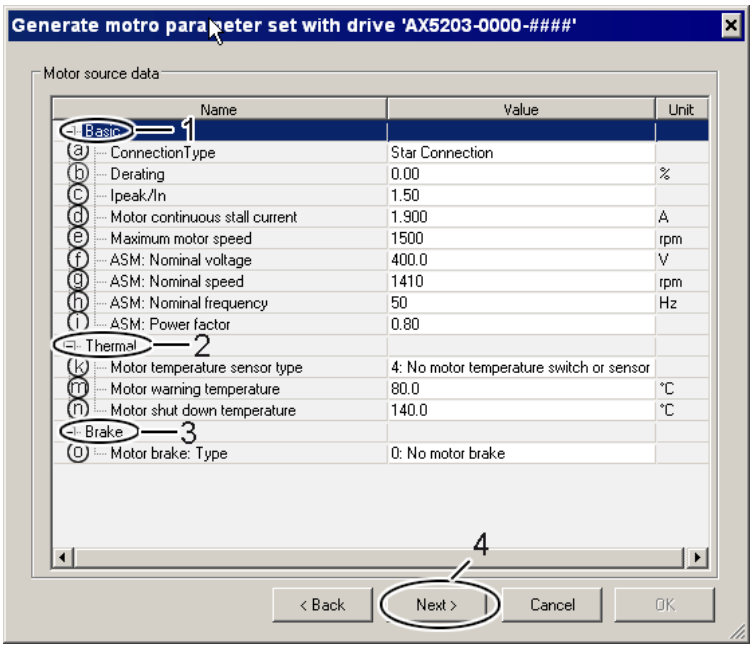
m) The temperature at which a warning is given is set to 80 °C. This parameter is effective only for KTY sensors.

n) The temperature at which the motor is switched off is set to 140 °C and must be checked against the motor documentation or name plate. This parameter is effective only for KTY sensors.

Brake (3)

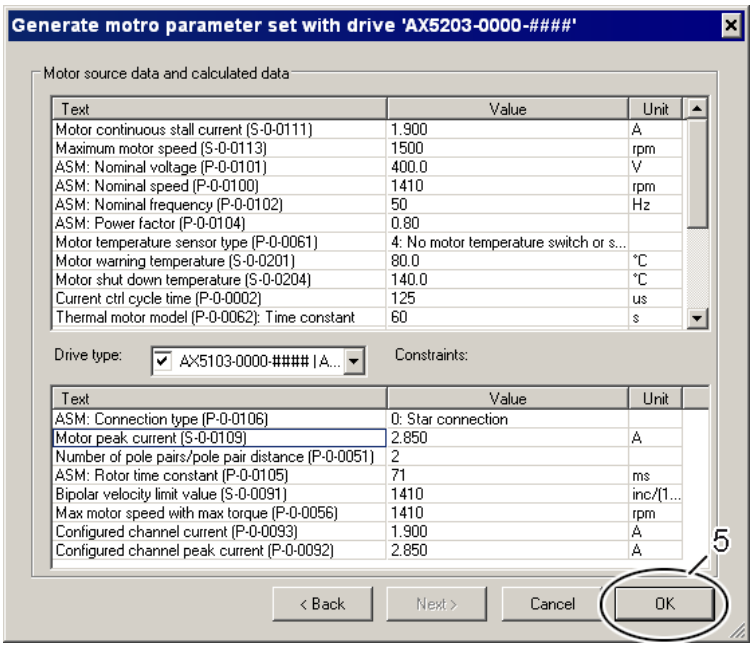
o) The type of motor brake used must be selected and checked against the motor documentation or name plate.

Double-check all entries and click 'Next' (4) to move to the next menu.



4. Summary

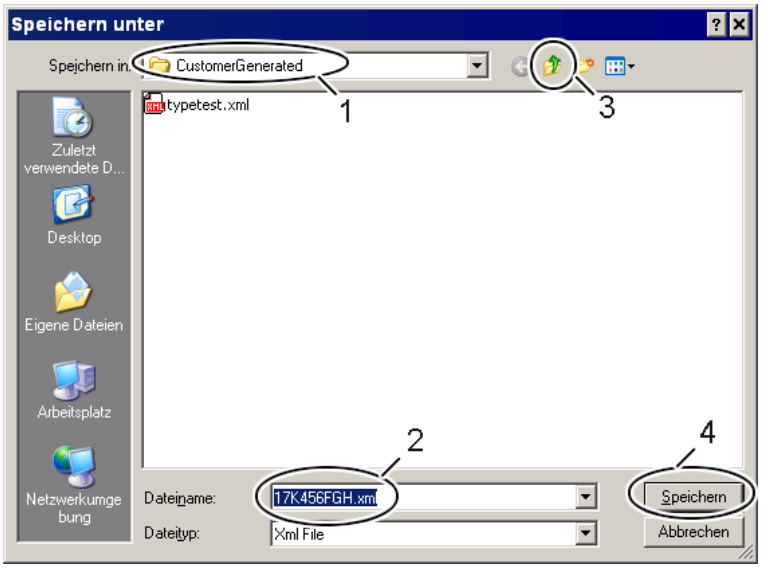
The motor data entered and the data calculated from them are displayed in this window. Please check ALL parameters once more for plausibility and click 'OK' (5) to move to the next menu.



5a. Default storage folder for self-generated motor data sets

The default storage folder for self-generated motor data sets is called ‘CustomerGenerated’ (1) and the suggested file name (2) corresponds to the type of motor entered above (see 2. ‘Identifying motor data’, above). This storage folder has the advantage that you can find your self-generated motor data sets at a glance; however, they are not included in the above list above under 1. ‘Motor selection’, but are only visible if you click the ‘Load’ button at the bottom right under 1. ‘Motor selection’. The suggested name designates only the XML file of the motor data set. For the purposes of displaying in the lists, the XML file is read and the corresponding identifying motor data (‘Vendor’, ‘Motor group’ and ‘Motor type’) are listed as a selection.
To save your data, click on ‘Save’ (4), which then takes you to the last menu.

If your self-generated motor data sets are to be listed directly in the above list under 1. ‘Motor selection’, click on the symbol (3) to open the 'MotorPool’ folder.



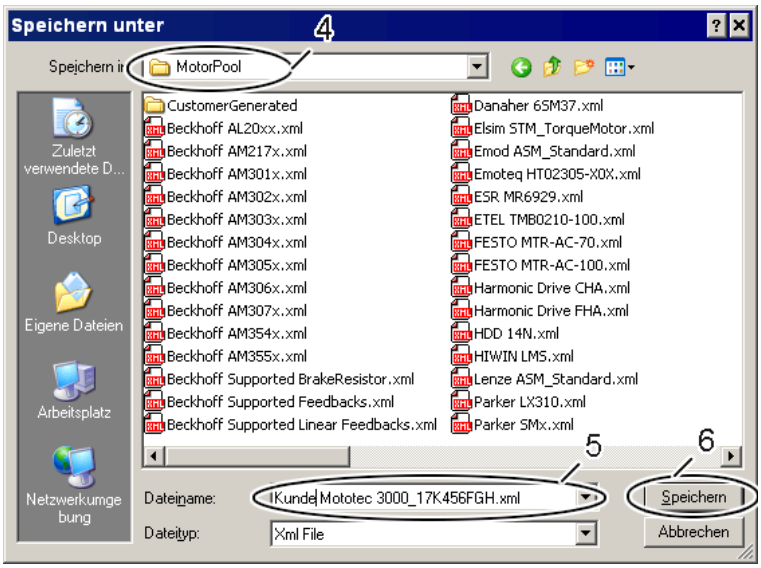
5b. Default storage folder for the motor data sets from the Beckhoff motor database

The default storage folder for the motor data sets provided is called ‘MotorPool’ (4). All motor data sets from the Beckhoff motor database are located here in the form of XML files. We recommend that you assign a unique file name to your self-generated motor data set, so that you can identify it (5):
Customer = name of your company
Mototec = The name (Vendor) assigned by you under 2. ‘Identifying motor data’
3000 = The motor group assigned by you under 2. ‘Identifying motor data’
17K456FGH = The motor type assigned by you under 2. ‘Identifying motor data’

Of course, you can also assign an arbitrary file name. The assigned name designates only the XML file of the motor data set. For the purposes of displaying in the lists, the XML file is read and the corresponding identifying motor data (‘Vendor’, ‘Motor group’ and ‘Motor type’) are listed as a selection.

You create one XML file for each motor data set; the motors from the same motor group of a manufacturer (Vendor) are always summarised in the XML files for Beckhoff motor data sets.

To save your data, click on ‘Save’ (6), which then takes you to the last menu.



6. Mains voltage and further settings

This window also appears when you select an existing motor data set (synchronous motor or asynchronous motor). You can adapt the following entries at any time.

a) You can select one of the pre-defined mains voltage variants or you can specify one of your own.

b) Enter the mains voltage (only possible if no voltage was selected in a)).

c) Enter the upper tolerance of the mains voltage (only possible if no voltage was selected in a)).

d) Enter the lower tolerance of the mains voltage (only possible if no voltage was selected in a)).

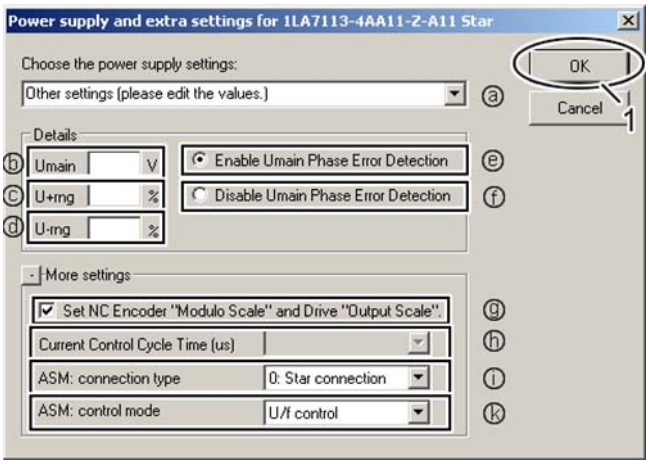
e) & f) Phase monitoring is only useful for a 3-phase mains supply. Switch phase monitoring on or off (only possible if no voltage was selected in a)).

g) Use this setting to enable automatic transfer of the resolution of the encoder and the scaling factor from the AX5000 to the NC. (Only required if the motor was integrated via an NC axis).

h) The cycle time of the current controller is 125 µs.

i) Selection of the type of ASM connection. If you have generated the motor data set, you can only select the type of connection entered under 3. 'Basic motor data –a)'. If Beckhoff has generated the motor data set, you can choose between star connection and delta connection.

k) Selection of the ASM control mode. If you select 'U/f control', only open-loop operation of the motor is possible; the AX5000 then acts like a frequency converter. If you select 'i-control with feedback', closed-loop operation of the motor is possible, but the motor must be equipped with a feedback system. Click on 'OK' (1) to complete the procedure.



Open-loop

If open-loop operation of the motor is desired, you can influence the operating behaviour with the following parameters.

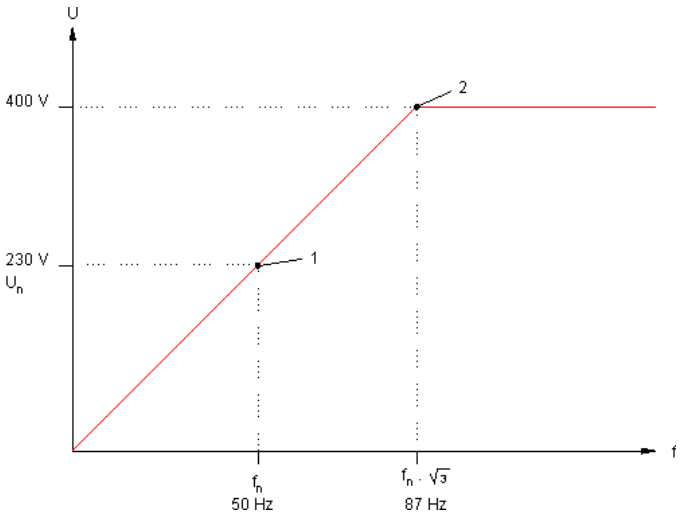
Interdependence between the type of connection of the motor, the speed and the rated output current of the AX5000

Example motor:

Asynchronous motor with rated voltage 230 V and rated current 6 A at 50 Hz for delta connection or rated voltage 400 V, rated current 3.5 A at 50 Hz

for star connection

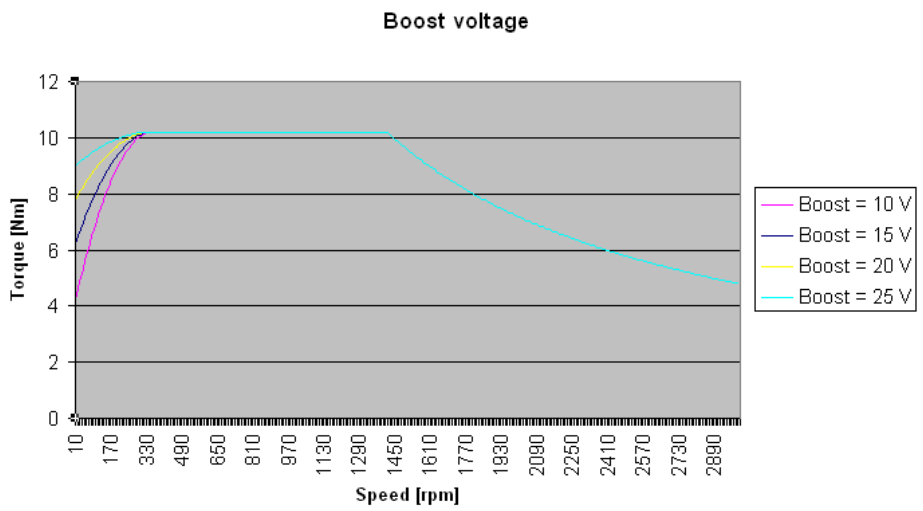
If your application requires speeds above the nominal speed (1), this requirement can be realised without having to use a bigger motor:
The AX5000 can provide 400 V of channel output power and thus operate the asynchronous motor in delta connection at up to 87 Hz (2) without field weakening occurring, i.e. with the nominal torque. You only need to note that a rated current of 6 A is required.



Boost voltage

The operation of an asynchronous motor with a linear U/f characteristic curve (see illustration above) results in a weakening of the torque in the lower speed range due to the dominant resistive component. The standstill torque is zero without a boost voltage. Furthermore, the asynchronous motor requires a certain time after the current is applied in order to build up the magnetic field on the rotor and, hence, to generate the magnetic force or the torque. If your application can not tolerate this delay, there is a possibility to reduce this time delay via the so-called 'boost voltage', which 'premagnetises' the rotor. With 'premagnetisation' a magnetic field is created in the rotor even though the rotor is not moving. Torque is hence immediately available to rotate the rotor shaft if a target speed is specified. The interdependence between the boost voltage, speed and torque is illustrated in the graphic below on the basis of an example motor. The influence of the boost voltage on to the torque is clearly visible at low speeds.

Example motor:
Nominal speed: 1410 rpm
Rated torque: 10.2
Breakdown torque: 28.6
Starting torque: 25.5
Power factor: 0.78
Efficiency: 0.79



The boost voltage is parameterised in the IDN-P-0-0103. Most applications will be covered by the default setting of 10 V.

Warning

Attention: destruction of the motor

In an asynchronous motor without an external fan, the motor temperature must be monitored in the lower speed range when boost voltage is used. If necessary, you can change the boost voltage online.

Settings for ramping up and down

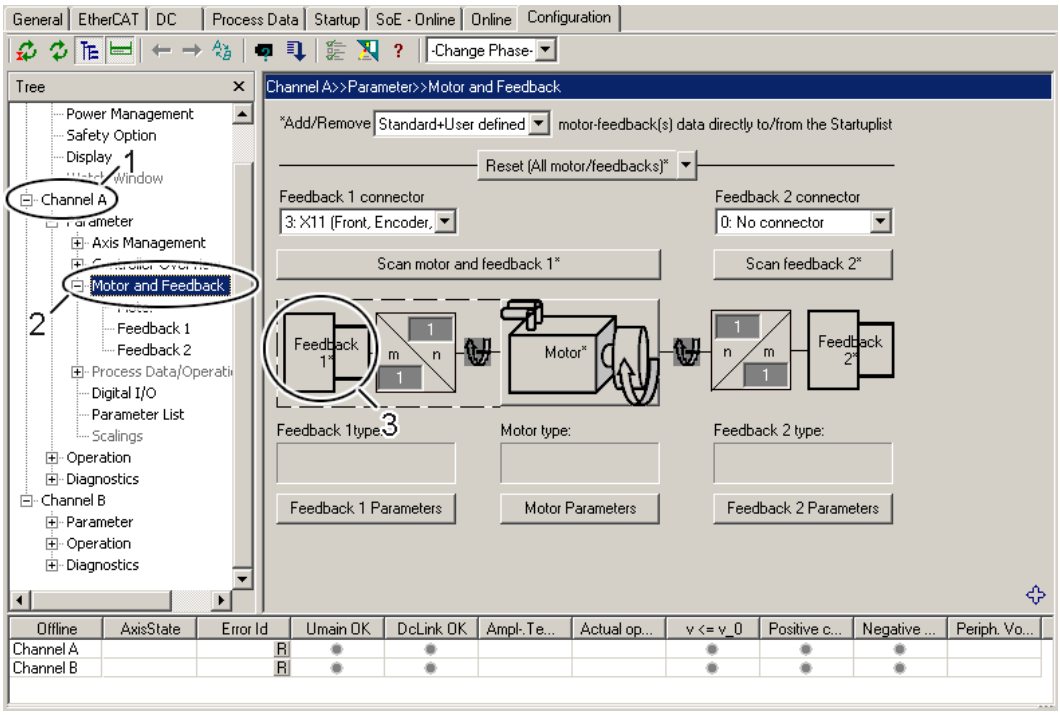
In the open-loop operation of the asynchronous motor, the values you need to adjust for the ramps depend on the application.
The ramp-up is parameterised in the IDN S-0-0136 and the ramp-down in the IDN S-0-0137.

Closed-loop

If closed-loop operation of the asynchronous motor is desired, you must select the feedback system used in the motor in the TCDM.

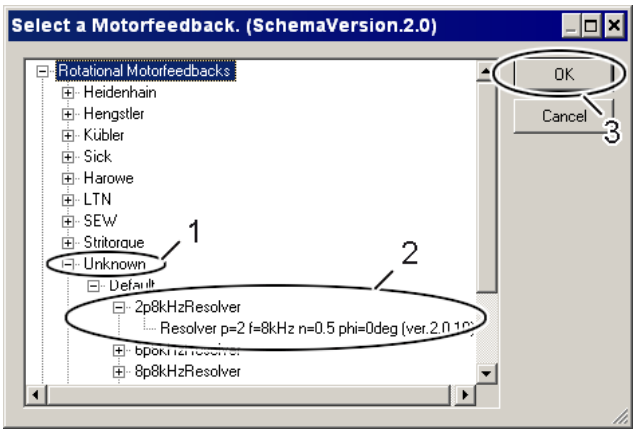
Feedback

Start the TCDM and click the entry (2) under the relevant channel (1) in the tree; the motor/feedback configuration appears in the TCDM working area. Click on the 'Feedback 1' (3) field to open the 'Feedback selection window'. You can view all available feedback systems in the 'Feedback selection window'.



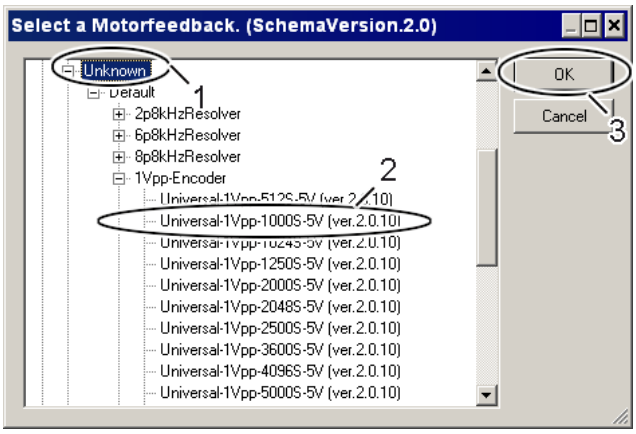
1a. Feedback selection - resolver

You can only select one existing feedback system. Either choose the feedback system of an existing manufacturer or choose a standard feedback system under 'Unknown' (1). If your motor is equipped with a resolver, determine the parameters of the resolver and select the appropriate resolver type (2). Typical parameters for the classification of resolvers are the number of poles 'p' and the gear ratio 'n'. Click on 'OK' (3) to complete the procedure.



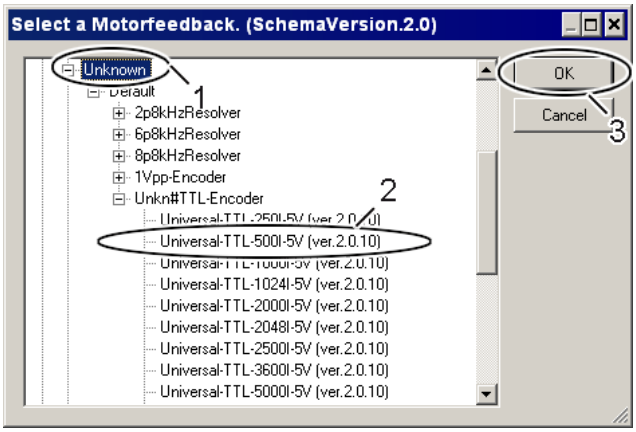
1b. Feedback selection - 1Vpp encoder

You can only select one existing feedback system. Either choose the feedback system of an existing manufacturer or choose a standard feedback system under 'Unknown' (1). If your motor is equipped with a 1Vpp encoder, determine the parameters of the feedback system and select the appropriate encoder (2). Typical parameters for the classification of 1Vpp encoders are the number of lines 's' and the supply voltage '5 V or 5 V fixed'. The difference between the two voltage variants is the use of a sense line (5 V). Click on 'OK' (3) to complete the procedure.



1c. Feedback selection - TTL encoder

You can only select one existing feedback system. Either choose the feedback system of an existing manufacturer or choose a standard feedback system under 'Unknown' (1). If your motor is equipped with a TTL encoder, determine the parameters of the feedback system and select the appropriate TTL encoder (2). Typical parameters for the classification of TTL encoders are the number of lines 's' and the supply voltage '5 V or 5 V fixed'. The difference between the two voltage variants is the use of a sense line (5 V). Click on 'OK' (3) to complete the procedure.



Commutation

In asynchronous motors the rotor magnetic field is generated electrically by means of rotor windings, which are energised by the servo drive. For this reason, neither a part-absolute nor an absolute encoder system is required for commutation; wake+shake also does not need to be used.

X13 (A), X23 (B): Motor connection

Terminal point	Signal
U	Motor connection U
V	Motor connection V
W	Motor connection W
PE	Protective conductor
Shroud	Screen

X14 (A), X24 (B): Motor brake, thermal contact

Terminal point	Signal	output current
T-	Temp. - *	
T+	Temp. + *	
PE	Protective conductor and signal pair screen	
B-	Brake, GND	
B+	Brake (Un) +	max. 1,5 A

*) Switch, KTY 83-1xx or KTY 84-1xx

Destruction of the AX5000!

CAUTION Read the 'Cables' chapter carefully and be sure to adhere to the specifications contained in it.

Thermal protection contact for Beckhoff motors

AM2000 with resolver

Via resolver cable.

AM2000 with EnDat

The thermal protection contact is implemented in the encoder cable to the AX5000 and must be bridged to the resolver connection via an adapter / Y cable.

AM2000 with BiSS

Not available.

AM3000 with resolver

Via resolver cable.

AM3000 with EnDat

Via motor cable.

AM3000 with BiSS

Via motor cable.

Linear motors AL2000

The thermal protection contact exits the motor via a separate cable.

1. If the pre-assembled Beckhoff motor and encoder cable is used, an additional thermal protection contact cable (ZK4540-0020-xxx) is required for connecting the thermal protection contact with the AX5000 resolver interface, where temperature evaluation takes place.
2. If the AL2250 connector box is used, the thermal protection contact is automatically bridged to the motor cable.

Temperature monitoring and evaluation for motors from other manufacturers

1. Temperature monitoring via PTC, Klixon or bimetal

Evaluation either on the resolver interface (X12 / X22) or the temperature contact (X14 / X24)

2. Analog temperature evaluation (e.g. KTY)

Evaluation only on the temperature contact (X14 / X24)

BECKHOFF AX5000: Commissioning

Basic Principles

In general, two TwinCAT software modules are required for controlling the AX5000: TwinCAT NC PTP and TwinCAT PLC.

TwinCAT NC is a closed software module whose features the user can only influence via parameters. The *TwinCAT NC* parameters can be set in the *TwinCAT System Manager*.

TwinCAT PLC is an interpreter for a program code which the user creates in the *PLC Control* development environment.

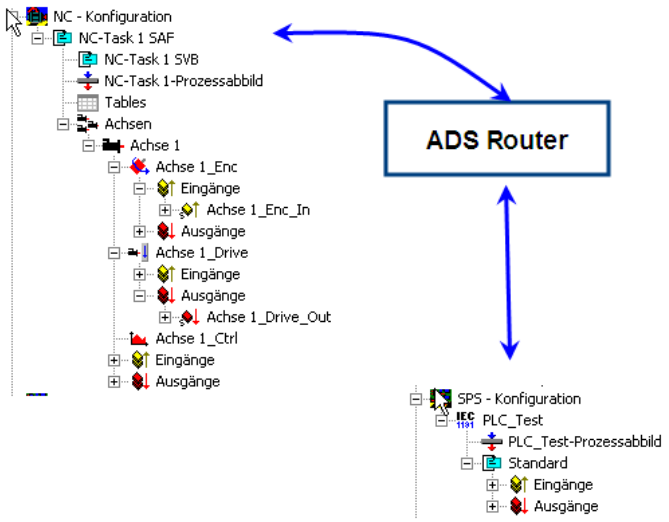
Structure of TwinCAT NC PTP

TwinCAT NC has 2 tasks:

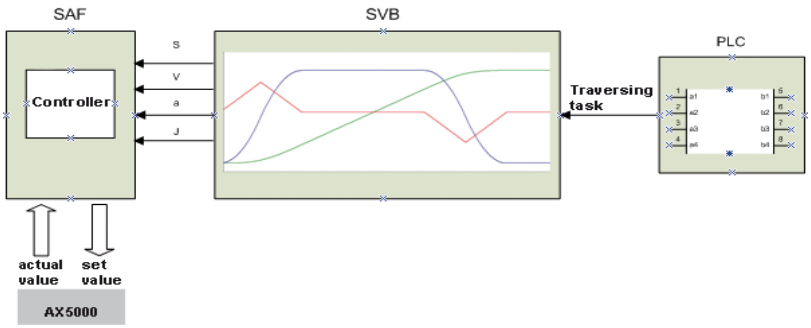
- NC task 1 SPP (**S**et **P**re**P**aration task)
- NC task 1 SEC (**S**et **E**xe**C**ution task)

The SPP task is responsible for planning the requested traversing task. The SEC task is responsible for maintaining this path.

The traversing task leaves the PLC in the direction of the ADS router with destination *NC-Task 1 SVB* (NC task 1 SPP). The router relays the telegram to this task.



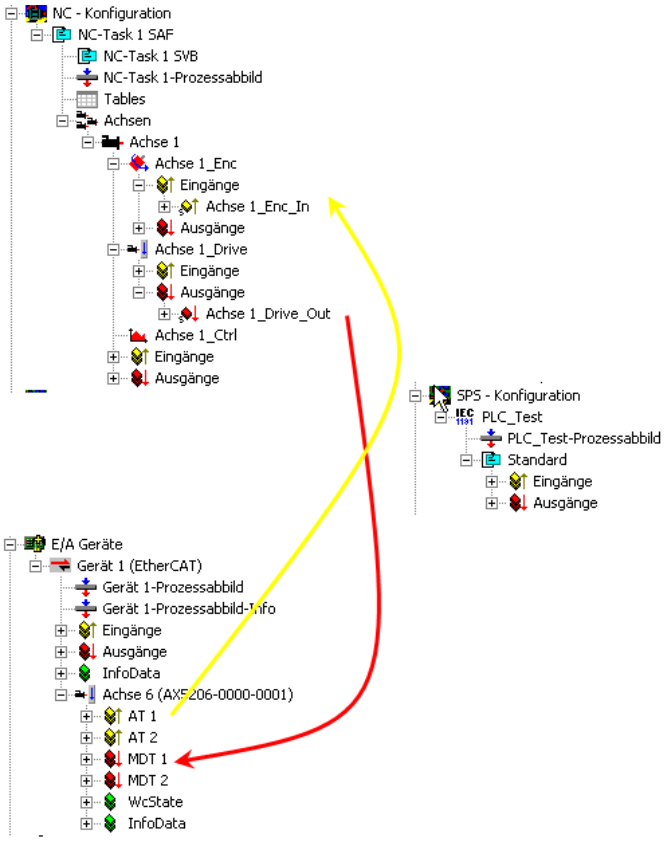
The NC accepts or rejects the message. The response arrives back at the calling block in the PLC via the same route. Instructions are issued based on blocks contained in TCMC.lib. Once the NC has accepted the instruction, the system tries to calculate a solution taking into account the boundary conditions (max. velocity, acceleration, deceleration, and jerk).



If a solution exists, a table containing the position (s) velocity (v), acceleration/deceleration (a) and jerk (j) for the whole travel time within the sampling time of the SEC task is transferred to the SEC.

If no solution exists, the system deviates downwards based on maximum jerk, maximum acceleration, and maximum velocity (in this order).

Actual and set values shown in the diagram are served by the 1_Enc axis and 1_Drive axis components.



Since the AX5000 is known to the system as a slave, linking can take place automatically if required. In the event of problems the link can be checked by the user.

NC / AX5000 link specification

NC set values	AX5000 set values	NC actual values	AX5000 Actual values
axis n_Drive / outputs/axis n_DriveOut / nOutData1	MDT n / position set value (option)	axis n_Enc / inputs / axis 1_Enc_In / nInData1	AT n / actual position value sensor 1
axis n_Drive / outputs/axis n_DriveOut / nOutData2	MDT n / velocity set value		
axis n_Drive / outputs/axis n_DriveOut / nCtrl1	MDT n / master control word (Hi-byte)	axis n_Drive / inputs/axis n_DriveIn / nStatus1 & nStatus2	AT n / drive status word
		axis n_Drive / inputs/axis n_DriveIn / nStatus4	WcState' / WcState

Structure of the AX5000 slave in the TwinCAT System Manager.

The AX5000 parameter management is based on the Sercos profile. The parameter description is based on a standardised structure.

Element 1: IDN (required)

IDN description. Bit 15 distinguishes between standard parameters (S-0-nnnn) and manufacturer-specific parameters (P-0-mmmm).

Bit	Value	Description
15	0	S-0-nnnn (standard parameter)
	1	P-0-mmmm (manufacturer-specific parameter)
12-14		product data (manufacturer-specific)
0-11	0...4095	block number

Element 2: Name (optional)

The name includes a brief description of the parameter in text form.

Byte 1,2	Byte 3,4	Byte 5, max. 64
Current length of the name in characters (1 character = 1 byte)	maximum length of the name in characters (1 character = 1 byte)	name (max. 60 characters)

Element 3: Attributes (required)

This double word describes the IDN properties (write protection, data type, decimal places).

Bit	Value	Description	
31	-	Reserved	
30	1 / 0	Write protection in Op phase / no write protection in Op phase	
29	1 / 0	Write protection in SaveOp phase / no write protection in SaveOp phase	
28	1 / 0	Write protection in PreOp phase / no write protection in PreOp phase	
24-27	0000 - 1111	Number of decimal places for floating point numbers	
23	-	Reserved	
20-22	Value	Data type	Represented as
	000	Binary	Binary
	001	Unsign Integer	Unsigned decimal
	010	Sign Integer	Sign decimal
	011	Unsign Integer	Hexadecimal
	100	Character string	Text
	101	Unsign Integer	IDN
	110	Floating point number	Sign decimal with exponent
	111	Reserved	
19	1 / 0	Command / Parameter. A command executes an assigned function	
16-18	000	Reserved	
	001	Length: 2 bytes	
	010	Length: 4 bytes	
	011	Length: 8 bytes	
	100		
	101		
	110		
	111		

Element 4: Units (optional)

Byte 1,2	Byte 3,4	Byte 5, max. 16
Current length of the name in characters (1 character = 1 byte)	maximum length of the name in characters (1 character = 1 byte)	Physical units max. 12 characters.

Element 5 & 6: Min. & max. values (optional)

The limits for the associated IDN entries are specified here.

Element 7: Value (required)

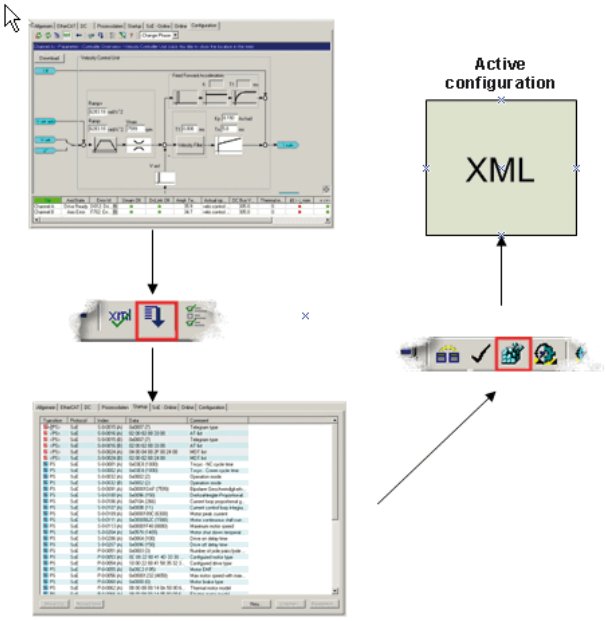
Four different memory lengths are used.

- Fixed length of 2 bytes
- Fixed length of 4 bytes
- Fixed length of 8 bytes
- Variable length of up to 65532 bytes

With this variables IDN structure different data types can be stored, displayed and managed. These parameters specify the controller characteristics:

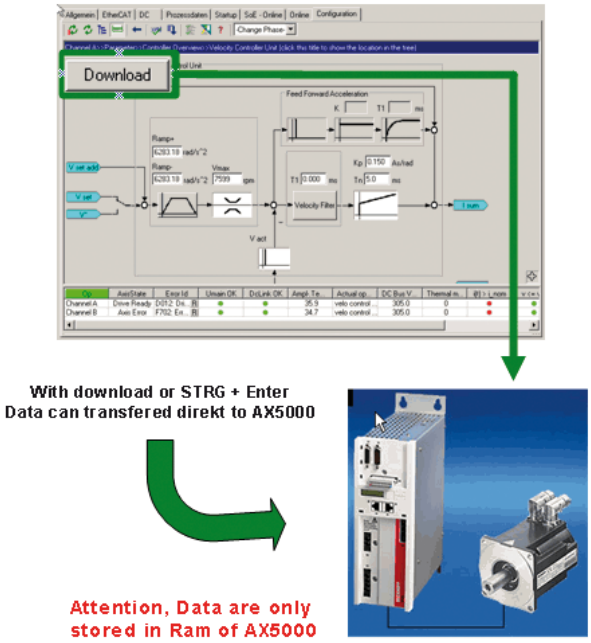
- Motor data
- Feedback data
- Controller settings
- Special functions

These data are not stored in the controller but in the TwinCAT configuration. The following diagram illustrates how the data configured in the TcDriveManager are stored.



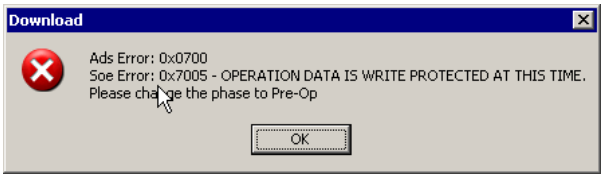
Once the parameters have been set in the TcDriveManager they can be transferred to the Startup list.
After the data have been transferred to the Startup list, they are downloaded to the controller after configuration has been saved and TwinCAT has been restarted.

Some parameter can simply be transferred temporarily into the controller RAM. These parameters are lost during a restart or a power failure.



Inactive write protection is a prerequisite for a successful download. Write protection is set for some parameters when the EtherCAT slave reaches the SafeOP or OP state.

An attempt to change a read-only parameter results in the following error message.



In this case the only available procedure is as follows:

1. Parameter transfer to the Startup list
2. Saving the configuration

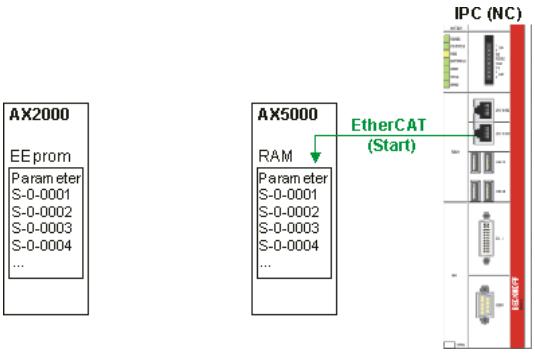
3. Restart TwinCAT

BECKHOFF AX5000: Commissioning

Parameter handling

The servo drives from the AX5000 series use a new method for managing their configuration parameters (IDNs).

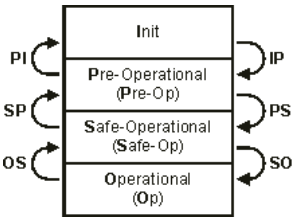
In contrast to conventional servo drives (e.g. AX2000) these parameter are not stored on the AX5000 itself, but in the TwinCAT project for the higher-level control system (NC on the IPC).



The parameter are transferred from the NC to the servo drive during startup of the EtherCAT system. Due to the high data transfer rate offered by EtherCAT this process is very fast, even in larger systems.

Transitions

During startup the EtherCAT system passes through the following states: Init, Pre-Operational, Safe-Operational, and Operational (see section EtherCAT state machine).

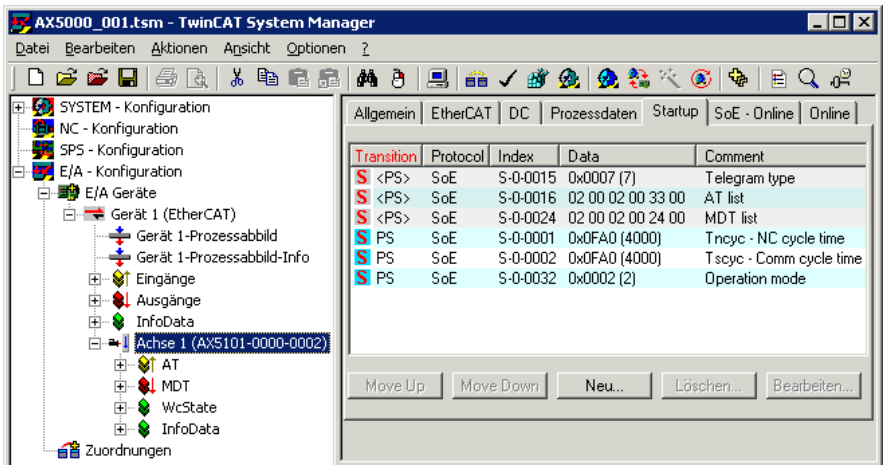


The diagram shows the following transitions:

IP: Transition from **I**nit to **P**re-Operational
PS: Transition from **P**re-Operational to **S**afe-Operational
SO: Transition from **S**afe-Operational to **O**perational
OS: Transition from **O**perational to **S**afe-Operational
SP: Transition from **S**afe-Operational to **P**re-Operational
PI: Transition from **P**re-Operational to **I**nit

In practice the parameters (IDNs) are transferred from the higher-level control system to the AX5000 during transitions IP, PS and SO.

The TwinCAT System Manager indicates at which transition the individual AX5000 parameters can be transferred.



BECKHOFF AX5000: Commissioning

First steps

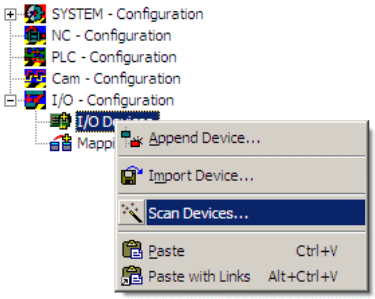
To facilitate commissioning of AX5000 servo drives the commissioning tool is integrated in the TwinCAT System Manager. This means that existing and familiar tools such as the oscilloscope can be used without the need to use a different tool for fine-tuning in TwinCAT after the axes have been optimised. Before the actual commissioning you should first consider the overall configuration of the machine. There are several things to observe, particularly in relation to fault management in the case of the 2-channel AX5000.

Integration of axes

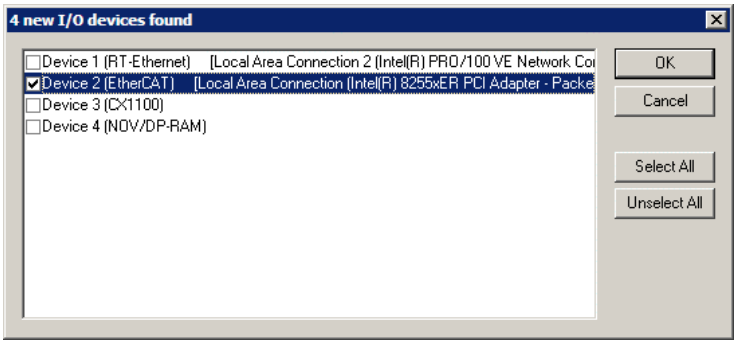
Requirements:

- Control voltage : 24 V_{DC}
- EtherCAT connection with master card
- TwinCAT in Config Mode

First the bus is scanned for connected EtherCAT devices:



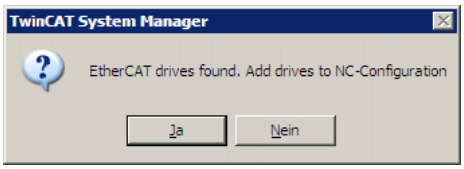
Select the EtherCAT interface card



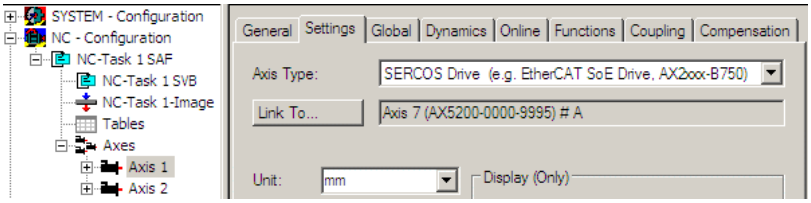
Search for connected devices (Scan for boxes):

Acknowledge the request "Activate Free Run" with NO.

If EtherCAT axes are found the system asks whether the axes should be linked in TwinCAT NC. Confirm with Yes.



All axes that were found appear in the NC configuration. They now have to be configured in turn. Open the "Settings" tab.
AX5000 servo drives are displayed as EtherCAT with communication type SoE (Sercos profile over EtherCAT).



The axis details can be found in the I/O Configuration. Open the required axis. Open the TC Drive Manager via the "Configuration" tab.
The TC Drive Manager includes all required data, parameters and tools for configuring and commissioning a servo axis. The menu tree distinguishes between equipment data and axis data. For multi-axis devices (e.g. AX5206) the axis data are identified as channel A and channel B.

Description of the menu bar:

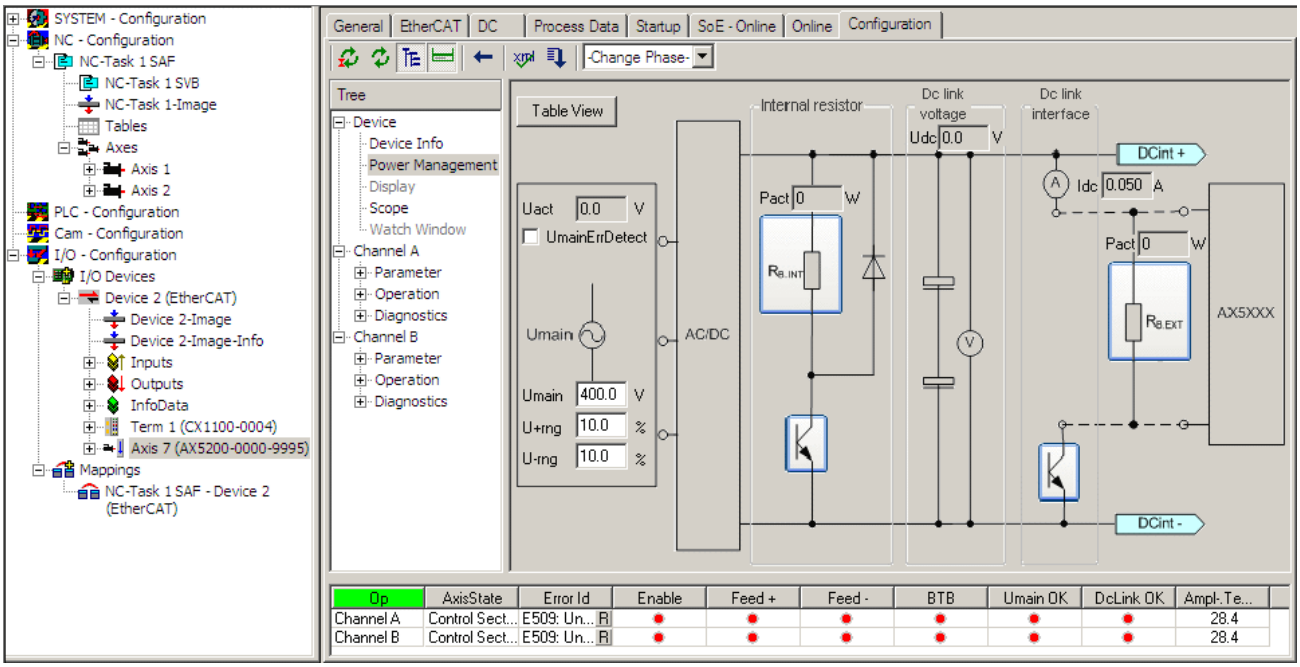
Menu item *Device* Info contains all device-specific data such as capacity, serial number, ...

Menu item *Power Management* is used to set the mains voltage with country-specific upper and lower tolerance. The internal or external brake resistor can also
be selected and dimensioned in this menu.

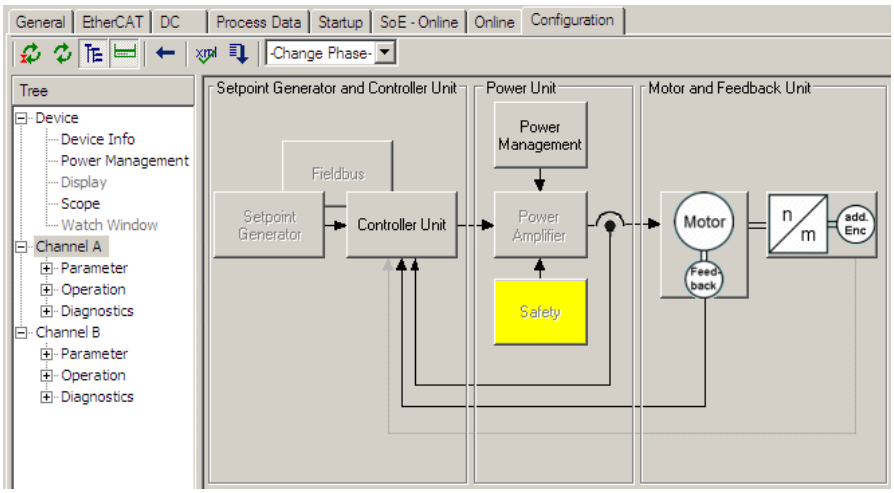
Menu item *Display* is used to specify individual error messages etc.

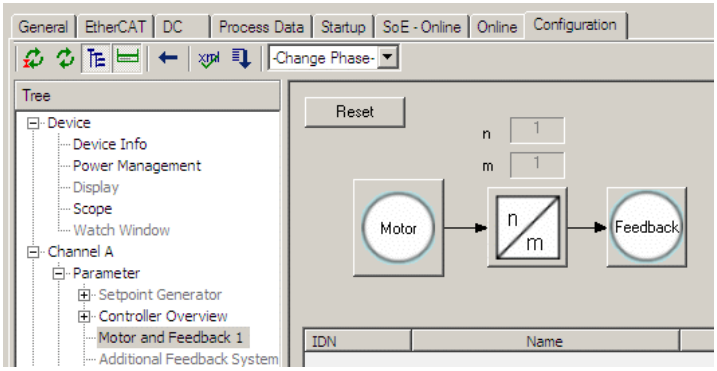
Menu item *Scope* .....

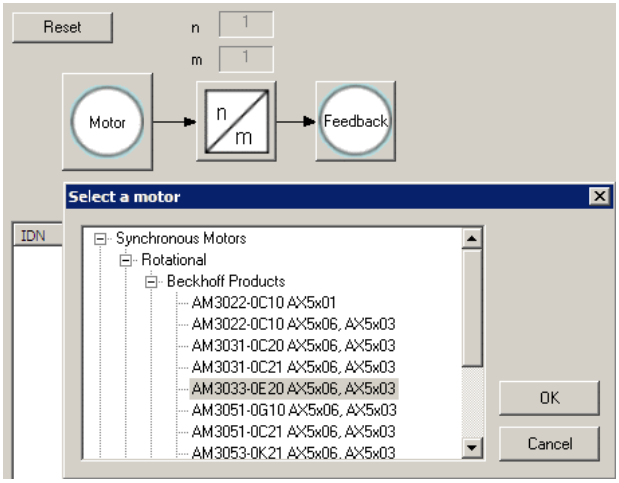
Menu item *Watch Window* .....

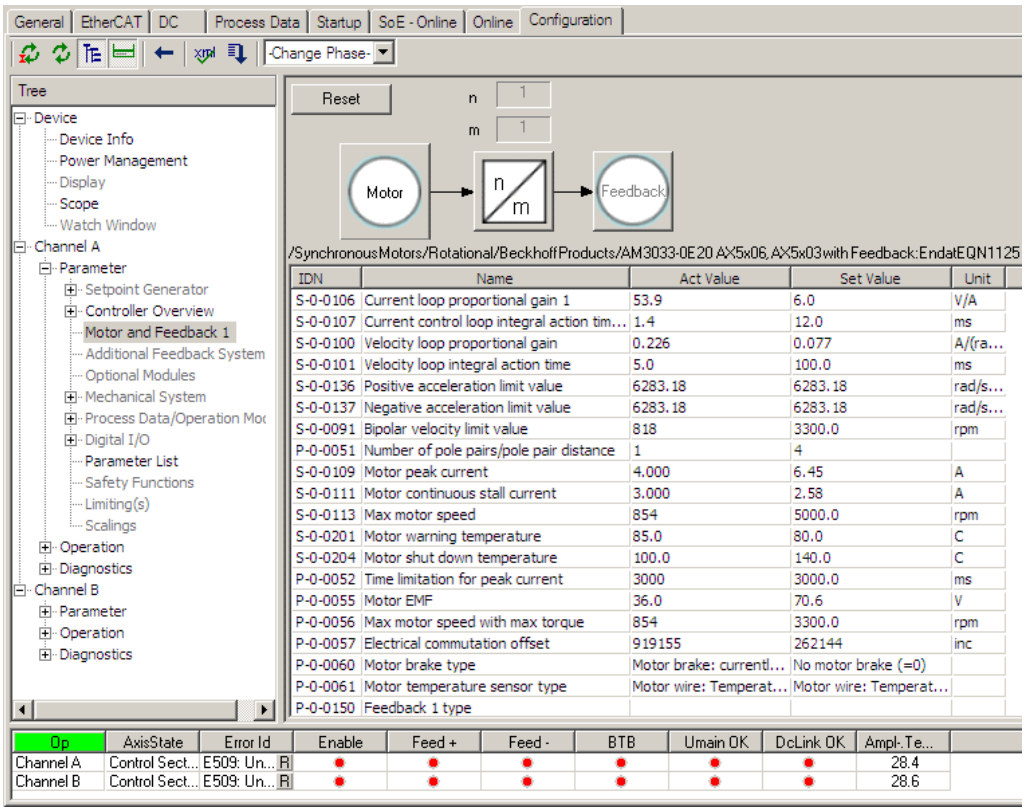


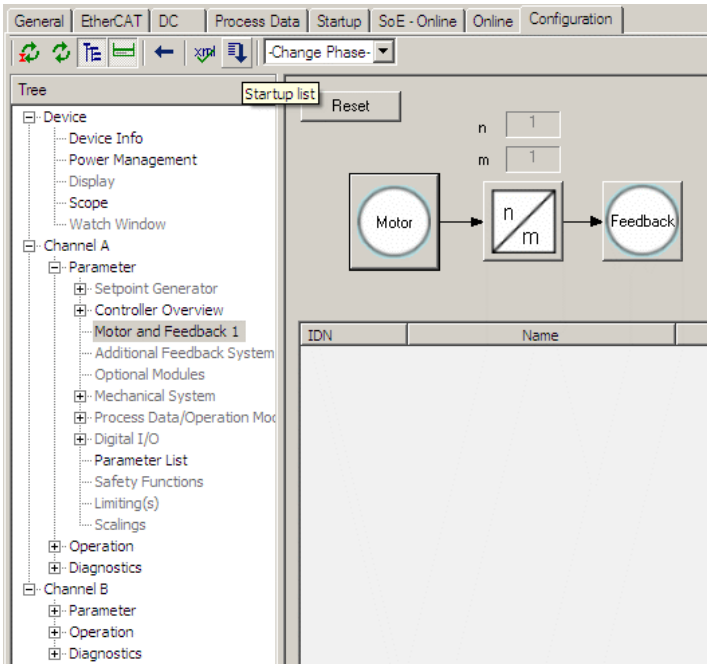
In the next step the axis-specific parameters and data are set.
The connected motor is selected from the motor database in the Motor and Feedback section.


General
EtherCAT
DC
Process Data
Startup
SoE - Online
Online
Configuration
-Change Phase-
Tree
Device
Device Info
Power Management
Display
Scope
Watch Window
Channel A
Parameter
Operation
Diagnostics
Channel B
Parameter
Operation
Diagnostics
Setpoint Generator and Controller Unit
Power Unit
Motor and Feedback Unit
Fieldbus
Setpoint Generator
Controller Unit
Power Management
Power Amplifier
Safety
Motor
Feed-back
n
m
add. Enc

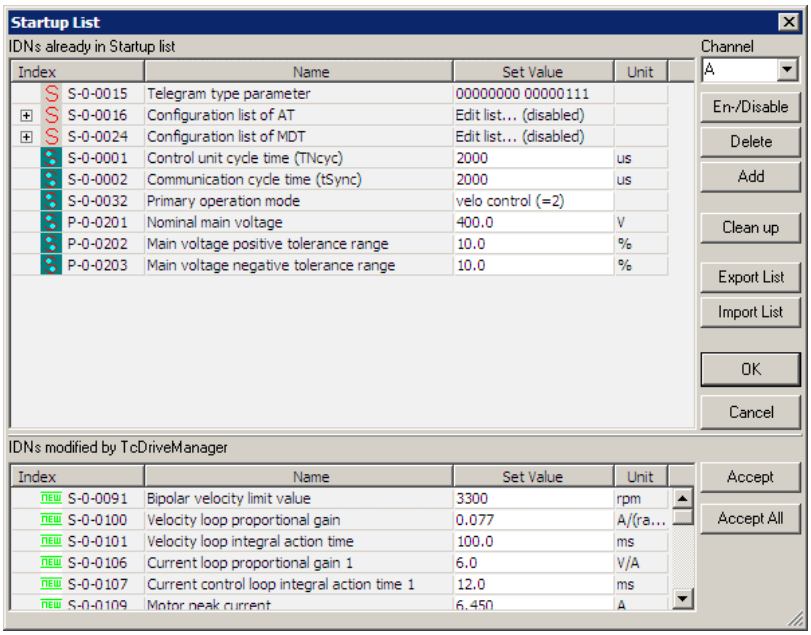

General
EtherCAT
DC
Process Data
Startup
SoE - Online
Online
Configuration
-Change Phase-
Tree
Device
Device Info
Power Management
Display
Scope
Watch Window
Channel A
Parameter
Setpoint Generator
Controller Overview
Motor and Feedback 1
Additional Feedback System
Reset
n
1
m
1
Motor
n
m
Feedback
IDN
Name


Reset
n
1
m
1
Motor
n
m
Feedback
Select a motor
IDN
Synchronous Motors
Rotational
Beckhoff Products
AM3022-0C10 AX5x01
AM3022-0C10 AX5x06, AX5x03
AM3031-0C20 AX5x06, AX5x03
AM3031-0C21 AX5x06, AX5x03
AM3033-0E20 AX5x06, AX5x03
AM3051-0G10 AX5x06, AX5x03
AM3051-0C21 AX5x06, AX5x03
AM3053-0K21 AX5x06, AX5x03
OK
Cancel

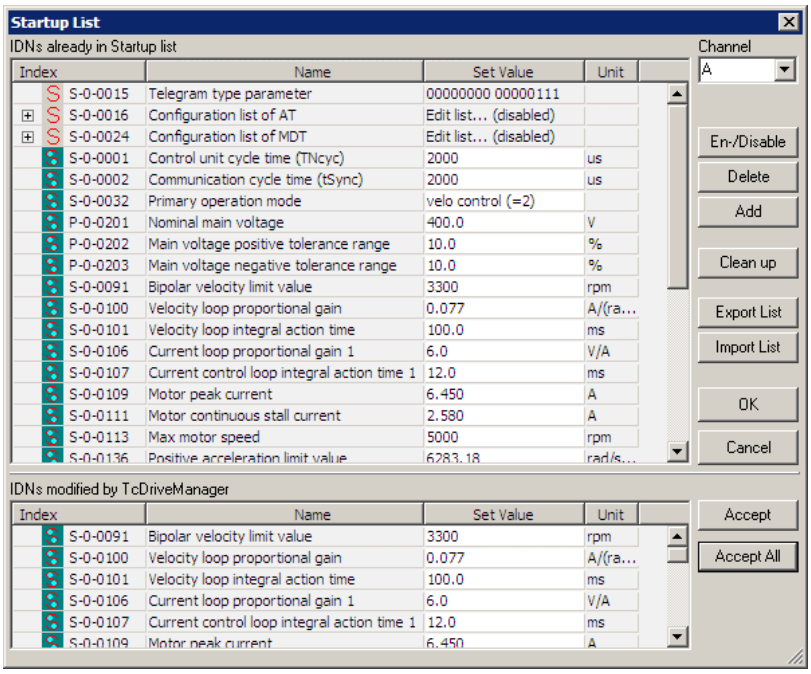




In the upper section of the Startup list all parameters / IDNs can be found that are available as default or may already have been modified. All further parameters that are called up via the TC Drive Manager can be found in the lower section. Add these parameters to the Startup list with ***Accept All***.

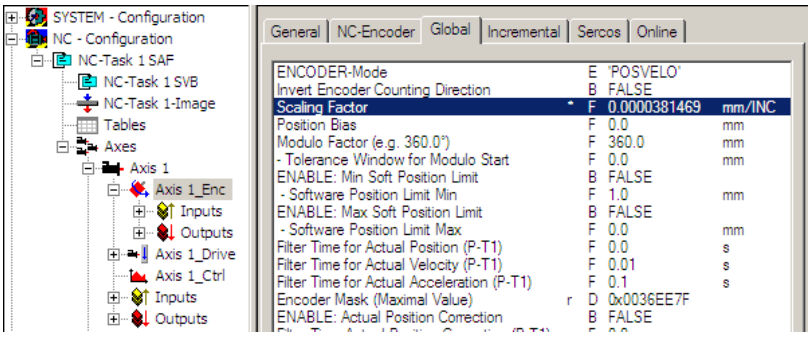


Startup list after all parameters have been entered:

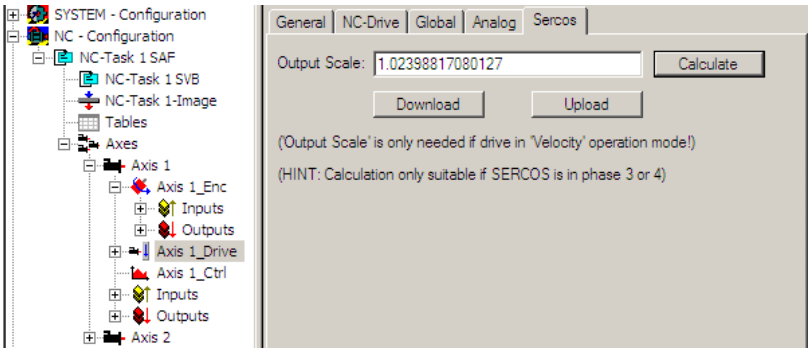


Repeat this procedure is for all other axes.

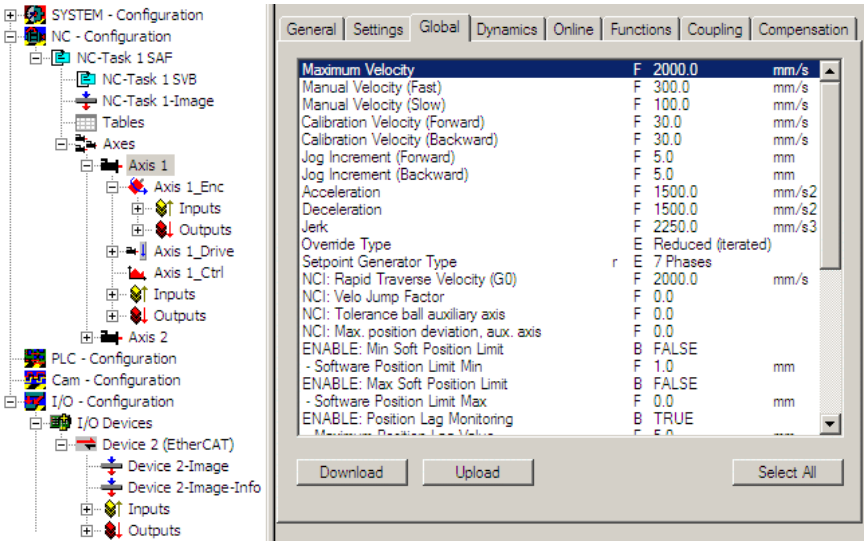
Now switch to NC configuration:
First the scaling factor has to be calculated. Example: One motor revolution corresponds to 40 mm linear feed. The resolution of the encoder in TwinCAT is 2^20. The scaling factor is therefore 40 / 2^20 = 0.0000381469 mm/INC. Enter and save this value.



If the AX5000 is operated via the velocity interface the encoder overflow for modulo mode must be calculated. Click ***Calculate*** and ***Download***.



In the next step the maximum permissible axis velocity is calculated and entered: In our example: 40 mm feed x 3000 rpm / 60 = 2000 mm/s. This value can be stored as ***reference velocitiy***.



Diagnostics

Display

Description in preparation

LED

Description in preparation

BECKHOFF AX5000: Product overview

Operating modes

In drive technology a distinction is made between the following operating modes:

- Current / torque control
- Speed control
- Position control

Electrical drives tend to be speed- or position-controlled. In the SoE standard the individual operating modes are specified via the standard parameter S-0-0032 (main operating mode).

Mode parameterisation according to SoE

S-0-0032 (main operating mode)		
Bits 0-8	**Operation mode**	**Bit 3**
0 0000 0000	no mode selected	
0 0000 0001	torque control	

0 0000 0010	Velocity regulation	
0 0000 X011	Position control with position encoder 1 (motor resolver MG)	0 with following error / 1 without following error
0 0000 X100	Position control with position encoder 2 (external encoder EG)	0 with following error / 1 without following error
0 0000 X101	Position control with position encoder 1 + 2	0 with following error / 1 without following error

The diagram shows a typical control structure with higher-level position controller and subordinate speed and current controller.

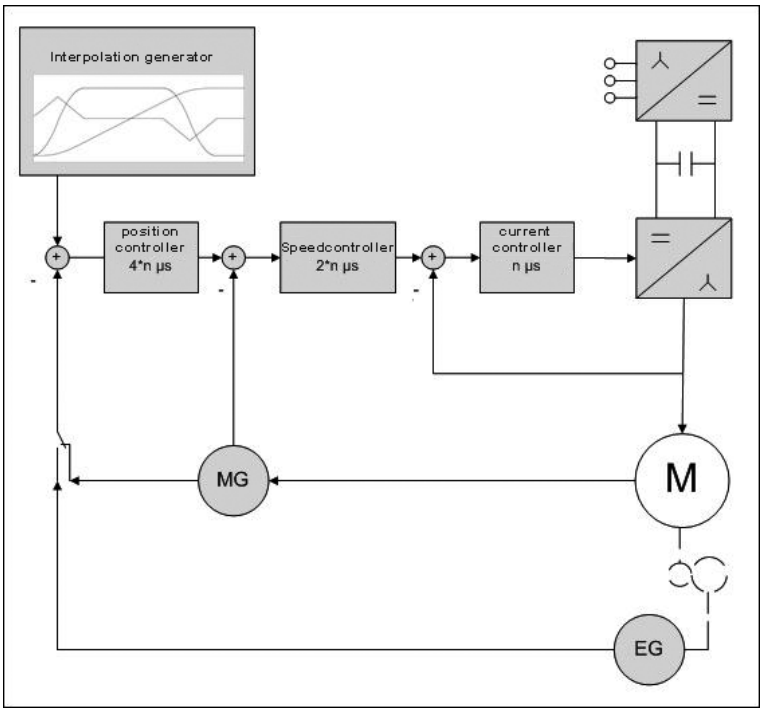


Fig. 1: Controller structure

A cascaded controller structure consisting of current, speed and position controllers has proven to be necessary for achieving high dynamics and positioning accuracy. The diagram illustrates the time constants of the individual control loops, rising from inside to outside. Two operating modes are suitable for positioning: velocity set value specification or position set value specification.

Position specification

Fig. 1 also shows the interpolation generator. This can take the form of an external software or hardware solution or an option inherent in the servo drive. For the AX5000 TwinCAT PTP/NCI or TwinCAT CNC is used. This set value generator splits the travel command into small position segments. These segments have a temporal resolution that is set via the interpolation cycle (task time of the SAF task of the NC).

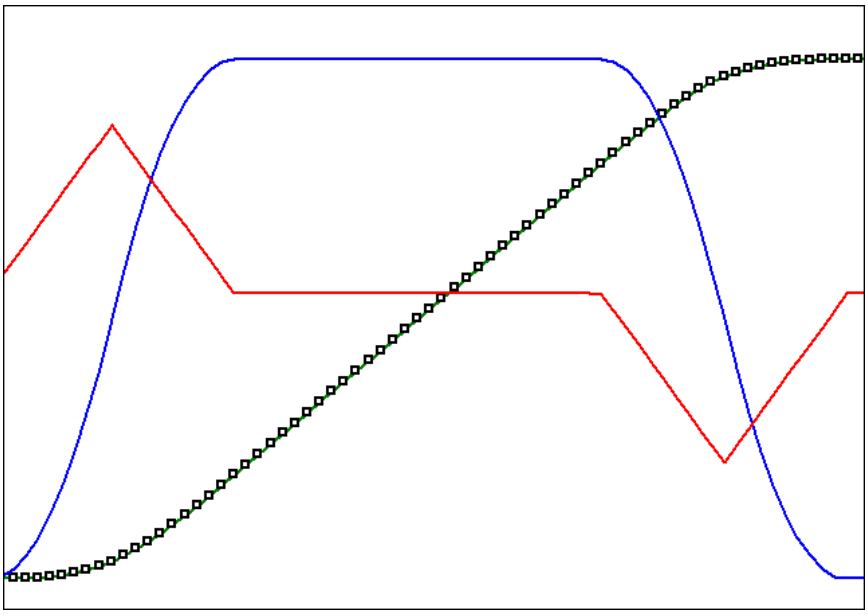


Fig. 2: Position specification

This mode is configured via parameter S-0-0032. The individual modes are shown in Table 1. In addition to the internal position controller velocity pre-control can be activated. If no pre-control is used the set value for the speed controller only consists of the product of the control deviation and the position controller gain.

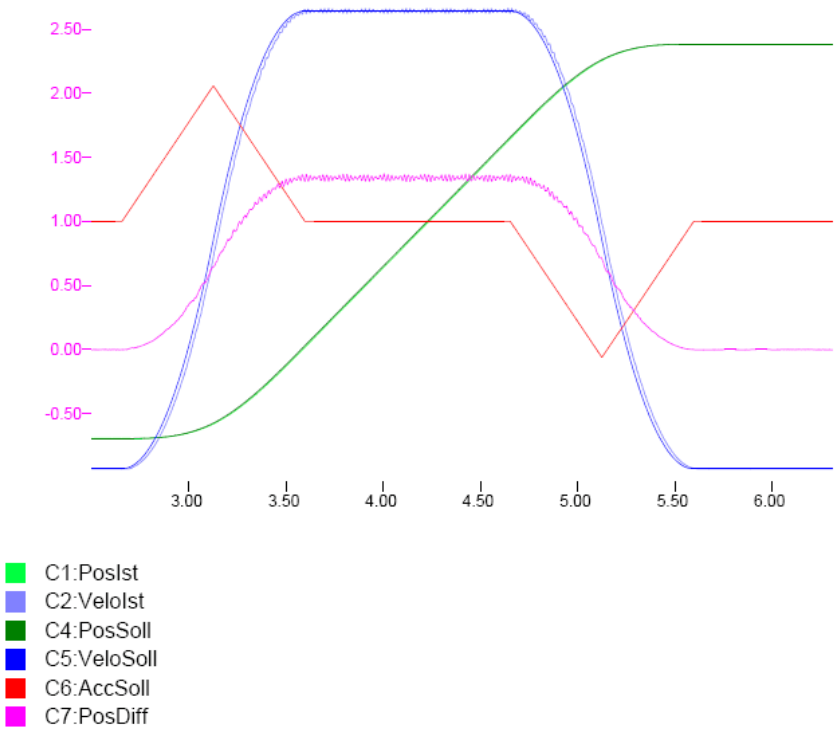


Fig. 3: Positioning without velocity pre-control

S-0-0032 (main operating mode)		
0 0000 0011	0x03	Position control with position encoder 1 (motor resolver MG) / with following error
0 0000 0100	0x04	Position control with position encoder 2 (external sensor EG) / with following error

Pre-control is generally advisable. Depending on the application the weighting of this parameter can be set between 0 and 100%. The following block diagram shows two options. One option is to calculate the pre-control in the drive. Using a simplified technique, the set position at time n Sn is subtracted from the set position from the pre-cycle and divided by the cycle time. Another option is to use the set velocity of the interpolation generator.

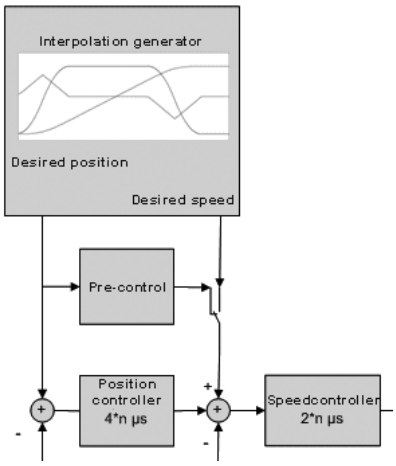


Fig. 4: Velocity pre-control

If velocity pre-control is used for positioning, the following error during the whole positioning process is relatively small (see Fig. 5).

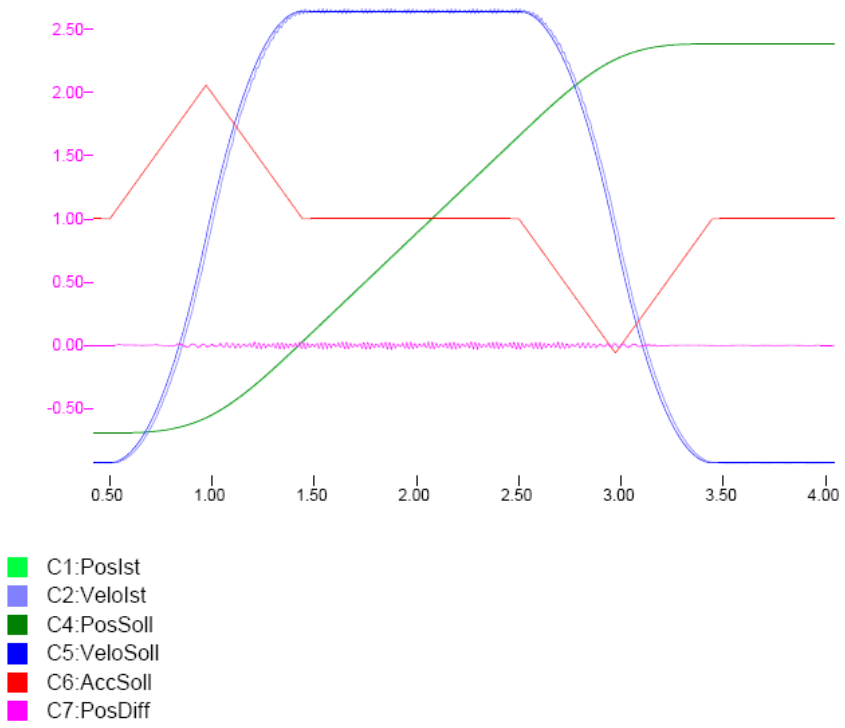


Fig. 5: Positioning with velocity pre-control

S-0-0032 (main operating mode)		
0 0000 1011	0x0B	Position control with position encoder 1 (motor encoder MG) / without following error
0 0000 1100	0x0C	Position control with position encoder 2 (external encoder EG) / without following error

Velocity specification

If the servo drive has no position controller or if the set velocity has to be influenced with additional components, the position controller can be moved to the interpolation generator. In this mode is the travel command is not only split into small position segments but also into velocity segments. The set velocity calculated by the interpolator is complemented by the value calculated by the TwinCAT-PTP position controller due to a following error.

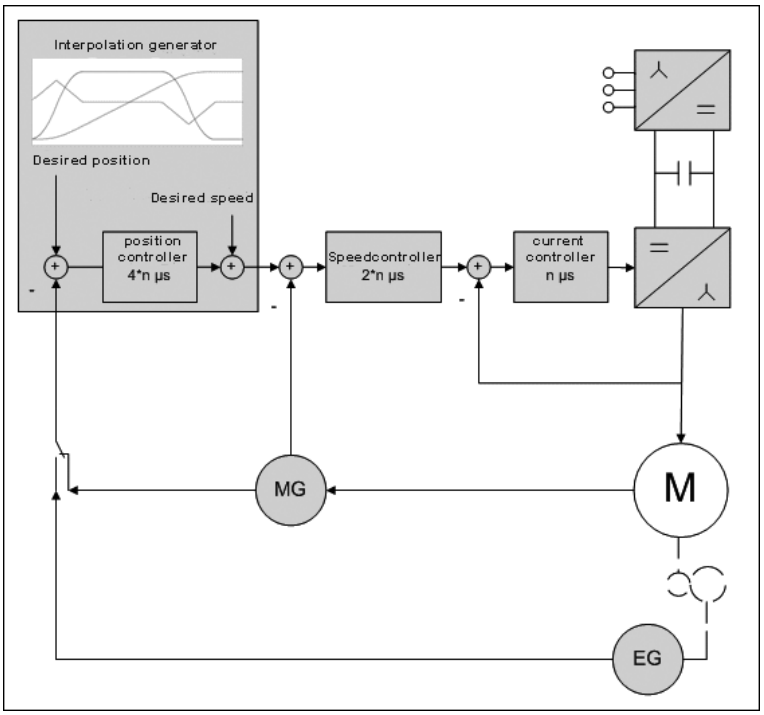


Fig. 6: Control structure in velocity specification mode

As for position specification, the interpolation points for the velocity set values have a temporal resolution that is greater than the interpolation cycle (task time of the SAF task of the NC).

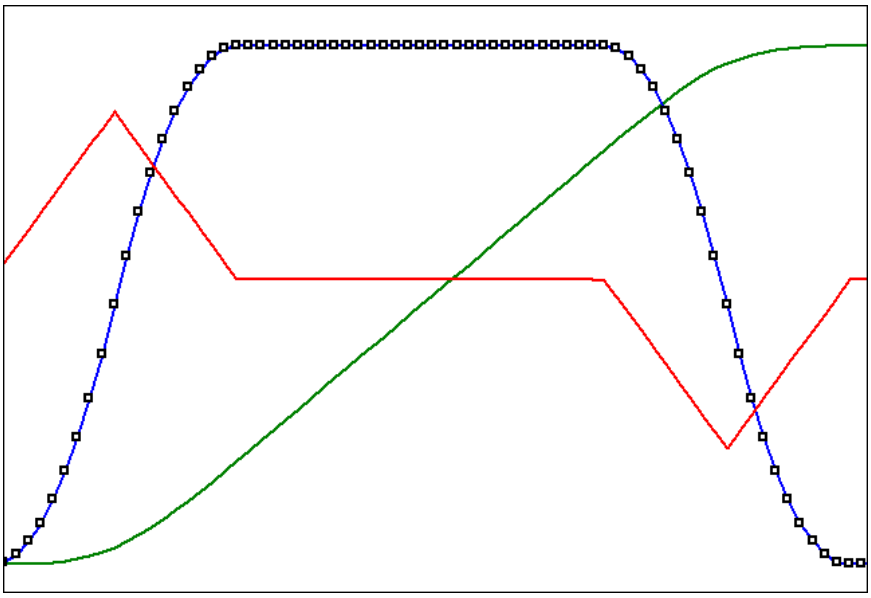


Fig. 7: Velocity specification

This mode is configured via parameter S-0-0032.

S-0-0032 (main operating mode)		
0 0000 0010	0x02	Velocity regulation

A further mode is torque control. In this mode is the set torque is specified. The actual torque is returned as feedback. Torque control is handled by the drive. If the actual value is based on an external measuring point, regulation (set value generation) should be provided in the control system.

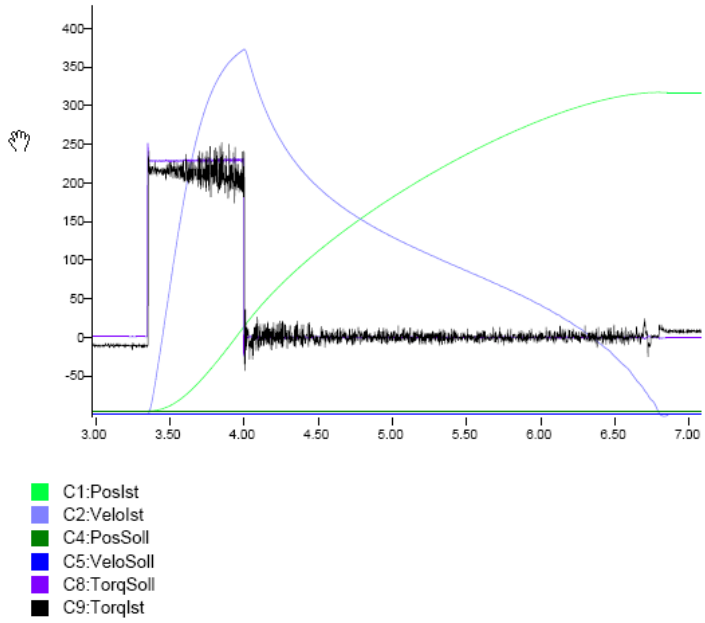


Fig. 8: Torque specification

S-0-0032 (main operating mode)		
0 0000 0001	0x01	torque control

BECKHOFF AX5000: Commissioning

Drive functions

CAUTION

Hazard to individuals and devices!

Please read the following functional descriptions carefully and parameterise the relevant functions.

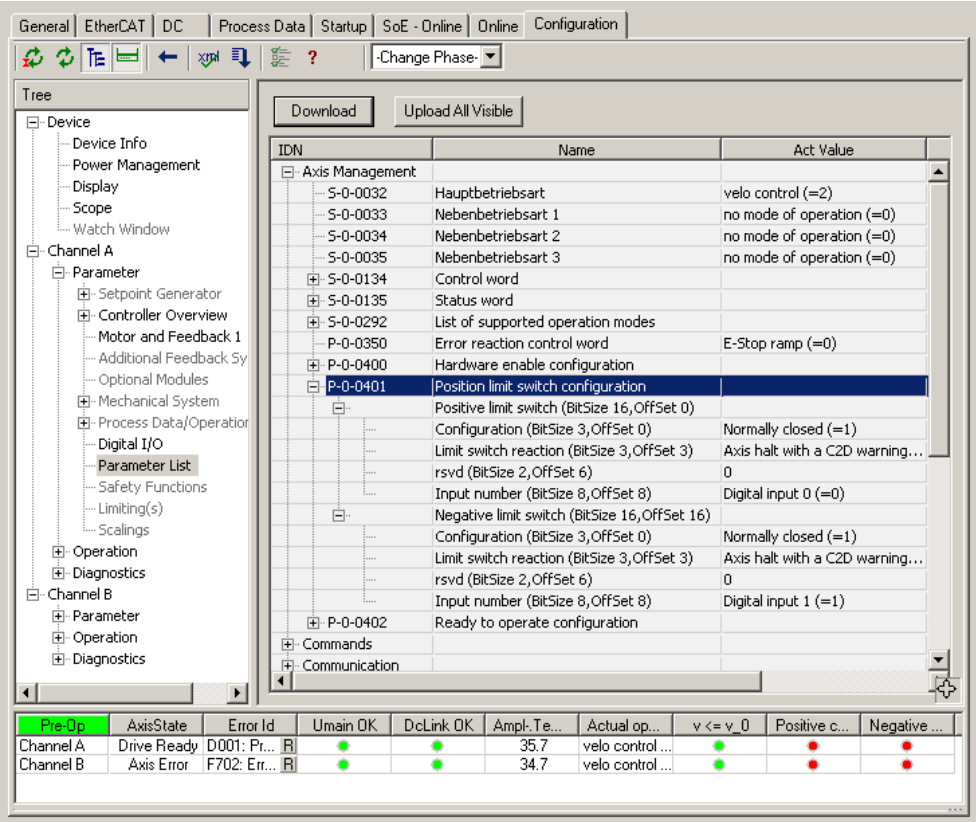
Limit switch monitoring

A translatory drive motion generally results in a finite path. In order to be able to protect the mechanical end positions, limit switches must be installed at a distance s to the end positions. If one of the switches is actuated, the servocontroller slows the drive down to 0 velocity with the emergency ramp (S-0-0372).

In the AX5000 the switch has the following properties:

Limit switch properties (P-0-0401)			
Configuration		**Reaction**	**Source**
0	No limit switch (default)		digital input 0 ... 7
1	N/C contact	0 = axis stops with a emergency ramp (S-0-0372) error (C1D) 2 = axis stops with a emergency ramp (S-0-0372) warning (C2D) 2 = axis stops with a stop ramp (S-0-0429) warning (C2D)	
2	N/O contact		

This structure is available twice under IDN P-0-0401, i.e. for the negative and the positive limit switch.



Example

A short example for calculating the distance between the limit switch and the mechanical limit stop is shown below:

Example			
Parameter no.	**Designation**	**Value**	**Unit**
S-0-0372	Emergency ramp	6283.18	rad/s^2
S-0-0429	Stop ramp	6283.18	rad/s^2
S-0-0091	Maximum speed, bipolar	6000	rpm
S-0-0079	Rotational position resolution	1048576	inc/rev
Machine data	Feed	20	mm/rev

Distance between mechanical limit stop and switch:

$$\omega = \frac{6000U/\min}{60s/\min} = 100U/s*2*\pi = 628{,}3rad/s$$

$$t = \frac{628{,}3rad/s}{6283{,}18rad/s^2} = 0{,}1s$$

$$\upsilon = \frac{\omega*t}{2} = \frac{628{,}3rad/s*0{,}1s}{2} = 31{,}4rad$$

$$s = \frac{31{,}4rad}{2*\pi} = 5U*20mm/U = 100mm$$

Hardware enable

On the AX5000 a hardware enable can be configured. This function operates in addition to the software enable originating from the controller via the bus system and a logical AND link. The digital input for the servocontroller is activated and allocated via parameter P-0-0400.

Axis Management			
S-0-0032	Hauptbetriebsart	velo control (=2)	velo control (=2)
S-0-0033	Nebenbetriebsart 1	torque control (=1)	torque control (=1)
S-0-0034	Nebenbetriebsart 2	no mode of operation ...	no mode of operation ...
S-0-0035	Nebenbetriebsart 3	no mode of operation ...	no mode of operation ...
S-0-0134	Control word		
S-0-0135	Status word		
S-0-0292	List of supported operation modes		
P-0-0350	Error reaction control word	E-Stop ramp (=0)	E-Stop ramp (=0)
P-0-0400	Hardware enable configuration		
	Configuration (BitSize 2,OffSet 0)	High acitve (=1)	High acitve (=1)
	rsvd (BitSize 1,OffSet 2)	0	0
	Input number (BitSize 5,OffSet 3)	Digital input 0 (=0)	Digital input 0 (=0)
	rsvd (BitSize 8,OffSet 8)	0	0
P-0-0401	Position limit switch configuration		
P-0-0402	Ready to operate configuration		

This function is not limited to a special input.

Ready to operate

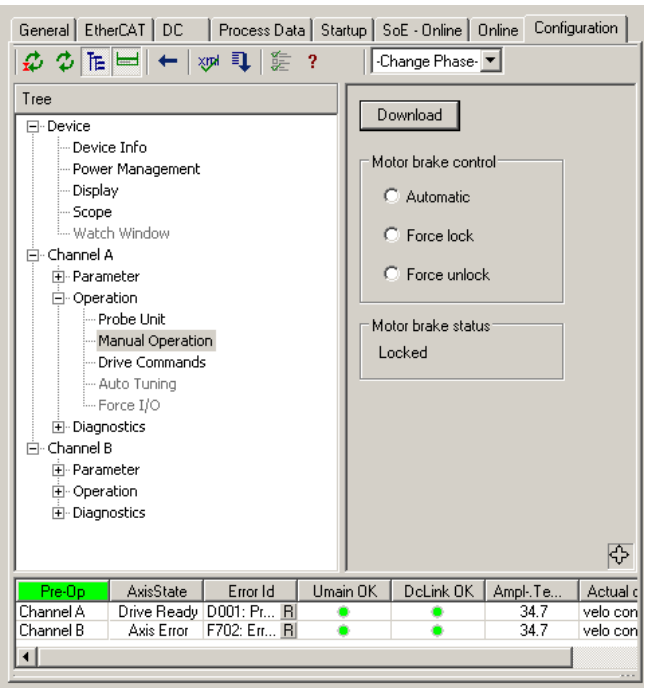
The AX5000 can be integrated in the ready-chain of the machine via the device configuration. This function requires a digital input and a digital output. Activation of this function and allocation to the respective input and output is realised in parameter P-0.04002. Since only digital input no. 8 can optionally be configured as output, only digital output no. 8 is offered as output number.

P-0-0402	Ready to operate configuration		
	Ready to operate output (BitSize 8,OffSet 0)		
	Configuration (BitSize 3,OffSet 0)	High active (=1)	High active (=1)
	Output number (BitSize 5,OffSet 3)	Digital output 8 (=7)	Digital output 8 (=7)
	Ready to operate input (BitSize 8,OffSet 8)		
	Configuration (BitSize 3,OffSet 0)	High active (=1)	High active (=1)
	Input number (BitSize 5,OffSet 3)	Digital input 6 (=6)	Digital input 6 (=6)

(Electrical properties in preparation)

Controlling the motor brake

If the motor is equipped with a motor brake, this brake is controlled via the servocontroller. The brake is configured via parameter P-0-0060. This parameter is part of the XML description of the motor. The brake can be locked and unlocked via the TcDriveManager as required.



If the brake has to be controlled from the application, parameter P-0-0096 is available as motor control word and P-0-0097 as motor status word. The following table shows the command sequence for unlocking and locking the brake from the PLC.

Unlock the brake		Lock the brake	
Control word	**Status word**	**Control word**	**Status word**
	0x0000		0x0000
0x0002		0x0001	
	0x0002		0x0001

The brake response times are configured in parameter S-0-0206 for (enable) and parameters S-0-0207 (disable).

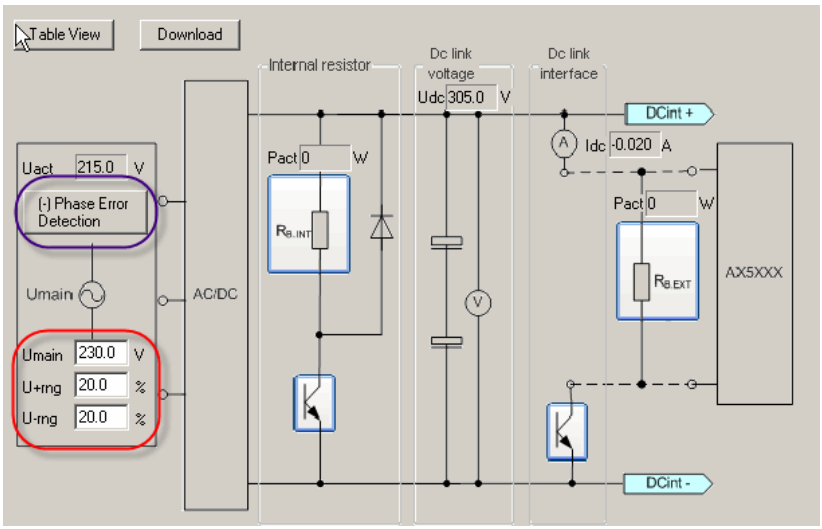
Mains voltage monitoring

The servo drive monitors the minimum and maximum values of the connected mains voltage. To this end the value of the connected voltage and the permitted tolerance values are specified. The diagram below shows the TCDriveManager configuration option. The section outlined in red is used for configuring the mains voltage with min./max. values. Mains phase monitoring is activated or deactivated in the section outlined in purple. Phase monitoring is always based on 3-phase mains.

Note

Phase monitoring

With a single-phase mains supply phase monitoring must be deactivated for the servo drive to work.



The values are limited to 50% in maximum and minimum direction. The relevant parameters are P-0-0201, P-0-0202, P-0-0203, and P-0-0204.

P-0-0201	Nominal main voltage	230.0	230.0	V
P-0-0202	Main voltage positive tolerance range	20.0	20.0	%
P-0-0203	Main voltage negative tolerance range	20.0	20.0	%
P-0-0204	Power Management control word			
	Internal brake (BitSize 1,OffSet 0)	Internal brake enable...	1	
	reserved (BitSize 1,OffSet 1)	0	0	
	reserved (BitSize 1,OffSet 2)	0	0	
	UmainPhaseErrorDetection (BitSize 1,OffSet 3)	UmainPhaseErrorDete...	0	
	reserved (BitSize 12,OffSet 4)	0	0	

Active DC link integration

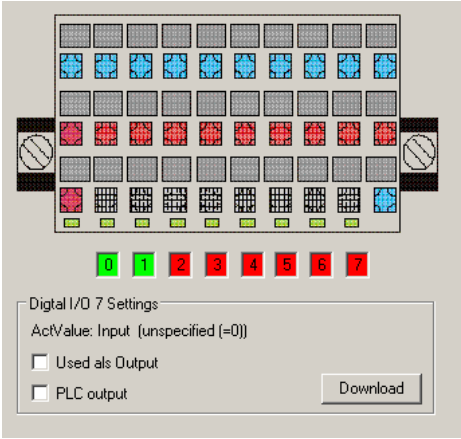
(in preparation)

Digital inputs and outputs

All AX5000 devices have 8 digital inputs, irrespective of the type (1- or 2-channel) (inputs 0 to 7). Input no. 7 can be reconfigured as output. The digital I/Os can be allocated to channel A or B.

The status of the digital inputs is represented in parameter P-0-0801. This parameter can be transferred in the cyclical interface, so that the information is available in the PLC and NC.

The decision to use input no. 7 as output can be implemented in two different ways, through allocation to the PLC output (P-0-0800), or through allocation of this bit to a drive function that sets this output as a result. An example for the second option is the ready to operate function of the servocontroller. If the PLC output is used the value is transferred via parameter P-0-0802.



The differentiation between the controller and the PLC as the signal source is specified in parameter P-0-0801.

(Electrical properties in preparation)

Measuring probe functions

The measuring probe function enables the actual controller position to be stored event-dependent. This could also be achieved via the control unit, although with a velocity greater than 0 an error would be introduced that is proportional to the velocity. For this reason this function is allocated to the drive, where the actual position is stored and transferred to the control unit almost without time offset, depending on the digital input or a combination of event signals.

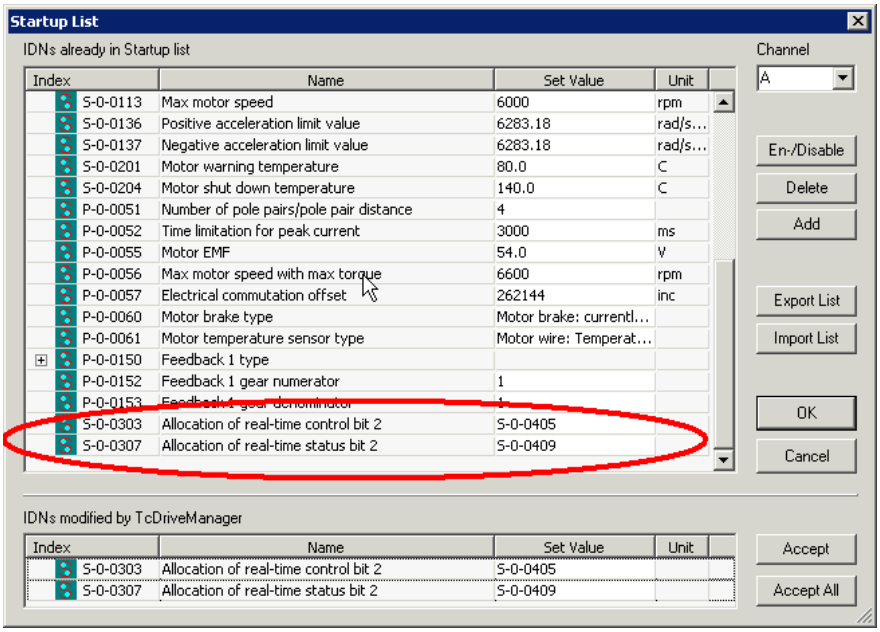
BECKHOFF AX5000: Commissioning

Reference Movement

The TwinCAT NC can reference the axis at the AX5000 using the probe unit of AX5000.

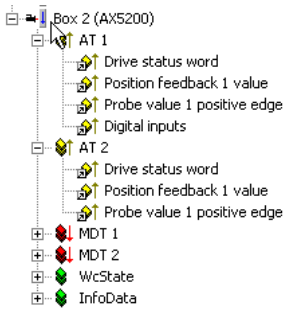
The probe unit should be configured within the startup list, although configuration is also possible during axis operation (at runtime). In order for the TwinCAT NC to be able to control the probe unit and respond to its status, IDNs S-0-0405 and S-0-0406 have to be mapped into the real-time control and status bit 2. This is achieved through associated entries in IDNs S-0-0303 and S-0-0307.

Configuration of the real-time control and status bits:



The position stored by the drive with the probe unit is held in IDN S-0-0130 (probe value 1 positive edge) or in IDN S-0-0131 (probe value 1 negative edge). One of these two IDNs is cyclically transferred to the NC with the AT telegram according to the configured edge.

Cyclical transfer of IDN S-0-0130 with the AT frame:



The AX5000 probe unit is activated with the "Probing cycle procedure" command (S-0-0170). When this command is activated the probe unit configuration are transferred internally. The configuration data are write-protected while the command is active.

The "Probing cycle procedure commands" can be activated by setting the IDN parameter to 3 (set and enable). The commands can also be started via the startup list in the transition from safe SafeOp to Op.

Configuration of the probe unit see AX5000_ProbeUnit.

BECKHOFF AX5000: Commissioning

Probe Unit

The latch/probe functionality implemented in the AX5000 is compliant with the probe functionality defined in the Sercos specification (v2.4).

IDNs involved

Note

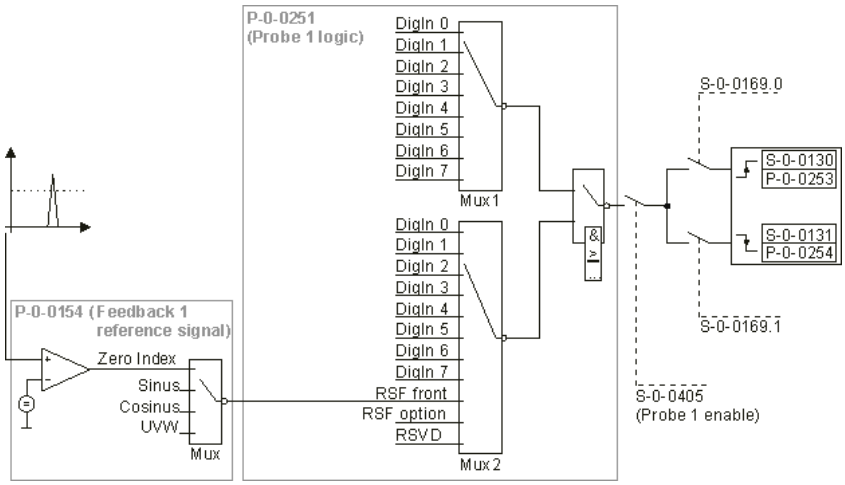
IDN-description

A detailed description of the individual IDNs can be found the following document: *AX5000 - IDN Descriptions*.

IDN	Name
S-0-0130	Probe 1 value positive edge
S-0-0131	Probe 1 value negative edge
S-0-0169	Probe control parameter
S-0-0170	Probing cycle procedure command (pc)
S-0-0179	Probe status
S-0-0405	Probe 1 enable
S-0-0409	Probe 1 positive latched
S-0-0410	Probe 1 negative latched
P-0-0154	Feedback 1 reference signal
P-0-0250	Probe 1 value source
P-0-0251	Probe 1 logic configuration
P-0-0252	Probe 1 logic state
P-0-0253	Probe 1 time positive edge
P-0-0254	Probe 1 time negative edge
P-0-0255*	Probe 1 time difference: reference switch to index
P-0-0256*	Probe 1 data

*) In preparation.

Functioning



The signal source (reference signal feedback, RSF) is selected with IDN P-0-0251. The reference signal of the encoder system or a simple digital input or a combination of 2 inputs can be selected.

The following signals are available for selection:

Multiplexer 1, see drive parameter description (IDNs)

P-0-0251.Mux1	Input
0	DigIn 0
1	DigIn 1
2	DigIn 2
3	DigIn3
4	DigIn4
5	DigIn5
6	DigIn6
7	DigIn7

Multiplexer 2

P-0-0251.Mux1	Input
0	DigIn 0
1	DigIn 1
2	DigIn 2
3	DigIn3
4	DigIn4
5	DigIn5
6	DigIn6
7	DigIn7
8	Reference Signal Feedback Front
9	Reference Signal Feedback Option Card
	rsvd.

Reference Signal Feedback Front

P-0-0154	Input
0	Zero Index
1	Magnitude of sine signal
2	Magnitude of cosine signal
3	rsvd

The parameter P-0-0154.ThresholdVoltage can be used to modify the threshold level (if zero index is selected).

IDN P-0-0154 can only be edited in EtherCAT state *PreOperational*. In states *SafeOperational* and *Operational* this IDN is write-protected.

The selected signals are linked via the following logic:

Logic

P-0-0251.Logic	Logic output
0	Output Mux 1
1	Output Mux 2
2	Ouptut Mux 1 AND Output Mux 2
3	Output Mux 1 OR Output Mux 2
5	Output Mux 1 AND rising edge output Mux 2

Probe Value-Source

IDN P-0-0250 is used to select which value (e.g. actual position) is to be stored for the latch event.

P-0-0250	Source
0	Position feedback value 1 (S-0-0051)
1	rsvd

The command S-0-0170 is activated internally in the probe cycle, and the parameters of IDNs P-0-0250 and P-0-0251 are transferred internally. These two IDNs are write-protected as long as this command is active.

IDN P-0-0252 indicates the current sate of the logic upstream of the probe unit.

IDN S-0-0169 is used to activate edges at which a latch event is to be triggered.

The probe unit is activated with IDN S-0-0405. If S-0-0405 is associated with a falling edge the result-registers are reset to 0.

IDN-S.0-0179 (or S-0-0409 and S-0-0410) indicates whether a latch event has occurred.

After a latch event the associated data are entered in IDNs S-0-0130, S-0-0131, P-0-0253, and P-0-0254.

Configuration sequence

1. Feedback 1 reference signal (P-0-0154) (only possible in EtherCAT state *PreOperational*)
2. Probe 1 value source (P-0-0250)
3. Probe 1 logic configuration (P-0-0251)
4. Start of "Probing cycle procedure commands" (S-0-0170)
5. Probe control parameter (S-0-0169)
6. Probe enable (S-0-0405)

Beckhoff AX5000: Homing

Homing

Homing refers to an axis initialisation run during which the correct actual position is determined by means of a reference signal. This procedure is referred to as *homing*, *referencing* or *calibration*. A switch that is triggered at a known, unique position along the travel path serves as reference signal. Further signals such as the encoder zero track can be analysed in order to increase the precision.

In general a distinction is made between drive-controlled homing and NC-controlled homing. Drive-controlled homing is carried out automatically by a suitable drive without input from the control system and is not discussed in detail in this documentation. NC-controlled homing is fully controlled by the control system and supports a wide range of drive types. The different NC-controlled homing mechanisms are described below.

Position reference systems and encoder systems

A distinction is made between different position reference systems (measurement systems), depending on which position measuring system is used. An *absolute measurement system* provides an absolute position (directly after switching on) that is unique over the whole travel path. Such a measurement system is calibrated once and set via a persistently stored position offset. In this case homing is not required even after a system restart. In contrast, *relative measurement systems* provide a non-unambiguous position value (after switching on) that must be calibrated through homing. Relative measurement systems are subdivided further into purely relative systems (incremental encoders) and part-absolute systems, which only provide a unique position during a motor or encoder revolution.

- Absolute position - e.g. multi-turn encoder
  - BiSS
  - EnDat
  - Hiperface
  - SSI
- Part-absolute position - e.g. single-turn encoder
  - BiSS
  - EnDat
  - Hiperface

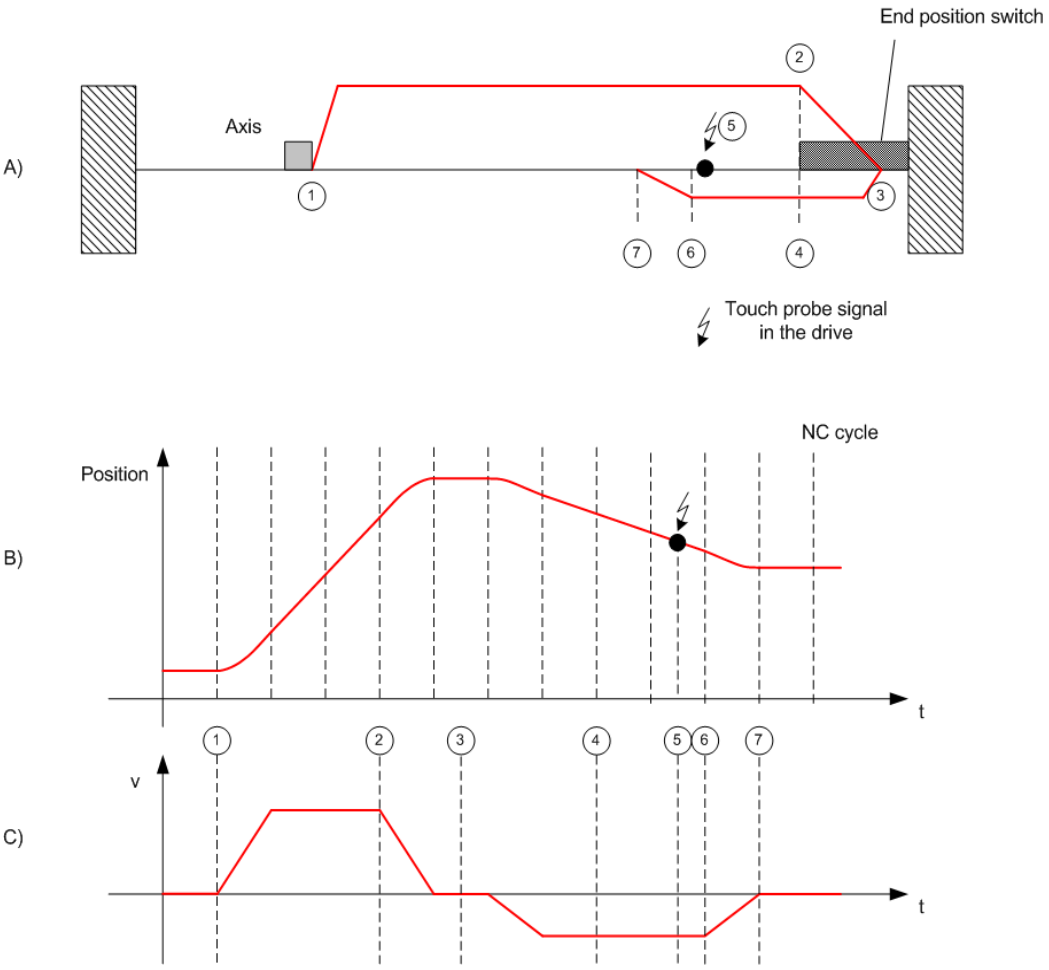
  - MES (Beckhoff)
  - Resolver
- Relative position - incremental encoders
  - Sine / cosine (sine 1 Vss)
  - TTL, HTL (rectangle)

General description of a homing procedure

Figure A shows a schematic diagram of a homing procedure with individual velocity profile phases.

1. When the machine is switched on the axis is in a random position (1).
2. Homing is initiated, and the axis travels towards the reference cam.
3. Once the reference cam is detected, the axis stops and reverses.
4. The axis moves away from the reference cam and detects the falling edge of the reference cam signal.
5. The axis continues and searches for a sync pulse or another distinctive event, depending on the reference mode setting. This step may be omitted where appropriate.
6. The occasion is detected and the specified reference position is set.
7. The axis stops at a certain distance from the reference position, which was set shortly beforehand with maximum precision.

Figures B and C show the position and velocity profile during homing.



Referencing modes

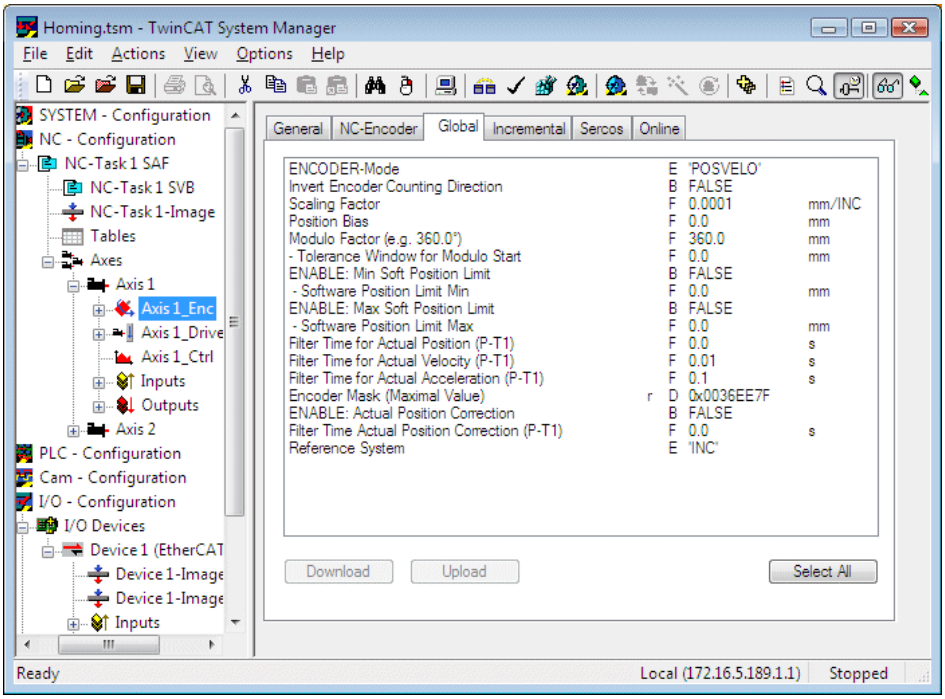
The NC system supports different referencing modes, depending on the encoder system type.

- Homing based on reference cam (Plc Cam)
  The simplest axis referencing mode uses a reference cam that generates a digital signal at a defined position along the travel path. During homing the NC determines the signal edge and allocates a configurable reference position to this position. Referencing based on a reference cam is always possible, irrespective of the encoder type, and is a prerequisite for other, more precise modes.
- Software Sync
  Software Sync mode enhances the homing precision by additionally detecting the encoder count overflow after an encoder or motor revolution, after the reference cam signal has been detected. This mode requires a part-absolute encoder (e.g. resolver) with constant overflow interval relative to the reference cam. Overflow detection is parameterised via the *Reference Mask* parameter (see System Manager section).
- Hardware Sync
  Some encoder systems provide a sync pulse per revolution (zero track) in addition to the count. The homing precision can be enhanced by selecting this mode, if the encoder evaluation logic is able to pick up the sync pulse. The precision is comparable with Software Sync. Hardware Sync mode may require parameterisation or special wiring of the drive or encoder system.
- Hardware Latch
  Hardware Latch reference mode (*Hardware Latch Pos* or *Hardware Latch Neg*, depending on edge) requires an external digital latch signal for

storing the encoder position in the evaluation unit of the encoder system. The encoder system must support such a latch function and may have to be configured first in order to be able to utilise this function.

	Absolute encoder system	Part-absolute encoder system	Relative encoder system
NC	Referencing not required	Recommended reference mode *SoftwareSync* (also possible: *PlcCam, HardwareSync*)	Recommended reference mode *HardwareSync* (also possible: *PlcCam*)
Drive	Referencing not required	Drive setting not required	Drive parameterisation required (for Sercos/SoE see Probe Unit)

Parameterisation in the System Manager



Reference system: The encoder parameters *reference system* determines whether the encoder system used is incremental or absolute. In an absolute encoder system the encoder value is taken from the control system without modification.

Not all NC encoders support this optional parameter, i.e. only those types that offer a choice between absolute and incremental encoder reference system (measurement system) support it (e.g. SERCOS, KL5001, M3000, ProfiDrive, Universal). This choice determines whether the actual encoder position is interpreted and evaluated as an absolute or incremental position, based on an absolute or incremental reference system (measurement system).

In an absolute reference system no further processing takes place with regard to encoder counter value overflow or underflow. It is assumed that the counter value is unique within the axis traversing range and no encoder counter value overflow or underflow occurs. Otherwise there would be a discontinuity in the actual position, resulting in a position following error. Axis referencing via MC_Home is not possible. Instead, the actual position is calibrated once via the *Position Bias* parameter *(zero offset / position offset)*.

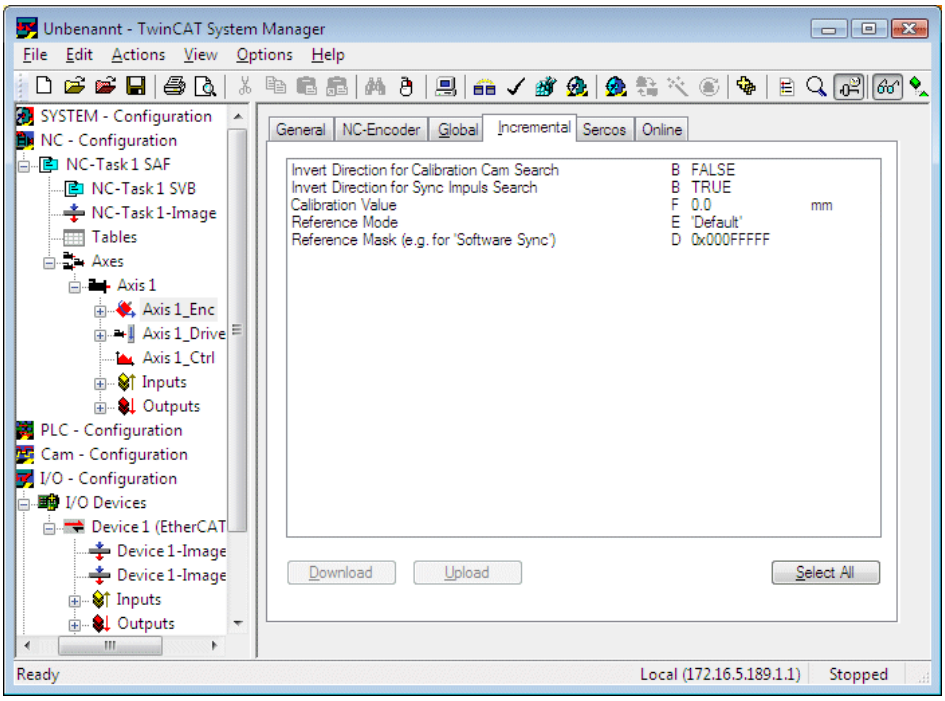
In an incremental reference system axis referencing via MC-Home is generally required. In addition the NC automatically detects and accounts for encoder counter value overflow or underflow events, so that continuous axis operation is possible over many months ("infinite range").

***Encoder Mask** (maximum value)*: The *encoder mask* determines the bit width for the incremental encoder position. The encoder mask is used for detecting and counting in range overflow events.

Scaling Factor: The *scaling factor* is multiplied with the incremental encoder position (including all overflows) and used as the basis for calculating an absolute axis position with the parameterised physical unit.

Position Bias (zero offset): Position offset; moves the axis coordinate system relative to the encoder coordinate system. This value is mainly used in absolute encoder systems. In relative systems an offset is usually not required, since the system moves to a parameterised reference position after homing.

Invert Encoder Counting Direction: The encoder count direction can be inverted if it does not match the required logical count and travel direction.



Reference Mode: *Referencing mode* as described above (*Plc CAM, Hardware Sync, Hardware Latch Pos, Hardware Latch Neg, Software Sync*). The *default* mode corresponds to *Plc CAM* mode.

The *Reference Mode* parameter is used to specify the type of reference event (physical or logical event) for the referencing process. Depending on which referencing mode is parameterised the referencing procedure is either based on the hardware characteristics of the drive/encoder (e.g. hardware latch), or the reference event is only detected within the control system, i.e. without additional hardware reference.

Reference Mask: The *reference mask* parameterises overflow detection for *Software Sync* reference mode. It is less or equal the encoder mask and defines an encoder value range, which is part-absolute. Examples include the bit width of a motor revolution or the bit width of a sine period in a sine/cosine encoder. Software Sync therefore always detects the same overflow position in a part-absolute encoder system.

Calibration Value: *Reference position* to which the axis position is set after homing.

Invert Direction for Calibration Cam Search: The parameter inverts the axis travel direction for searching the referencing cam during homing. The standard direction is negative, i.e. towards the axis coordinate system origin.

Invert Direction for Sync Impulse Search: The parameter inverts the axis travel direction for searching the sync pulse during homing.

Referencing of coupled axes

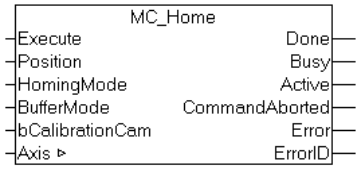
TwinCAT enables axis coupling during referencing. The coupled axes do not necessarily have to be referenced. Axis coupling enables referencing of gantry axes, for example, provided the system can ensure that the two axes are suitably oriented relative to each another before homing. In this case the procedure is as follows:

- Ensure that both axes can be moved in coupled mode. (Position comparison is not possible at this stage, because none of the axes is referenced.)
- Couple axis 2 with axis 1.
- Start homing for axis 1. Slave axis 2 will travel with axis 1.
- Decouple the axes after the homing procedure.
- Couple axis 1 with axis 2.
- Start homing for axis 2. Slave axis 1 will travel with axis 2.
- Decouple the axes after the second homing procedure.
- Move both axes to a set position for alignment. The travel path for both axes should be minimal and may correspond to the mean value from both positions, for example.
- Couple the axes. The coupled system is now referenced.

Programming a homing procedure in the PLC

MC_Home

The MC_Home function block is used to initiate homing from the PLC. The reference mode and further parameters are configured in the System Manager as described above. Only the reference cam signal (bCalibrationCam) is fed into the block.



Drive types and I/O interface

Homing is largely independent of the drive types used. In some cases the drive has to be parameterised, particularly if a drive latch function is used. The following section describes the AX5000 version.

Beckhoff AX5000: Homing

Special characteristics in hardware end positions

If a SERCOS or SoE drive (e.g. AX50xx) is in a hardware end position (positive or negative), the drive blocks further traversing commands in end position direction and beyond the end position (see also bit 3, *drive follows command value*, in the SERCOS status word), and is therefore no longer operational from a control system perspective. This means that, without special measures, the axis can often no longer be moved from the end position into the valid traversing range via TwinCAT or the control system. This situation is particularly likely to occur with drives in the velocity interface, because in this case the position control leads to frequent changes in direction in the drive velocity output.

In order to rectify this special situation, a control bit in the PlcToNc axis interface (see bit 8 called *AcceptBlockedDriveSignal* in *nDeCtrlDWord*) can be used to force TwinCAT to accept the AX50xx axis as operational and therefore enable a move from the end position into the valid traversing range.

In the past, in many cases the only alternative was to mechanically move the axis away from the end position.

NC interface:

PlcToNc axis interface, bit 8 called *AcceptBlockedDriveSignal* in *nDeCtrlDWord*

PLC interface:

TcNc-Lib, see PLC function *AxisSetAcceptBlockedDriveSignal* in folder *NC Axis Control Flag Functions*

Homing with latch function

During homing a trigger event is expected and a position value is latched, depending on the referencing mode (*hardware latch*). Parameterisation is required in order to be able to use the drive latch function (see AX5000 Probe Unit).

Beckhoff AX5000: Homing

Probe Unit function

A probe unit is a hardware-oriented functional group that can store the current axis position for a parameterisable event. The event may be an edge of a digital input in the drive, for example. The position is stored immediately without significant delay for subsequent evaluation by the control system.

The probe unit of the drive can be used for event-driven position sensing through the application program (*MC_TouchProbe*), or for registering a reference position during homing (MC_Home) if the NC referencing mode is set to *hardware latch*.

In any case, the probe unit has to be parameterised before it can be used. The following parameterisation description refers to an AX5000 drive (SoE), although it can also be used more generally for the parameterisation of a SERCOS drive.

Parameter overview

SERCOS parameters

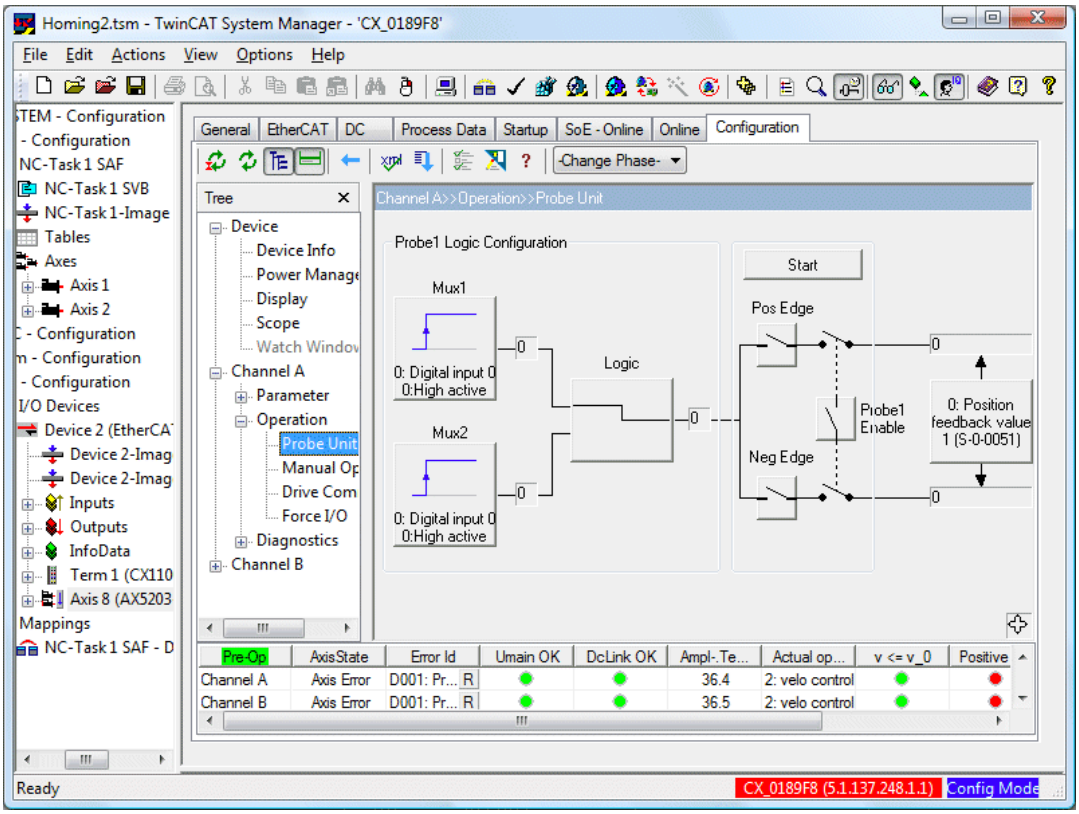
Parameter	Value	EtherCAT transition (startup)	Description
S-0-0303	405	P -> S	Allocation of real-time Control bit 2
S-0-0307	409 or 410	P -> S	Allocation of real-time Status bit 2
S-0-0169	1, 2, 3	P -> S	Probe control parameter
S-0-0170	3	S -> O	Probing cycle procedure command

Process data - cyclic data between drive and NC axis

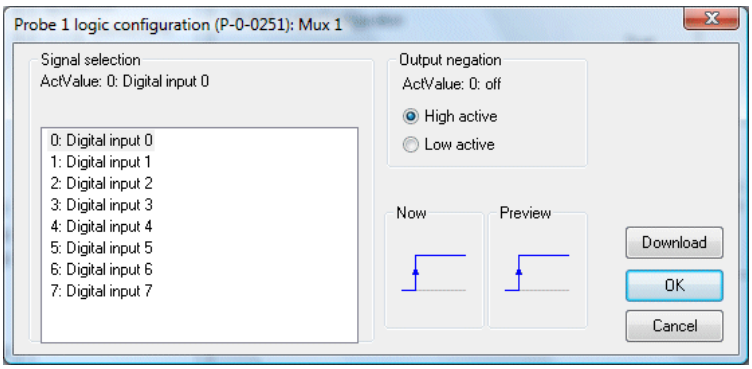
Parameter	Description
S-0-0130	Probe value positive edge
S-0-0131	Probe value negative edge

Probe unit parameterisation

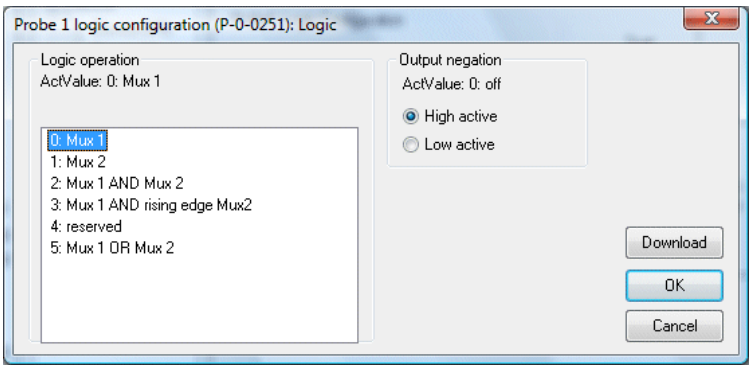
The probe unit is controlled via an AX5000 configuration dialog. In multi-channel devices a probe unit is available for each channel.



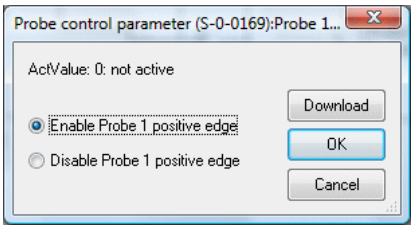
In the first step a signal source (*Mux1*) for triggering the probe unit is selected. Digital drive inputs 0 to 7 are available for selection. To parameterise the probe unit for homing with evaluation of the encoder zero track, select *Mux 2*, which is the only option offering *reference signal feedback*.



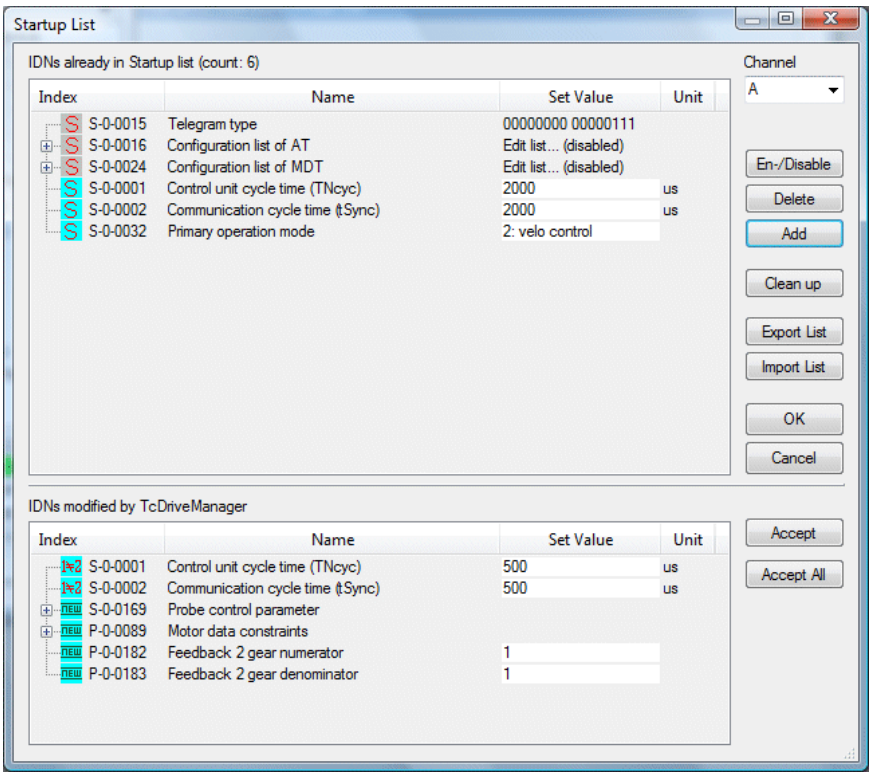
The trigger signal can be linked with a further signal source (*Mux 2*). In the simplest case only one signal source is used, and the linkage *logic* is set accordingly.



A signal parameter determines whether the positive or negative signal edge is evaluated (*Pos Edge* or *Neg Edge*). The decision to use a particular signal edge is therefore made during drive parameterisation and cannot be made later in the control program.



The modifications entered during these initial configuration steps can be stored in the startup list for the drive, so that they are transferred to the drive on system startup. In the *Startup List* dialog save the modified parameters by clicking *Accept All* and or exit the dialog with *OK*.

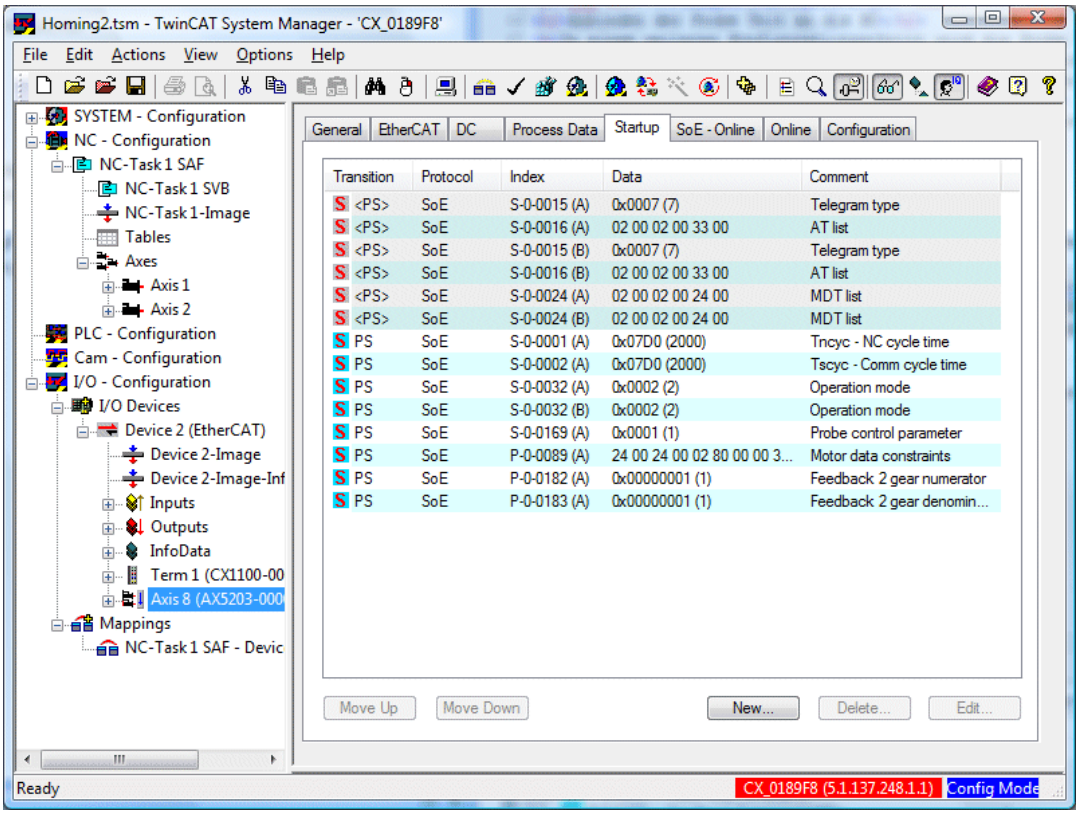


Linking the probe unit with the NC

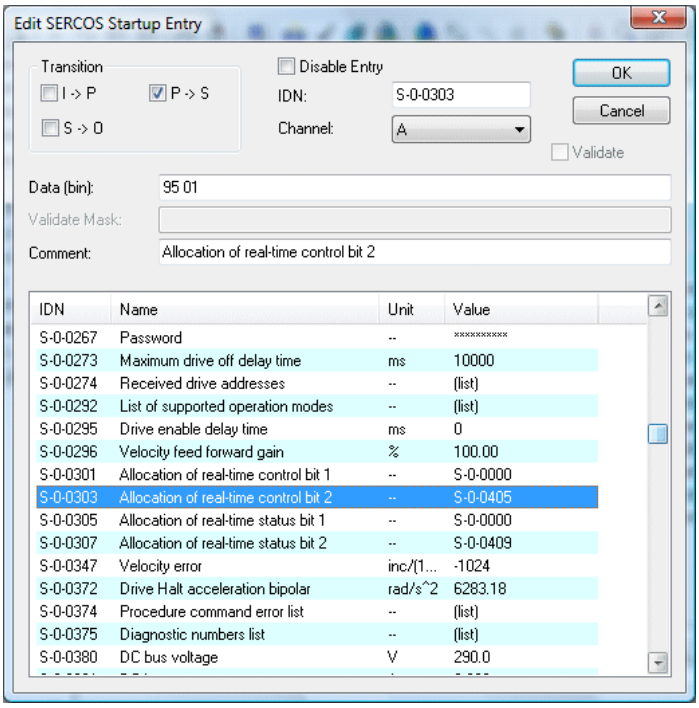
In a further configuration step the probe unit for the drive is linked with the NC controller. The control system operates the probe unit via the SERCOS real-time bits in the master control word and the drive status word and retrieves the latch position from the drive process data.

Startup list

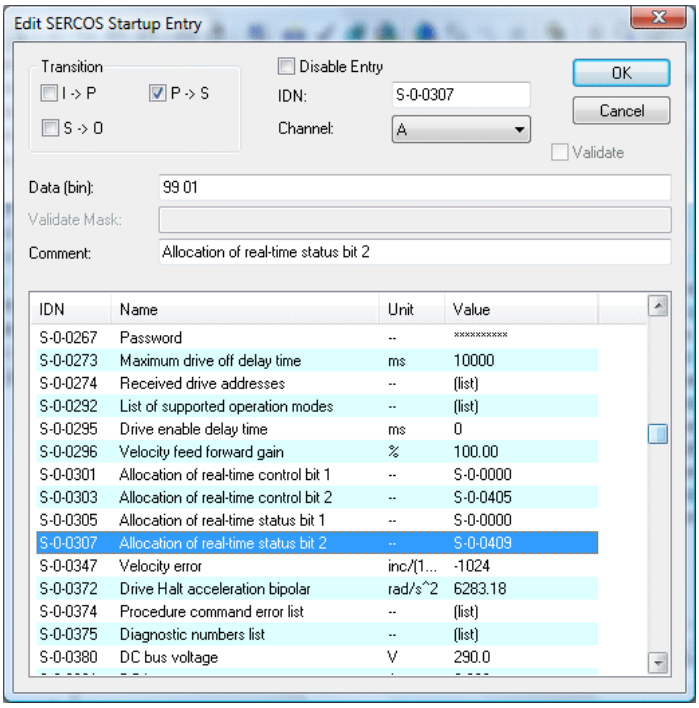
To configure the real-time bits the drive startup list is extended (*New...*).



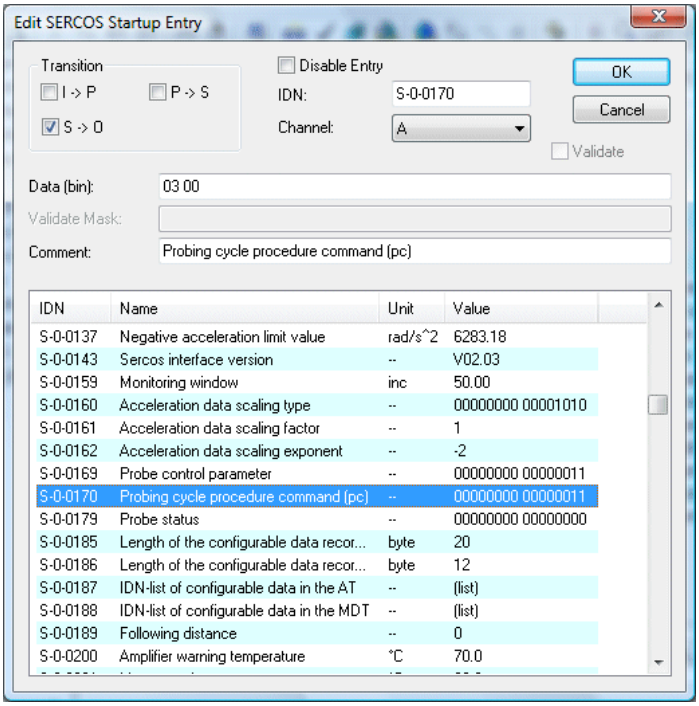
To enable activation of the probe unit set S-0-0303 to 405 (95 01).



The drive response is signalled in a status bit. To this end S-0-0307 is set to 409 (99 01) for a positive signal edge and 410 (9A 01) for a negative signal edge.

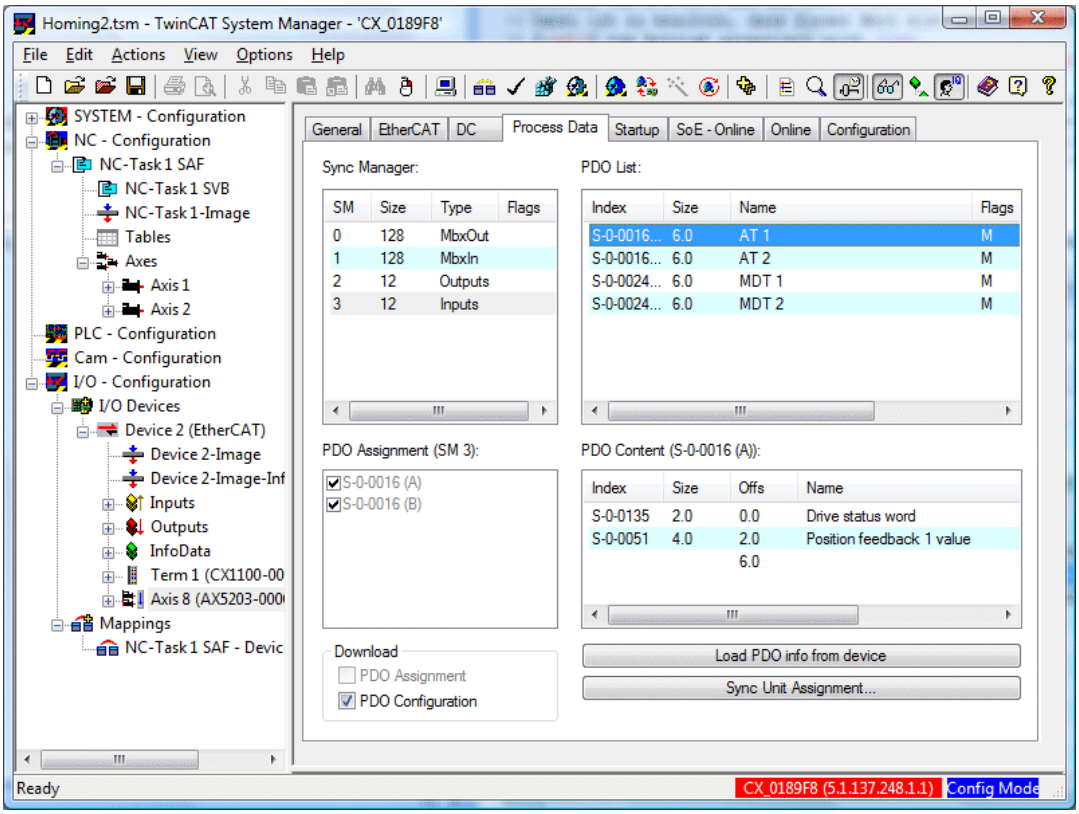


Finally the probe unit function must be activated. This can be achieved by setting the command S-0-0170 to 3 during startup. Please note that the drive only accepts this value during the EtherCAT transition S->O.

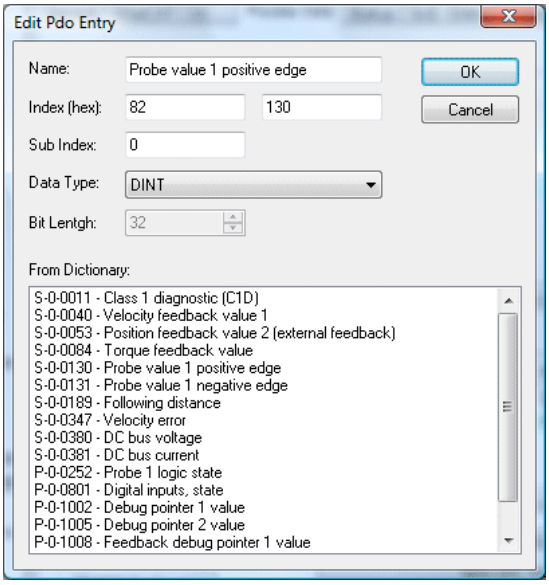


Process data

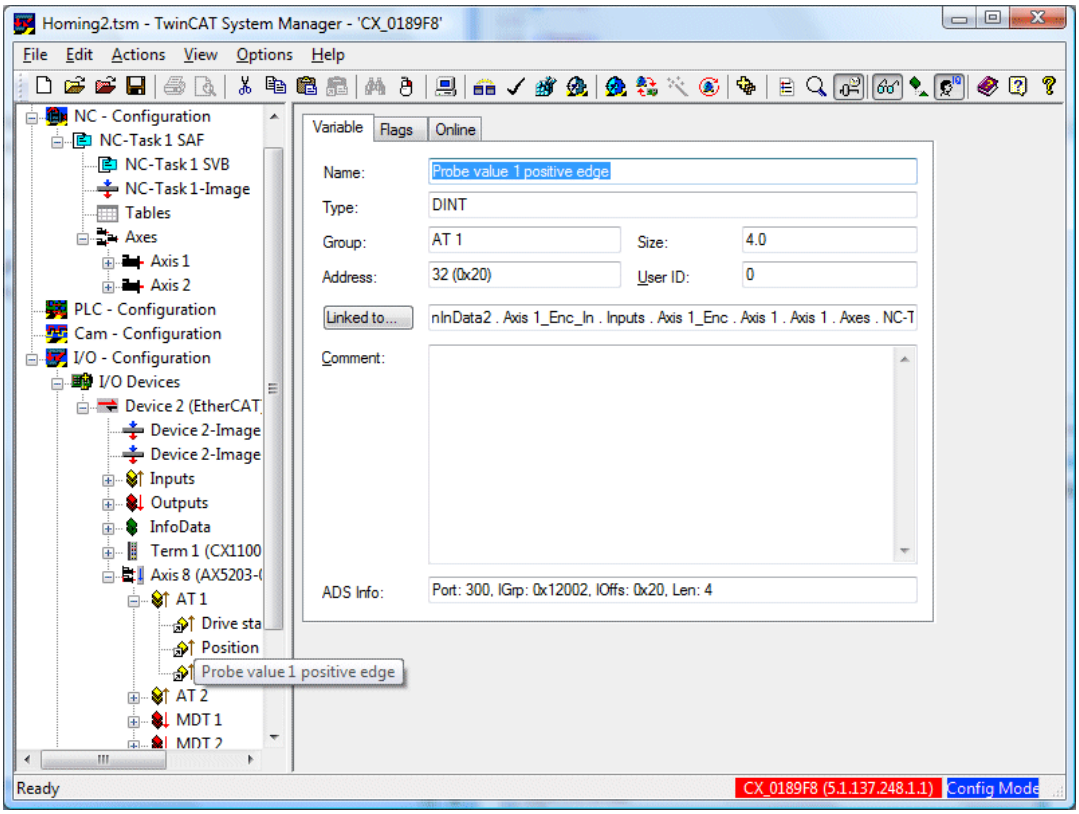
In order to enable the control system to evaluate the measured value, the value is included in the process data and linked with the NC axis. On the drive side one measured value is available for the positive signal edge and one for the negative signal edge.



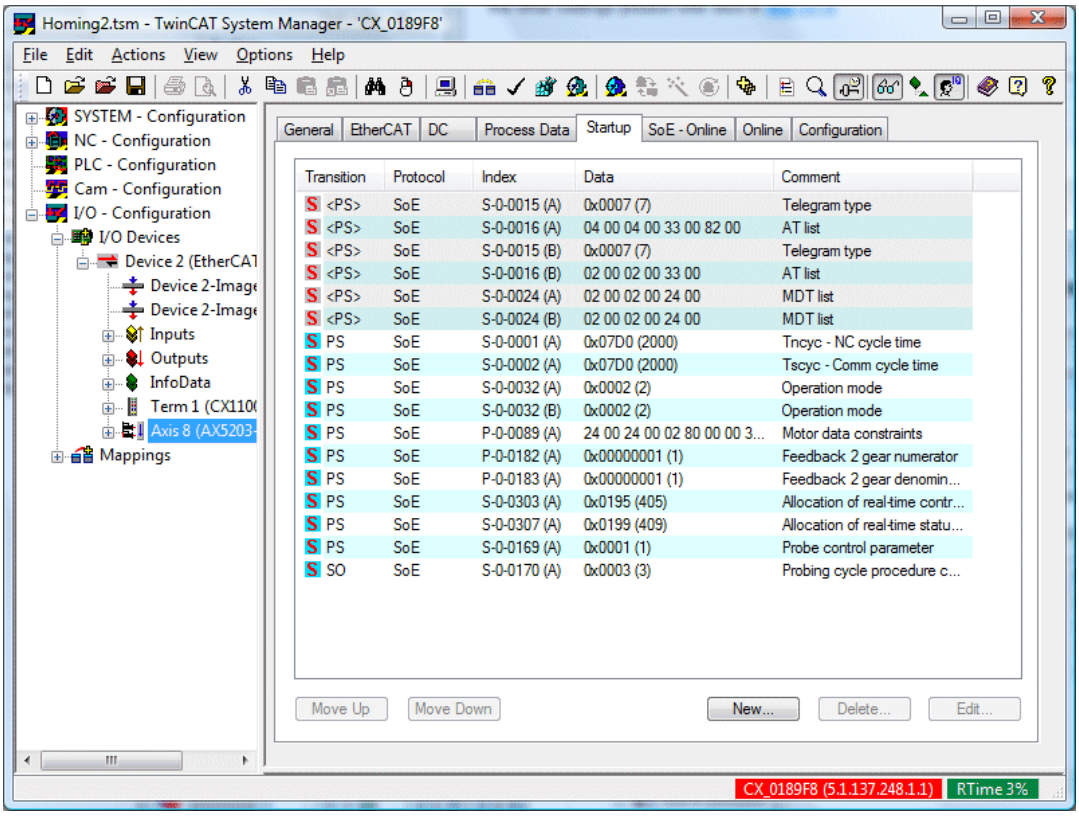
Right-click in the *PDO Content* list to add a new value. Depending on the configuration the value of S-0-0130 or S-0-0131 is stored in the process data.

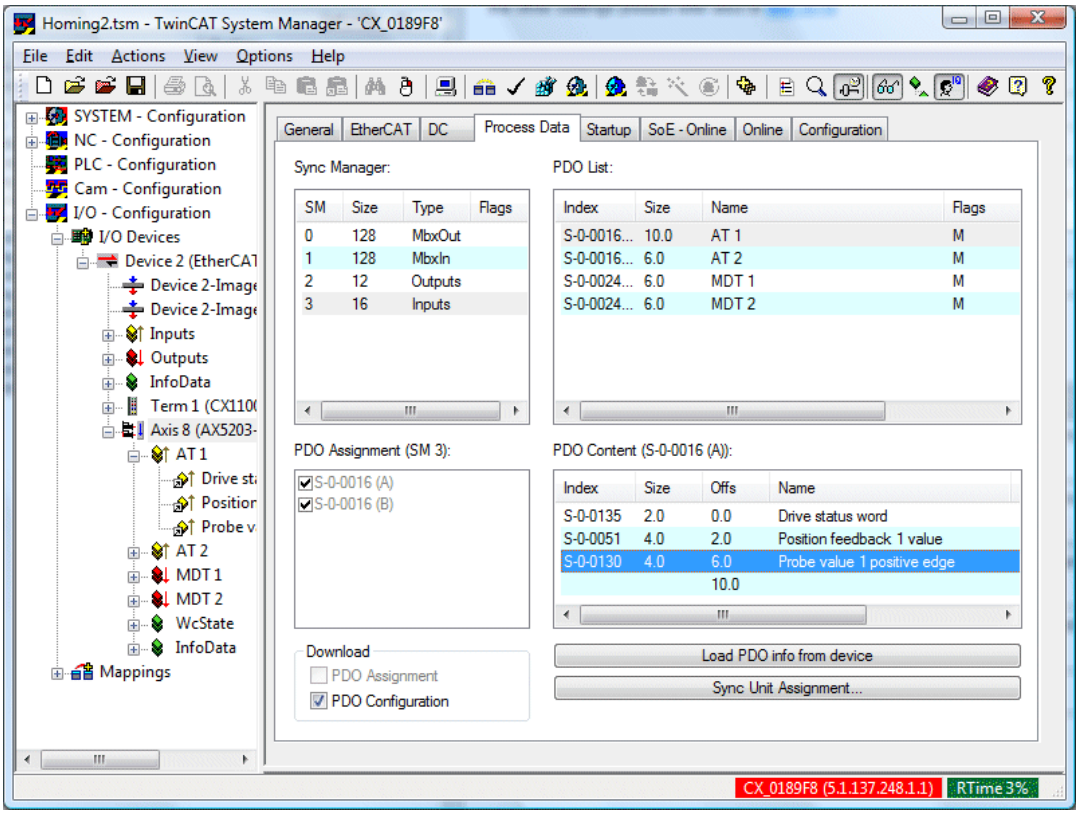


The measured value is automatically linked with the NC axis when a link is created between the axis and the drive. If the link was already established before the configuration described here, the link can be cancelled and recreated in order to ensure that the measured value is linked.



Startup parameter overview





BECKHOFF AX5000: Commissioning

Motor brake management

IDNs involved

IDN	Name
S-0-0206	Drive on delay time
S-0-0207	Drive off delay time
P-0-0058	Motor brake type
P-0-0096	Motor control word
P-0-0097	Motor status word

Functioning

IDN S-0-0206 defines the switch-on delay between the motor current feed and releasing of the brake.

IDN-S-0-0207 defines the switch-off delay between activation of the motor brake and deactivation of the current feed.

IDN-P-0-0058 is used to configure the motor brake.

IDN-P-0097 displays the state of the motor brake.

IDN-P-0096 can be used to release the motor brake manually or requesting activation of the brake manually. This bits overwrite the internal brake request. The brake is therefore released or engaged irrespective of the motor current feed and any travel command.

CAUTION

Risk of injury!

Improper operation of IDN P-0-0096 can therefore lead to sagging of a non-energised Z axis or closing of the motor brake at full speed!

BECKHOFF AX5000: Commissioning

Commutation methods

The important characteristics of a servomotor, such as its very smooth running, high efficiency and optimum thermal utilization, are strongly influenced by the commutation. Commutation refers to the transfer of current from one winding to the next. The moment at which commutation takes

place must be harmonized with the magnetic field of the rotor if the servomotor is to operate most effectively.

Rotary servomotors

Mechanical commutation

These motors, which use brushes, generate the alternating fields necessary for operation of the motor through sliding contacts, whose geometrical arrangement switches the current paths. Brush losses and wear are disadvantages of this simple, mechanical commutation method.

Electronic commutation

These modern motors generate the alternating field needed for operation of the motor by means of an electronic circuit which is not subject to either wear or friction. The type of motor and the encoder system in use determine the commutation method.

Absolute encoder system (motor feedback) within one rotation

Samples of this type of encoder system includes: Resolver, EnDat, BiSS and HIPERFACE

Two different commutation methods are involved here:

Mechanical adjustment of the encoder

The motor's encoder system is mechanically adjusted at the factory (the encoder and rotor are matched to one another), but the rotor position is unknown.
The commutation angle is determined once by the P160 command, using the IDN "P0-0-165_Command mode_Static current vector" and the IDN "P-0-057 "Electrical commutation offset". This means that the corresponding mechanical angle coming from the encoder system is displayed and read out in P-0-0058, and is saved in the IDN "P-0-0150_Parameter chanel_Adjustable commutation offset" (motor database). In order for the parameter to be used, the IDN "P-0-0150_Parameter chanel_Commutation mode" (motor database) must be set to 3: "Adjustable offset". The associated value of the IDN "P-0-057 "Electrical commutation offset" is also saved in the motor database.

Electronic adjustment of the encoder system

Note

Synchronous motors!

Electronic adjustment is only required for synchronous motors. In the case of a synchronous motor, the magnetic field of the rotor is generated electronically, and therefore can be set appropriately for the electromagnetic field of the winding.

Depending on the encoder system there are, again, two different commutation methods:

1. The encoder is always attached to the rotor by the manufacturer in the same rotary position, but the rotor position is not known.
   The commutation angle is determined once by the P160 command, using the IDN "P0-0-165_Command mode_Static current vector" and the IDN "P-0-057 "Electrical commutation offset". This means that the corresponding mechanical angle coming from the encoder system is displayed and read out in P-0-0058, and is saved in the encoder system's data store (exceptionally) and in the IDN "P-0-0150_Parameter chanel_Adjustable commutation offset" (motor database). In order for the parameter to be used, the IDN "P-0-0150_Parameter chanel_Commutation mode" (motor database) must be set to 3: "Adjustable offset". The associated value of the IDN "P-0-057 "Electrical commutation offset" is also saved in the motor database. This method requires a encoder system having a data store and a data line.

2. The angle between the encoder system and the rotor is determined by the motor manufacturer using a command that is specific to the encoder, and is communicated to the encoder system. The encoder system stores this angle, using it for internal calculation, but the rotor position is unknown.
   The commutation angle is determined once by the P160 command, using the IDN "P0-0-165_Command mode_Static current vector" and the IDN "P-0-057 "Electrical commutation offset". This means that the corresponding mechanical angle coming from the encoder system is displayed and read out in P-0-0058, and is saved in the encoder system's data store (exceptionally) and in the IDN "P-0-0150_Parameter chanel_Adjustable commutation offset" (motor database). In order for the parameter to be used, the IDN "P-0-0150_Parameter chanel_Commutation mode" (motor database) must be set to 3: "Adjustable offset". This angle is always included in internal calculation processes. This method requires an intelligent encoder system.

Non-absolute encoder system (feedback) within one rotation

Samples of this type of encoder system includes: SIN / COS 1Vss, TTL

In this case, a special commutation procedure (wake&shake) must be run in order to determine the commutation angle. This angle is stored internally, and is taken into account during operation. If the AX5000 is switched off, or if the "EtherCAT-State machine" is switched into "Pre-op" or a lower state, the commutation angle will be lost because the encoder system is not absolute. "Wake&shake" can only operate without error when the drive system is running steadily; in other words there must not be any vibrations affecting the motor from outside. In addition, a stability investigation using the default values of the "IDN P-0-0165" is necessary the first time the system is operated.

Stability investigation

Note

Oscillatory system!

It is important for this stability investigation to examine the application in advance and to determine the oscillation that is potentially most problematic. This case can occur under load conditions, or may be found when unloaded.

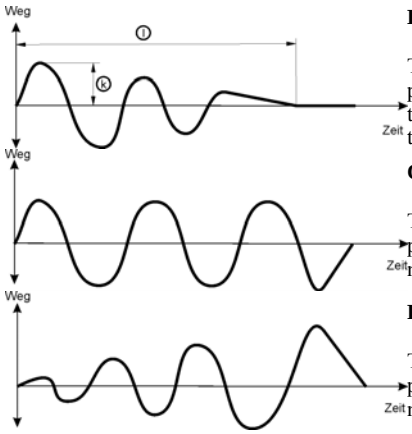
WARNING

Warning, risk of injury from **uncontrolled movements!**

In the method described below, the motor shaft is brought directly to a certain position. Make sure that your application permits this movement, secure the surroundings to prevent unintentional entry, and make sure that nobody is in the hazardous area.

Oscillatory system

It is necessary to analyze the vibration pattern of an oscillating system, and to take appropriate damping measures. Oscillations always have their effect in Phase 2 of "wake&shake"; oscillations are not particularly critical in Phase 1.



Decaying oscillation

The amplitude (k) and the decay time (l) of this kind of oscillation must be found. The parameters IDN-P-0-0165 "Commutation pos control: Kp" can affect both the amplitude (k) and the decay time (l). The parameter IDN-P-0-0165 " Second phase duration" should be greater than the decay time (l).

Constant oscillation

This kind of oscillation is unacceptable, as a stable regulation process is not established. The parameters IDN-P-0-0165 "Commutation pos control: Kp" must be checked, and modified if necessary. If this does not achieve the desired result, you must damp the vibration mechanically.

Rising oscillation

This kind of oscillation is unacceptable, as a stable regulation process is not established. The parameters IDN-P-0-0165 "Commutation pos control: Kp" must be checked, and modified if necessary. If this does not achieve the desired result, you must damp the vibration mechanically.

The motor shaft is brought to freely definable electrical positions by impressing an appropriate current in the course of this investigation. When this injected current is switched off, the motor should remain in the position that it has reached. BECKHOFF recommends positions of 0°, 90°, 180° and 270°. In critical applications, eight positions (0°, 45°, 90°, 135° ...315°) should be selected instead of four. The current injection is parameterized in the IDN P-0-0165 under "Static current vector", while the freely selectable electrical position is set in the IDN P-0-0057. "Wake&shake" should be carried out in each position; stability of the system is only ensured when this has been done successfully.

Wake&shake

Note

Oscillating system!
A mechanical remedy must be provided if the application oscillates. You can carry out the commutation up to a degree using wake&shake, but should carefully select the parameters for the IDN "P-0-0165" to make the effect of the oscillation as small as possible, since too much post-pulse oscillation will cause a commutation error. This is because the angle measured after completing the command will be entered as the commutation angle.

WARNING

Warning, risk of injury from **uncontrolled movements!**
The motor shaft will be moved in steps during the process described below. In Phase 1 the maximum electrical movement is 8 x (the value from "P-0-0-0165_Fist phase position monitoring limit"). In Phase 2 it is 0.5 x (the value from "P-0-0-0165_Fist phase step width"). This formula can only be applied if the previous investigation of stability has been concluded satisfactorily. Make sure that your application permits this movement, secure the surroundings to prevent unintentional entry, and make sure that nobody is in the hazardous area.

The wake&shake commutation function consists of two phases. An approximate determination of the rotor position is carried out in Phase 1, while Phase 2 determines the position more precisely. The aim of the commutation function is to determine the precise position of the rotor with a minimum amount of movement.

Due to the pairs of poles, servomotors exhibit a direct relationship between the electrical and mechanical rotation. One electrical rotation always corresponds to one mechanical rotation divided by the number of pole pairs. A motor with a single pair of poles is illustrated in the following example for the sake of simplifying the calculation.

Parameterization is carried out using the IDN P-0-0165 "Commutation offset calibration parameter". The quoted angles always refer to electrical rotations!

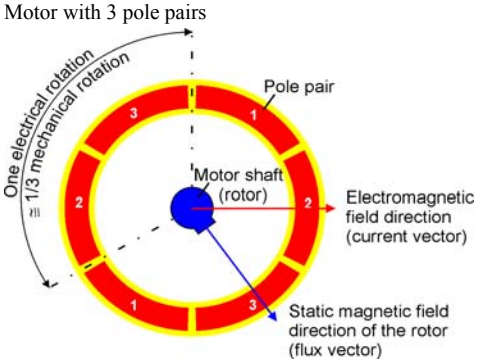
IDN P-0-0165 - Commutation offset calibration parameter

Parameter	Default	Description
Command mode	0: Static current vector	Selection between two commutation methods
Activation	0: manual	Selection of when the commutation process is started
Static current vector		Commutation methods
Current level	Stationary current in %	Current intensity of the current vector (value = 100% x P0-0093 / P0-0092)
Duration	3000 ms	Period for which the parameterized current is maintained so that any oscillations that may be present can settle, allowing an optimum commutation angle to be reached
Wake and shake		Commutation methods
First phase current vector	Stationary current in %	ⓐ Current intensity of the current vector (value = 100% x P0-0093 / P0-0092)
First phase ramp up time	100 ms	ⓑ Time for the current vector "a" to reach its parameterized magnitude
Second phase current level	Stationary current in %	ⓖ Current intensity of the current vector (value = 100% x P0-0093 / P0-0092)
Second phase ramp up time	500 ms	Time for the current vector "g" to reach its parameterized magnitude
Commutation pos control: Kp	0,04	Amplification factor. **Warning:** If "0" then Variant 2 will be carried out in Phase 2
Wake and shake expert		**Warning:** Only experienced users should change the following parameters!
First phase pos monitoring limit	0.5 degrees	ⓓ Minimum angle of rotation of the rotor required to detect movement
First phase step width	22.5 degrees	ⓔ Current vector offset or segment detection angle

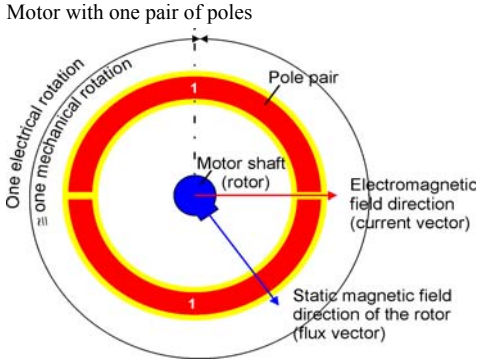
First phase waiting time after step	150 ms	ⓕ The time from detection of movement and the next step in Phase 1 or between Phase 1 and Phase 2 (any oscillations in the system have time to settle)
Second phase duration	3000 ms	ⓗ Period for which the parameterized current is maintained so that any oscillations that may be present can settle, allowing an optimum commutation angle to be reached
Error monitoring (range of motion)	90 degrees	The maximum movement of the rotor before it is switched off, since there would otherwise be a risk that the motor would make an uncontrolled movement.

ⓐ ⓑ ⓓ ⓔ ⓕ ⓖ ⓗ = identifying characters for the description below

Motor with 3 pole pairs

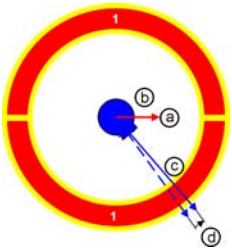


Motor with one pair of poles



Phase 1 - approximate determination of the rotor position (motor shaft)

Step 1

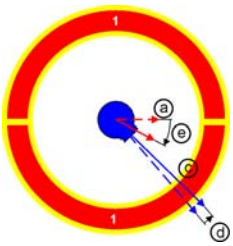


ⓐ ⓑ ⓓ = see the parameter description for IDN P-0-0165 above

ⓒ = flux vector of the rotor with permanent magnet.

Sequence:
A current vector "a" is developed during the time "b". Due to the rising magnetic force, the rotor "c" is turned in the direction of the current vector "a". The direction of rotation "d" is transmitted to the feedback system and the AX5000, where it is stored.

Step 2

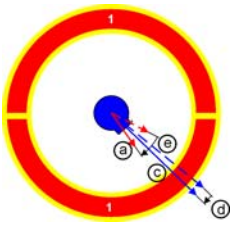


ⓐ ⓑ ⓓ ⓔ = see the parameter description for IDN P-0-0165 above

ⓒ = flux vector of the rotor with permanent magnet.

Sequence:
A current vector "a" is developed during the time "b". Due to the rising magnetic force, the rotor "c" is turned in the direction of the current vector "a". The direction of rotation "d" is transmitted to the feedback system and the AX5000, where it is stored and analysed. If the analysis shows that the direction of rotation "d" of the rotor "c" has not changed when compared with that of the previous impressed current, the process continues.

Step 3

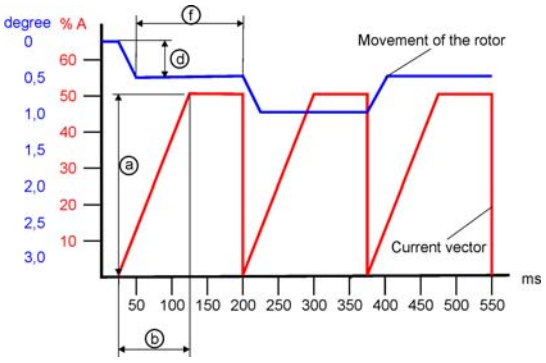


ⓐ ⓑ ⓓ ⓔ = see the parameter description for IDN P-0-0165 above

ⓒ = flux vector of the rotor with permanent magnet.

Sequence:
The current vector "a" is again set to the magnitude "e" in the direction of the rotor "c".
The current vector "a" is now again developed during the time "b". Due to the rising magnetic force, the rotor "c" is turned in the direction of the current vector "a". The direction of rotation "d" is transmitted to the feedback system and the AX5000, where it is stored and analysed. In this case, the analysis shows that the direction of rotation "d" of the rotor "c" has changed when compared with that of the previous impressed current. As a result, the sector in which the rotor "c" is located has been found, and Phase 1 is therefore completed.

Example of an oscilloscope display of Phase 1

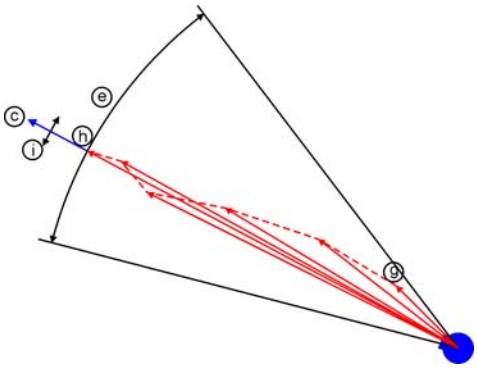


Phase 2 - precise determination of the rotor position (motor shaft)

There are two variants of the precise localization that may be used in Phase 2. In the first variant, the rotor only makes minimal movement, but this does require a very stable system with only a slight tendency to oscillate. In the second variant, the rotor can move by up to a maximum of half the sector e, but this method is much more tolerant against oscillation.

The value set in the parameter IDN-P-0-0165 "Commutation pos control: Kp" controls which variant is used:
IDN-P-0-0165 "Commutation pos control: Kp" > 0 --> Variant 1
IDN-P-0-0165 "Commutation pos control: Kp" = 0 --> Variant 2

Variant 1 (IDN-P-0-0165 "Commutation pos control: Kp" > 0)



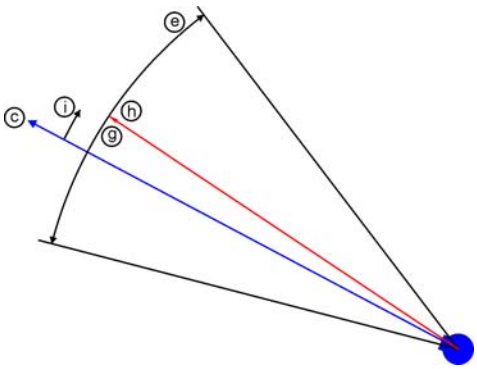
a e g h = see the parameter description for IDN P-0-0165 above

c = flux vector of the rotor with permanent magnet.

i = movement of the rotor

Sequence:
The current vector "g" is developed starting from the final position of the current vector "a" in Phase 1. Due to the rising magnetic force, the rotor "c" is turned in the direction of the current vector "g". The movement is passed through the feedback system to the AX5000, and supplied to a control loop. This control loop immediately corrects the direction of the current vector. This algorithm is executed until the parameterized current intensity is achieved, and the current vector approximately coincides with the flux vector. The current is now maintained over the period "h" which ensures that optimum commutation takes place. In this control algorithm, the rotor only moves minimally through "i".

Variant 2 (IDN-P-0-0165 "Commutation pos control: Kp" = 0)



a e g h = see the parameter description for IDN P-0-0165 above

c = flux vector of the rotor with permanent magnet.

i = movement of the rotor

Sequence:
After determining the sector "e" in Phase 1, the current vector "g" is placed exactly in the centre of the sector "e", and this current is developed. Due to the rising magnetic force, the rotor "c" is turned in the direction of the current vector "g" until they coincide. In this static alignment, the rotor cannot move more than half the width of the sector "e".

Using IDN P-0-0165 to affect wake&shake

Parameter	Default	Possible causes that might require a change in the default value
First phase current level	Stationary current	Sluggish system, high damping --> increase value

	in %	Easy-running system, low damping --> reduce value
First phase ramp up time	100 ms	Sluggish system, high damping --> increase value Easy-running system, low damping --> reduce value
First phase pos monitoring limit	0.5 degrees	Application only permits very limited uncontrolled changes in the movement --> reduce value The system has a small amount of damping --> reduce value The loading relationships require more overshoot --> increase value
First phase step width	22.5 degrees	
First phase waiting time after step	150 ms	Decay behaviour of the system: Long settling time --> increase value Short settling time --> reduce value
Second phase current level	Stationary current in %	
Second phase ramp up time	500 ms	
Second phase duration	3000 ms	
Error monitoring (range of motion)	90 degrees	Application only permits very limited uncontrolled changes in the movement --> reduce value The system has a small amount of damping --> reduce value The loading relationships require more overshoot --> increase value
Commutation pos control: Kp	0,04	High load stiffness --> increase value Low load stiffness --> reduce value A special case "0": Variant 2 is carried out in Phase 2

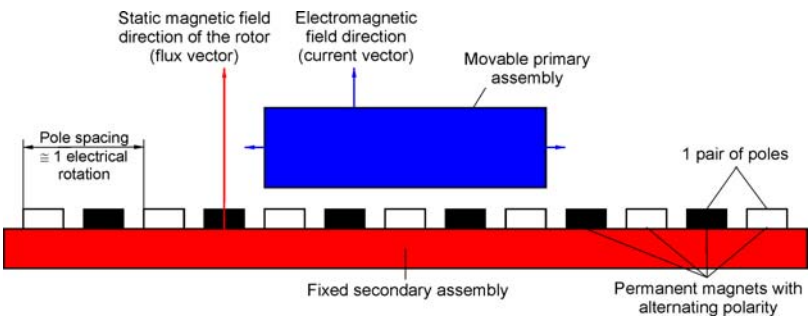
Linear motors

The above description of the commutation process applies equally to rotary motors and to linear motors. Depending on the construction, there are merely some differences of nomenclature (e.g. motor shaft (rotor) ≅ primary assembly; "degree" ≅ "mm" (recalculation is needed))

WARNING

Warning, risk of injury from **uncontrolled movements!**
The primary assembly is moved in steps during "wake&shake". In Phase 1 the maximum electrical movement is 8 x (the value from "P-0-0-0165_Fist phase position monitoring limit"). In Phase 2 it is 0.5 x (the value from "P-0-0-0165_Fist phase step width"). This formula can only be applied if the previous investigation of stability has been concluded satisfactorily. Make sure that your application permits this movement, secure the surroundings to prevent unintentional entry, and make sure that nobody is in the hazardous area.

Linear motors consist of a secondary assembly, whose position is fixed, onto which permanent magnets are attached with alternating polarity and regular spacing. A primary assembly can undergo translatory movement above this magnetic field. This movement is created by generating an electromagnetic field in the primary assembly. Linear motors always have only one pair of poles, and the distance between the poles therefore corresponds to one electrical rotation.



The "Electronic Commutation" section above can be applied to linear motors.

BECKHOFF AX5000: Commissioning

Maintenance

Servicing

- The devices are maintenance-free
- Opening the devices invalidates the warranty

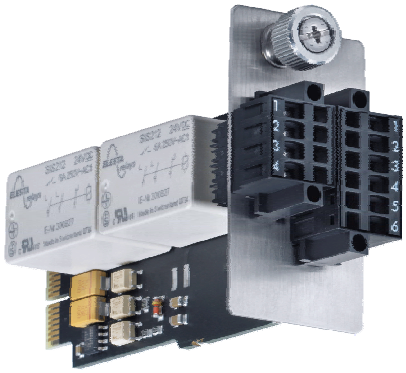
Cleaning

- Soiled housing: Clean with isopropanol or similar
  Do not immerse or spray!

- Contamination inside the device: Cleaning by the manufacturer
- Soiled fan guard: Clean with (dry) brush

BECKHOFF AX5000: Integrated Safety

Safety-Card AX5801



Appropriate use

The AX5801 Safety Card is designed exclusively for installation in the optional safety slot of a servo drive from the AX5000 series. The cards are installed together with the servo drive as components in electrical systems and machinery and may only be used in this way.

Scope of supply

The scope of supply includes the following components:

AX5801 Safety Card, 4-pin connector, 6-pin connector, technical documentation and packaging

If one of the components is damaged please notify the logistics company and Beckhoff Automation GmbH immediately.

Safety rules

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations and guidelines.

DANGER

Caution - Danger of death!

Even when the AX5000 is disconnected from the mains voltage, dangerous voltage continues to be present at the "X02" terminals of the DC link for at least 3 minutes. Never touch the terminals within this period.

WARNING

Caution - Risk of injury!

Elektronische Electronic equipment is not fail-safe. The machine manufacturer is responsible for ensuring that the connected motors and the machine are brought into a safe state in the event of a fault in the drive system.

CAUTION

Caution - electrostatic charging may lead to destruction of the Safety Card!

The Safety Card is an ESD-sensitive component. Follow the usual ESD safety procedures when handling the card (anti-static wrist straps, earthing of the relevant components, etc.).

Personnel qualification

This description is only intended for trained specialists in control, automation and drive engineering who are familiar with the applicable national standards. Knowledge of machine safety legislation is compulsory.

Product description!

Mit The AX5801 Safety Card from Beckhoff is used to realise the safe brake functions "STO or SS1 according to IEC 61800-5-2". STO stands for SafeTorqueOff, SS1 for SafeStop1.

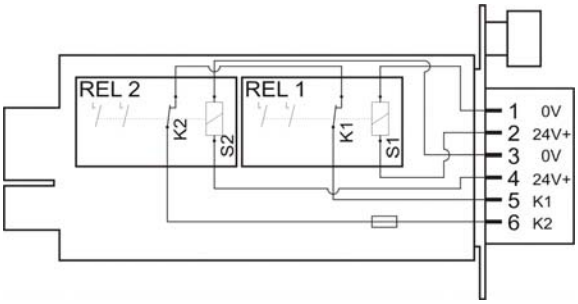
Through 2-channel monitoring integrated in the AX5000, stop category 0 or 1 according to IEC 60204-1 can be realised with minimum effort and additional TwinSAFE blocks from Beckhoff, resulting in control category 3 according to EN 954-1.

Two-channel monitoring is achieved through certified relays (Rel1 and Rel2). The relays are equipped with positively driven contacts including feedback contacts (K1 and K2). The feedback contacts are connected in series and potential-free with terminals (5) and (6) of the 6-pin connector.

The two coils (S1 and S2) have to be supplied with 24 V DC via terminals 1 and 2 or 3 and 4 of the 6-pin or 4-pin connector.

Terminals1-1, 2-2, 3-3 and 4-4 of the two connectors are bridged internally.

If a relay releases, the de-energising circuit of the AX5000 servo drive range ensures that the connected motors (both channels) become torque-free.



Technical data

Relay operating voltage (terminal1-4)	24 VDC -15% +20%	Feedback contacts operating voltage (5-6)	24 VDC-15% +20%	max. switching current of the feedback contacts (5-6)	0,35 A
Conductor cross section of terminals 1-6	0,2 -1,5 mm^2	Conductor strip length of terminals 1-6	10mm	current consumption	50 mA

We recommend using wire end sleeves!

Installation of the AX5801 Safety-Card

DANGER

Caution - Acute risk of injury!

Before installing the Safety Card disconnect the servo drive from the mains and system voltage. Dangerous voltage continues to be present at the X02 terminals of the DC link for at least 3 minutes. Never touch the terminals within this period.

Mechanical installation

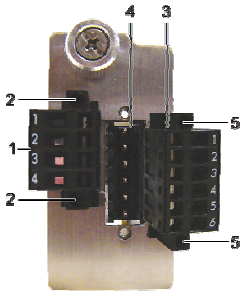
Installation of the two connectors on the AX5801 Safety-Card

– Insert the enclosed 4-pin connector (1) into the socket.

– Tighten the two bolts (2).

– Insert the 6-pin connector (3) into the socket.(4).

– Tighten the two bolts (5).



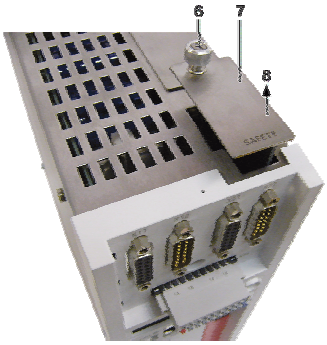
Installation of the AX5801 Safety-Card

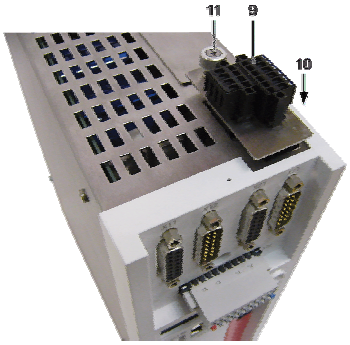
– Fully release the bolt (6).

– Remove the insert (7) in the direction of the arrow (8).

– Carefully insert the Safety Card (9) into the opening in the direction of the arrow (10). The slot has guides for the card on the short sides. Ensure that the card is inserted into these guides.

– Tighten the bolt (11).





Electrical Installation

Configure the safety operation of servo drive via IDN P-0-2000. During the next system start-up the servo drive automatically detects whether a Safety Card was inserted and whether the IDN P-0-2000 parameterisation is correct. Error message "0xFDD4" indicates incorrect configuration. If the servo drive with the Safety Card does not reach the safe state, error message "0xFDD5" appears on the display of servo drive. In this case please contact Beckhoff.

CAUTION

Hazard to individuals and devices!

If an error message appears on the display of the AX5000 the servo drive must not be put into service if the servo drive in the system or machine represents a safety-relevant part of the control system.

Application example (emergency stop - stop category 1)

Components involved:

- Emergency stop device (control switch S1) according to ISO 13850 and control switch S2
- 1 safety input terminal (KL1904) and 1 input terminal (KL 1404)
- 1 safety logic terminal (KL6904) with function block "ESTOP"
- AX5801 Safety Card and servo drive from the AX5000 range
- Programmable logic controller (PLC) and EtherCAT fieldbus

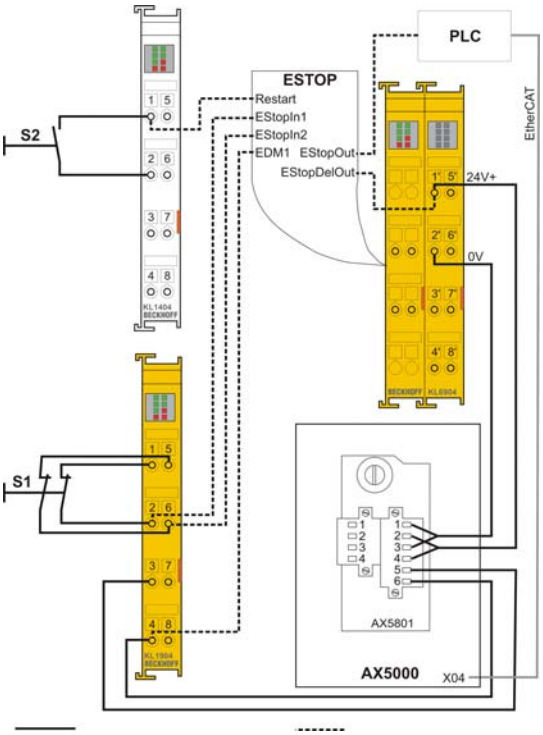
By activating the emergency stop device (S1) inputs EStopIn1 and EStopIn2 of FB "ESTOP" are switched to state "0", resulting in outputs EStopOut and EStopDelOut of FB "ESTOP" being switched to state "0". As a result, a quick stop command is issued to the PLC and therefore the AX5000 via EtherCAT. The output EStopDelOut of FB "ESTOP" ensures that after a specified delay time the 24 V supply of the AX5801 Safety Card is interrupted. This causes the relays (REL1 and REL2) to release and both channels (motors) to be made torque-free via the internal deactivation procedure of the AX5000.

In the event of a fault the controlled shutdown (quick stop) may fail. The Safety Card becomes active once the delay time has elapsed, and all motors connected to the device run out. The risk analysis for the machine must indicate that this behaviour can be tolerated. An interlock may be required.

The delay time must be set slightly longer than the maximum braking time of the quick stop.

Sticking relay contacts on the Safety Card are detected via input EDM1 of FB "ESTOP", and restarting is prevented.

When the emergency stop device is released again, the control switch (S2) must be operated (first rising then falling edge at the restart input of FB "ESTOP") in order to restart the AX5000.



elektrical connection logic link

BECKHOFF AX5000: Shutting down

Shutting down

DANGER

Serious risk of injury through electric shock!

Bring the AX5000 into a safe, de-energised state. Due to the DC link capacitors dangerous voltage may persist at the DC link contacts "X02" after the servo drive has been disconnected from the mains supply. After disconnecting the servo drive wait at least 3 minutes and measure the voltage at the DC link contacts DC+ and DC-. The device is safe once the voltage has fallen below 50 V.

Disposal

- Screw connections enable the servo drives to be dismantled into main components (aluminium heat sink, steel cases, PCBs)
- The device should be disposed of by a certified disposal company. You can obtain addresses from us. Housing components (polycarbonate, polyamide (PA6.6)) are suitable for plastic recycling.
- Metal parts can be sent for metal recycling.
- Electronic parts such as circuit boards and terminals must be disposed of in accordance with national electronics scrap regulations.

BECKHOFF AX5000: Accessories

AX-Bridge quick connection system

The AX5000 quick connection system enables simple and fast connection of several AX5000 devices to form a multi-axis system. The pluggable supply and connection module combines power supply, DC link, and control and braking voltage (24 V_{DC}).

Drive system with UL-Listing!

Please consult our Application Department with respect to the requirements for a drive system with UL-Listing.

CAUTION

Destruction of the AX5000!

All devices in a drive system are always to be disconnected from and reconnected to the mains supply together (emergency stop, mains contactor etc.)

CAUTION

Destruction of the external brake resistor!

An external brake resistor may not be connected to the X02 terminal point (DC link) in a drive system. Use an external brake module AX5021 for this.

Supply module for multi-axis system

If several AX5000 units are to be linked to form a multi-axis system, a supply module for connecting the supply voltage and the control voltage (24 V_{DC}) for the control electronics and the motor brakes is required.

Article no.	Description
AX5901	Supply module

To install the supply module connectors X01, X02 and X03 must be removed and replaced with the supply module.

AX-Bridge connection module for multi-axis system

The connection between the two AX amplifiers is established by moving the three busbar sliders of the first connection module of the next drive to the left.

Article no.	Description
AX5911	Connection module for housing size 1 (AX5000 with rated current between 1 A and 12 A)
AX5912	Connection module for housing size 2 (AX5000 from 18 A rated current)

Assembly

WARNING

Risk of injury through electric shock and destruction of the AX5000!

Move all busbar sliders to the left limit stop in order to ensure full current carrying capacity. Then tighten all screws with a torque of 2.2 Nm.

Current carrying capacity and number of modules

The number of AX5000 servo drives that can be connected depends on country-specific standards.

CE

According to CE the limit is defined by the current carrying capacity of the power busbars, which is limited to a rated current of 100 A.

Example: Up to eight AX5206 two-channel devices with a channel current of 6 A or a total current of 12 A can be connected with each other (resulting in a total rated current of 96 A).

BECKHOFF AX5000: Accessories

DC link expansion AX5001

(in preparation)

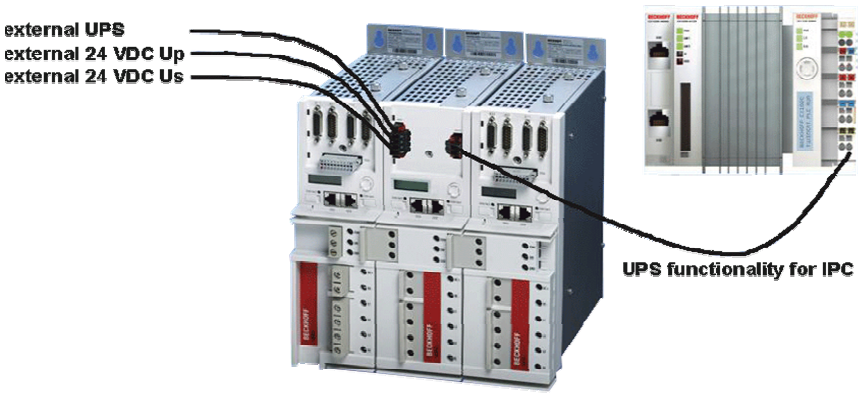
DC link expansion for buffering regenerative energy (brake energy).

During dynamic movements with short deceleration ramps energy is fed back from the motor to the servo drive (generative motor operation). This energy increases the DC link voltage. If the DC link voltage increases above a parameterisable limit value, the brake chopper, which converts the excess energy into dissipated heat in an internal or external braking resistor, is generally activated.

Increasing the DC link capacity increases the buffer for absorbing brake energy, and activation of the brake chopper is delayed or avoided. This is achieved through coupling of several servo drives via an AX bridge. To cater for simultaneous braking of several axes in several servo drives the DC link capacity can be increased through DC link expansion modules.

Connection to AX5000 servo drives is accomplished via AX bridge connection modules. Several DC link expansion modules can be connected in parallel. The configuration within a system is freely selectable. The DC link expansion modules are short-circuit-proof.

The DC link expansion modules feature an EtherCAT interface and a plain text display for parameterising threshold levels and limits and for diagnostic purposes.

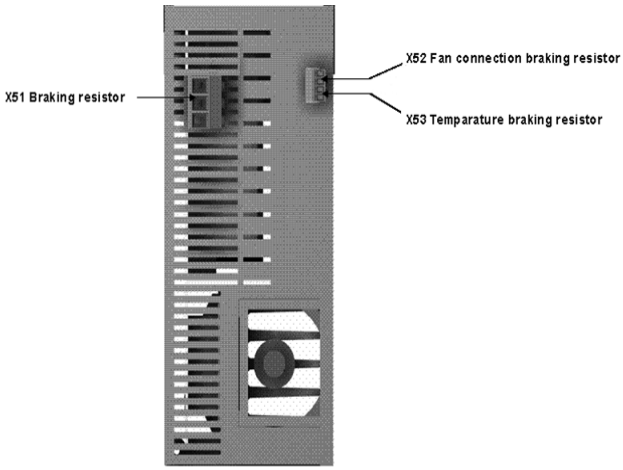


BECKHOFF AX5000: Accessories

AX5021 brake module

(in preparation)

Brake module with internal braking resistor (P_{rms} = 250 W) and active cooling. The system also features an integrated brake chopper for connecting an external braking resistor with a capacity of up to P_{rms} = 6 kW. Connection to the AX5000 series servo drives is accomplished via AX bridge connection modules.

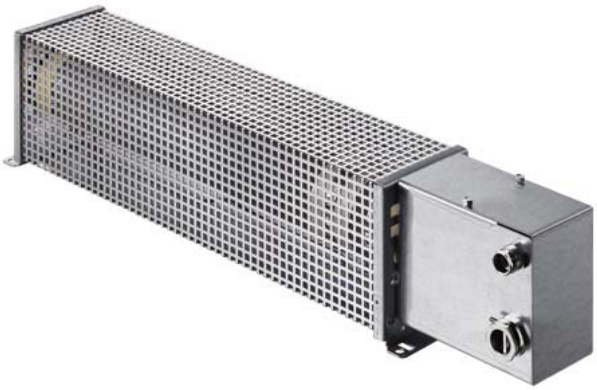


Performance data

Internal resistance Continuous braking power P_{rms} [W]	Internal resistance Peak power P_{peak} [W]	External resistance min. [Ω]	External resistance Continuous braking power P_{rms}	External resistance Peak power P_{peak} [W]
250	-	15	6.000	max. 47.600

BECKHOFF AX5000: Accessories

External Brake Resistor - AX2090-BW5x-xxxx



Appropriate use

The brake resistors from the AX2090-BW5x-xxxx series are exclusively designed for direct application with an AX5000 series servo drive or the

AX5021 brake module. They are designed for installation as components in electrical installations and machines together with the servo drive or the brake module, and this is their only purpose.

Scope of supply

The scope of supply includes the following components:

- Brake resistor from the required performance class
- Technical documentation
- Packaging

If one of the components is damaged please notify the logistics company and Beckhoff Automation GmbH immediately.

Safety rules

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations and guidelines.

DANGER

Caution – Danger of death!

Even when the AX5000 is disconnected from the mains voltage, dangerous voltage continues to be present at the "X02" terminals of the DC link for at least 5 minutes. Never touch the terminals within this period.

WARNING

Caution - Risk of injury through hot surfaces!

The temperature of the brake resistor housing surface may reach over 200 °C. Please ensure that the housing has cooled down below 40 °C before touching it.

UL-Listing!

It is essential to observe chapter "Product overview-->Guidelines and Standards-->UL-Listing" if you wish to operate an AX5000 in an economic area that requires a UL-Listing.

Product description

Attention

Caution - Destruction of the equipment

The brake resistor may only be connected to individual AX5000 devices or AX5021 brake modules. It must never be used in a drive system without the AX5021 brake module, since this may lead to its destruction through overload.

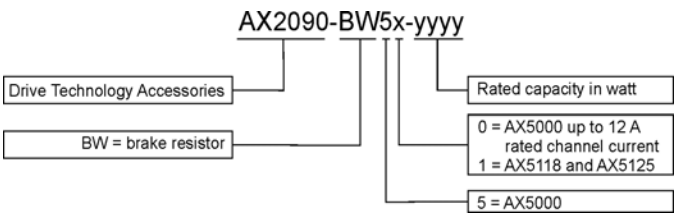
The external brake resistors of the AX2090-BW5x-xxxx series are able to convert the dynamic energy generated during braking of a servomotor into heat. The series covers a wide continuous power and peak power range. The built-in temperature switch enables the system to respond immediately to any overload of the brake resistor through analysis in the AX5000 or the PLC. All brake resistors of the AX2090-BW5x-xxxx series are UL and CSA approved.

Attention

Caution - Destruction of the brake resistor and consequential damage

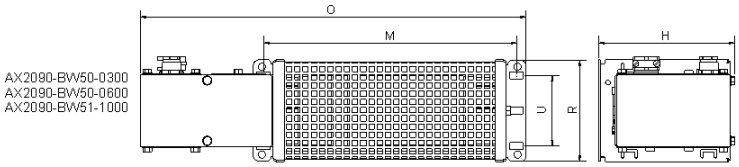
The built-in temperature switch must be monitored, so that the machine can be stopped in a controlled manner and switched off in the event of an overloading of the brake resistor.

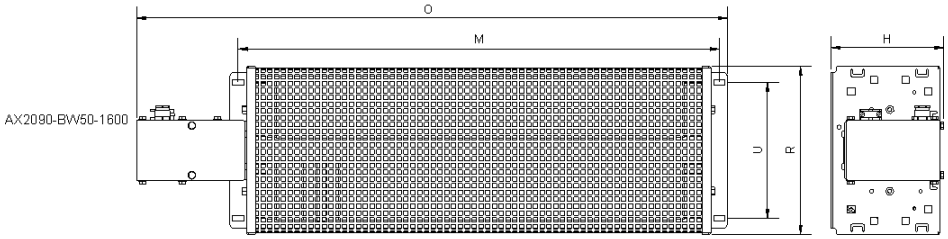
Type key

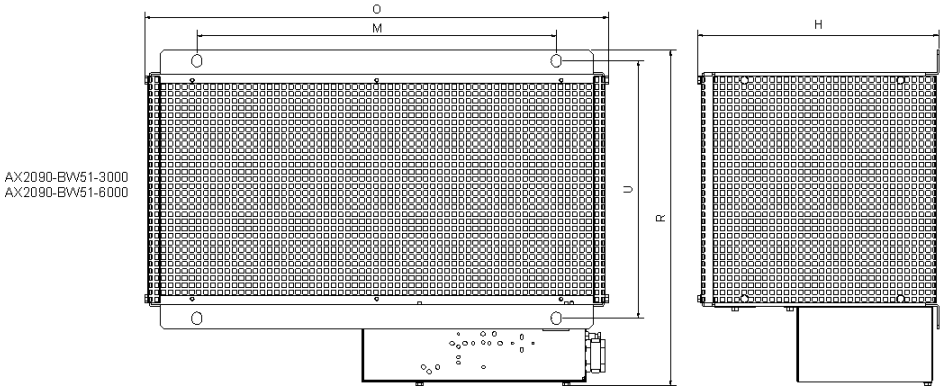


Mechanical installation

Dimensions and technical data





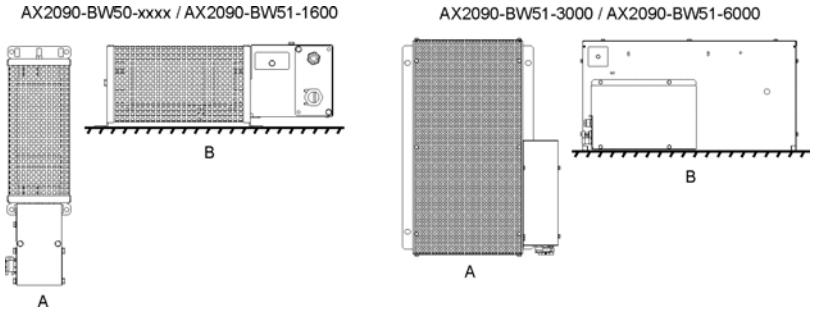


Type	Nominal capacity [W] * at 40 °C	Resistance [Ω]	O [mm]	R [mm]	H [mm]	M [mm]	U [mm]	Weight [kg]	AX5000
AX2090-BW50-0300	300	47	349	92	120	230	64	2	AX5x01-AX5112
AX2090-BW50-0600	600	47	549	92	120	430	64	3	AX5x01-AX5112
AX2090-BW50-1600	1600	47	649	185	120	530	150	5,8	AX5x01-AX5112
AX2090-BW51-1000	1000	23	749	92	120	630	64	4	AX5118, AX5125
AX2090-BW51-3000	3000	23,4	490	355	255	380	270	8	AX5118, AX5125
AX2090-BW51-6000	6000	23,2	490	455	255	380	370	12	AX5118, AX5125

*) 4% output reduction per 10K temperature difference

Mounting positions and distances

(A) = vertical installation is only permitted according to the diagram (terminal box facing downwards).
(B) = horizontal installation



For all mounting positions the following minimum distances must be adhered to:

200 mm to adjacent components, walls etc. and 300 mm to components, ceilings etc. above. If the device is installed vertically (A), the minimum distance to components, floors etc. below is 200 mm in order to allow unobstructed flow of air to the brake resistor.

Electrical installation


DANGER

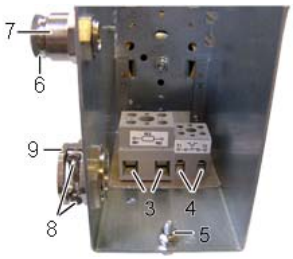
Caution – Danger of death!

Disconnect the AX5000 from the mains before installing the brake resistor!
Even when the AX5000 is disconnected from the mains voltage, dangerous voltage continues to be present at the "X02" terminals of the DC link for at least 5 minutes. Never touch the terminals within this period.

Remove the two screws (1) and remove the cover (2) in direction of the arrow. Connect an adequately dimensioned cable (see section Cables) to the terminals (3) of the resistor and the earthing stud (5) and take it out of the terminal box through the strain-relief assembly (9). Ensure adequate strain relief with the two screws (8). Connect the other side of the cable to the DC link contact connector X2 (10) of the AX5000. The connector is supplied with the AX5000. Connect the earthing cable to the earthing conductor of the control cabinet.

Connect an adequately dimensioned cable to the potential-free N/C contact (4) of the temperature switch and take it out of the terminal box through the strain-relief assembly (7) (see section Temperature switch). Ensure adequate strain relief with the nut (6).

Install the cover (2) in reverse order.



Cables

We recommend Beckhoff motor cables for connecting the brake resistors.

WARNING

Caution - Fire hazard!

The brake resistors become very hot. Only use cables with adequate heat resistance.

Attention

EMC-Safety

Use only shielded cables.

Type	Brake resistor		Temperature switch	
	[mm^2]	[AWG]	[mm^2]	[AWG]
AX2090-BW50-0300	1,5	16	0,75	18
AX2090-BW50-0600	1,5	16	0,75	18
AX2090-BW50-1600	1,5	16	0,75	18
AX2090-BW51-1000	2,5	12	0,75	18
AX2090-BW51-3000	2,5	12	0,75	18
AX2090-BW51-6000	2,5	12	0,75	18

We recommend wire end sleeves.

Temperature switch

Attention

Destruction of the brake resistor

The temperature switch is only used for temperature monitoring. The brake resistor is not switched off.

The temperature switch has a potential-free N/C contact, which enables immediate response to any overload of the brake resistor through analysis in the AX5000 or the PLC. Connect the cable directly to a free input of plug "X06". Then parameterise it such that the AX5000 stops the motor(s) with an emergency ramp or the PLC reads and processes this input.

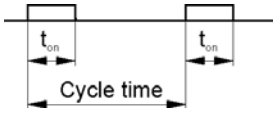
Type	Switching temperature	Switching current 24 VDC er 230 VAC
	[°C]	[A]
AX2090-BW50-0300	180	2
AX2090-BW50-0600	180	2
AX2090-BW50-1600	180	2
AX2090-BW51-1000	180	2
AX2090-BW51-3000	85	2
AX2090-BW51-6000	85	2

Short-term capacity

Brake resistors are usually not operated continuously, but only exposed to short-time duty. In the following section the permitted short-term capacity is calculated based on the continuous power, overload factor and duty cycle.

Duty cycle

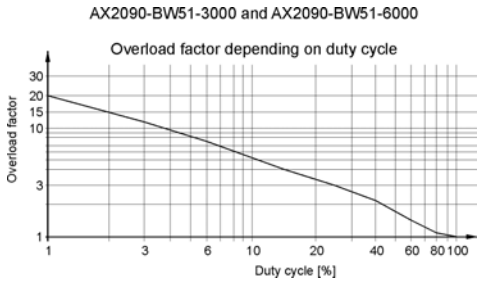
The duty cycle is a relative value that depends on the switch-on time (ton)and the cycle time. Cycle times up to 120 sec. are used directly in the calculation. Should the cycle time exceed 120 sec., the maximum relevant cycle time of 120 sec. is used in the calculation.

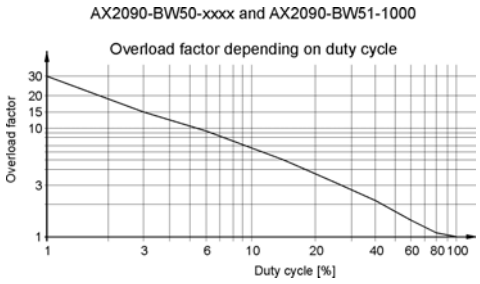


$$\text{duty cycle} = \frac{t_{on}}{\text{Cycle time}} \times 100\ \%$$

Example 1	*Example 2*
t_{on} = 60 s	t_{on} = 40 s
Cycle time = 280 s	Cycle time = 180 s
Duty cycle = 50 %	**Duty cycle = 40 %**

Overload factor





Calculation formula:

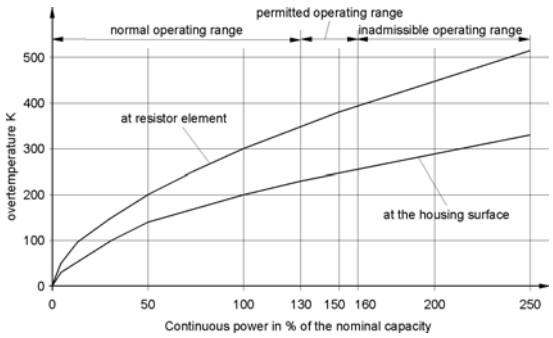
Short-term capacity = continuous power x overload factor

Overtemperature and continuous power at 100% duty cycle

If your application requires a higher continuous power than the specified nominal capacity, you can accept this state if a higher brake resistor temperature is permitted. The following diagram shows the overtemperature v. the continuous power.

Normal operating range, max. 130%:
This operating range is recommended for maximum service life and error-free operation.
Permitted operating range, max. 160%:
This operating range is still permitted, although it results in shorter service life with higher failure probability.

Inadmissible operating range, more than 160%:
In this operating range there is a risk of destruction of the brake resistor through overheating. Due to the high temperatures the adjacent components are also at risk.



Attention

Destruction of the brake resistor and adjacent components

Always ensure adequate ventilation of the brake resistor, since the temperatures of the housing surface may exceed 200 °C.

BECKHOFF AX5000: Accessories

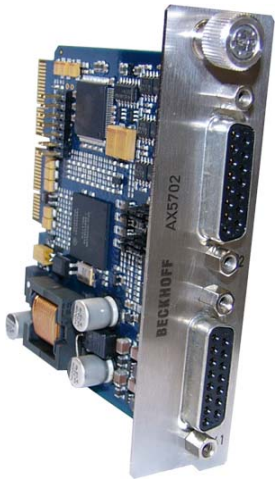
Energy recovery

(in preparation)

Mains inverter for feeding brake energy back into the supply network

BECKHOFF AX5000: Accessories

Optional encoder card - AX5701 / AX5702



Appropriate use

The optional encoder cards are exclusively intended for application in the optional rear slot of a servo drive from the AX5000 series. The cards are installed together with the servo drive as components in electrical systems and machinery and may only be used in this way.

Scope of supply

The scope of supply includes the following components:

- Optional encoder card AX570x
- Technical documentation
- Packaging

If one of the components is damaged please notify the logistics company and Beckhoff Automation GmbH immediately.

Safety rules

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations and guidelines.

Caution – Danger of death!

DANGER

Even when the AX5000 is disconnected from the mains voltage, dangerous voltage continues to be present at the "X02" terminals of the DC link for at least 5 minutes. Never touch the terminals within this period.

WARNING

Caution – Risk of injury!

Electronic equipment is not fail-safe. The machine manufacturer is responsible for ensuring that the connected motors and the machine are brought into a safe state in the event of a fault in the drive system.

Attention

Caution – Destruction of the optional encoder card through electrostatic charging!

The optional encoder card is an ESD-sensitive component. Follow the usual ESD safety procedures when handling the card (anti-static wrist straps, earthing of the relevant components, etc.).

UL-Listing!

It is essential to observe chapter "Product overview-->Guidelines and Standards-->UL-Listing" if you wish to operate an AX5000 in an economic area that requires a UL-Listing.

Product description

The optional encoder card enables connection of an additional feedback systems per channel. The system parameters match the standard parameters that are analysed via inputs X11 and X21. Through simple configuration via jumpers up to six further digital inputs (In “A” to In “F”) can be analysed, which are provided through special feedback systems via parameter channels. The X41 and X42 sockets are compatible with the plugs of the X11 and X21 front sockets of the AX5000, which means that the tried and tested cables from the ZK4510 series can be used. To analyse the additional digital inputs you simply have to insert an adapter or establish a suitable wiring.

Firmware-version

Operation of the optional encoder card requires firmware version 1.7 b01xx or higher on the AX5000.

Type key

Note

Operation of the optional encoder card

The AX5701 can only be used in single-channel servo drives, the AX5702 can only be used in two-channel servo drives.

AX5701 – optional encoder card for single-channel servo drives

AX5702 – optional encoder card for two-channel servo drives

Description of the digital inputs

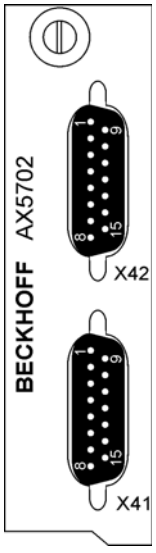
Note

Functional reliability

Ensure that the ground potentials of the digital inputs “A” to “D” are connected with the ground potential of the AX5000.

Inputs “A” to “D” are “single-wire” inputs (single-ended). They have a certain potential to ground, which is analysed.
Inputs “E” and “F” are “two-wire inputs” (differential). They require (+) and (-) and analyse the voltage difference between the conductors.

Overview of sockets X41 (channel A) and X42 (channel B)



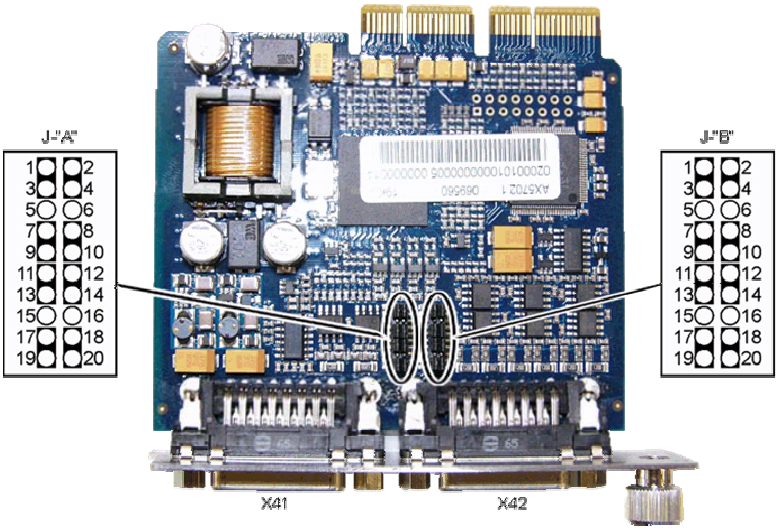
Pin	EnDAT / BiSS	Hiperface	Sin / Cos $1V_{pp}$	TTL	In "A"	In "B"	In "C"	In "D"	In "E"	In "F"
1	SIN +	SIN +	SIN +	n.c.	X				X (+)	
2	GND_5 V	GND_9 V	GND_5 V	GND_5 V						
3	COS +	COS +	COS +	n.c.			X			X (+)
4	U_s–5 V	n.c.	U_s–5 V	U_s–5 V						
5	DX + (Data)	DX + (Data)	n.c.	B +			Y			
6	n.c.	U_s–9 V	n.c.	n.c.						
7	n.c.	n.c.	REF Z	REF Z						
8	CLK + (Clock)	n.c.	n.c.	A +	Y					
9	REF SIN	REF SIN	REF SIN	n.c.		X			X (-)	
10	GND_Sense	n.c.	n.c.	GND_Sense						
11	REF COS	REF COS	REF COS	n.c.				X		X (-)
12	U_s–5 V Sense	n.c.	U_s–5 V Sense	U_s–5 V Sense						
13	DX - (Data)	DX - (Data)	n.c.	n.c.				Y		
14	n.c.	n.c.	Z +	Z +						
	CLK -									

15	(Clock)	n.c.	n.c.	n.c.		Y				

The digital inputs “A” to “D” can be connected to X or Y.
The digital inputs “E” and “F” must be connected to X (+) and X (-).

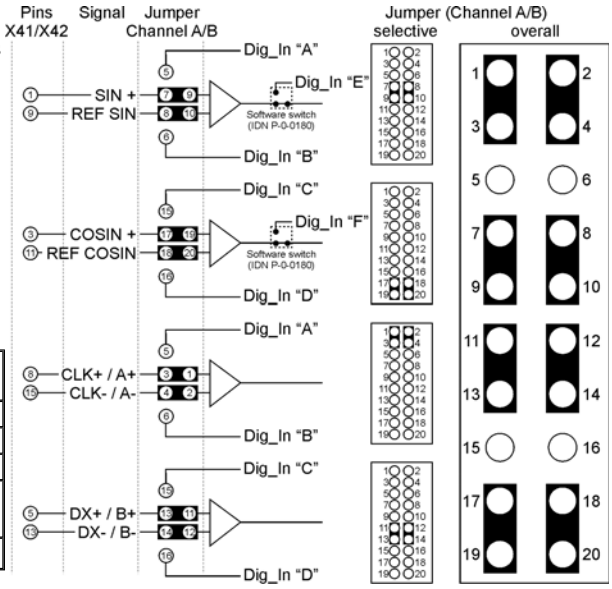
Configuration of jumpers J-“A” for channel “A” and J-“B” for channel “B”

Jumpers J-“A” and J-“B” (1) are located at the centre of the printed circuit board near the front panel of the card. For each channel there are 2 row of jumpers, each with 20 pins. The default setting without analysis of the additional inputs is shown in the following figure.



The opposite figure shows the basic jumper configuration, which is the same for channel A and channel B. The pins of input sockets X41 and X42 are wired firmly to the corresponding pins of the jumpers rows. The non-configurable pins are not shown. To use the additional inputs proceed as follows:

- Reposition the relevant jumpers und set IDN P-0-0180-->Feedback options-->Digital Inputs **“Input A”** to **“Input D”** to **“used”** or set IDN P-0-0180-->Feedback options-->Digital Inputs **“Input E”** or **“Input F”** to **“used”** without repositioning the jumpers.
- Connect the encoder cable as required for the relevant inputs or use an adapter.

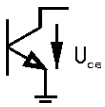


The following table shows a selection of combination options.

Feedback system	Input "A"	Input "B"	Input "C"	Input "D"	Input "E"	Input "F"
EnDat	not available					
BiSS	not available					
Hiperface	X	X				
Sin / Cos 1 V_{pp}	X	X	X	X		
TTL	X[1]	X[1]	X[2]	X[2]	X[1]	X[2]

1) Either inputs “A” and “B” or input “E” can be used
2) Either inputs “C” and “D” or input “F” can be used.

Technical Data

Digital inputs “A” to “D” (single-ended)	Open collector  max. 1 mA
Digital inputs “E” to “F” (differential)	0 - 5 V Inp. resistance: 120 Ω

Installation of the optional encoder card

Caution – Danger of death!

DANGER

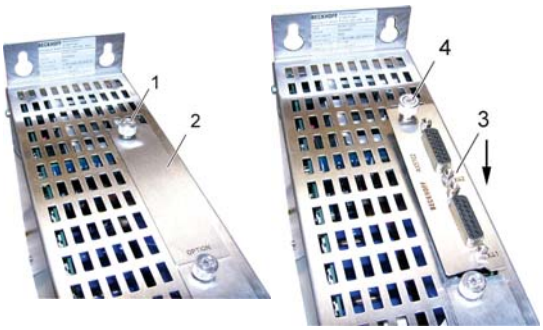
Even when the AX5000 is disconnected from the mains voltage, dangerous voltage continues to be present at the "X02" terminals of the DC link for at least 5 minutes. Never touch the terminals within this period.

Attention

Caution – Destruction of the optional encoder card through electrostatic charging!

The optional encoder card is an ESD-sensitive component. Follow the usual ESD safety procedures when handling the card (anti-static wrist straps, earthing of the relevant components, etc.).

1. Fully release the bolt (1).
2. Remove the panel (2).
3. Carefully insert the optional card (3) into the opening in the direction of the arrow. The slot has guides for the card on the short sides. Ensure that the card is inserted into these guides.
4. Tighten the bolt (4).



Example: Renishaw RGH 22Z30D00 (TTL encoder with 2 parameter channels)

Configuration via TCDrivemanager (IDN-P-0-0180)

Encoders and inputs

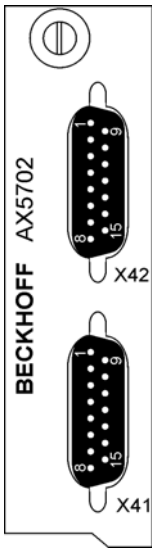
P-0-0180	Feedback 2 type		
	Manufacturer	13: Renishaw	13: Renishaw
	Feedback type	1: Linear feedback	1: Linear feedback
	Feedback type string	Reni#RGH22Z-TTL-5...	Reni#RGH22Z-TTL-5...
	Feedback use	1: Additional second m...	1: Additional second m...
	Feedback direction	0: Positive direction	0: Positive direction
	rsvd		
	Power settings		
	Process channel		
	Parameter channel		
	Manufacturer limits settings		
	Feedback options		
	Digital Inputs		
	Input A (single ended)	0: Not used	0: Not used
	Input B (single ended)	0: Not used	0: Not used
	Input C (single ended)	1: used	1: used
	Input D (single ended)	0: Not used	0: Not used
	Input E (differential)	1: used	1: used
	Input F (differential)	0: Not used	0: Not used
	reserved	0	0
	rsvd	0	0
	rsvd		

Scaling

P-0-0180	Feedback 2 type		
	Manufacturer	13: Renishaw	13: Renishaw
	Feedback type	1: Linear feedback	1: Linear feedback
	Feedback type string	Reni#RGH22Z-TTL-5...	Reni#RGH22Z-TTL-5...
	Feedback use	1: Additional second m...	1: Additional second m...
	Feedback direction	0: Positive direction	0: Positive direction
	rsvd		
	Power settings		
	Process channel		
	Process interface	2: Incremental 5V TTL	2: Incremental 5V TTL
	Connector	41: X41 (Option Slot, E...	41: X41 (Option Slot, E...
	rsvd		
	Data		
	Sin / Cos		
	TTL		
	Resolution per rotation	48000	48000
	Length per signal period	500	500
	rsvd		
	Resolver		
	MES		
	Parameter channel		
	Manufacturer limits settings		
	Feedback options		

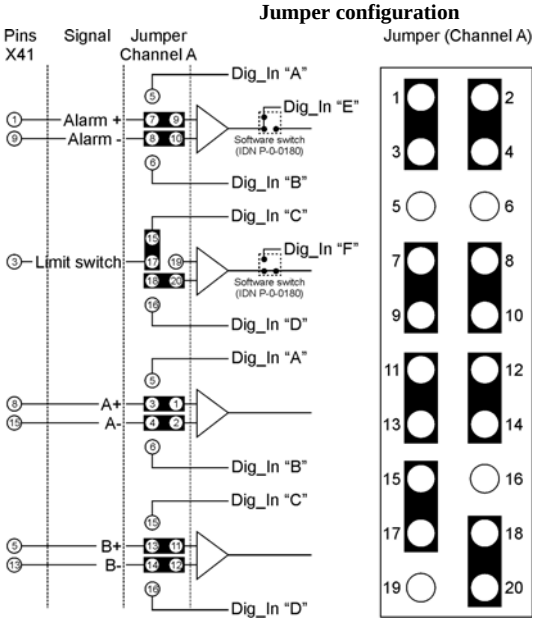
Overview of socket X41 (channel A) and jumper configuration

Socket X41



Pin	Renishaw	In "C"	In "E"
1	Alarm +		X +
2	GND_5 V		
3	Limit switch	X	
4	U_s–5 V		
5	B +		
6	n.c.		
7	REF Z		
8	A +		
9	Alarm -		X -
10	GND_Sense		
11	n.c.		
12	U_s–5 V Sense		
13	B -		
14	Z +		
15	A -		

Jumper configuration



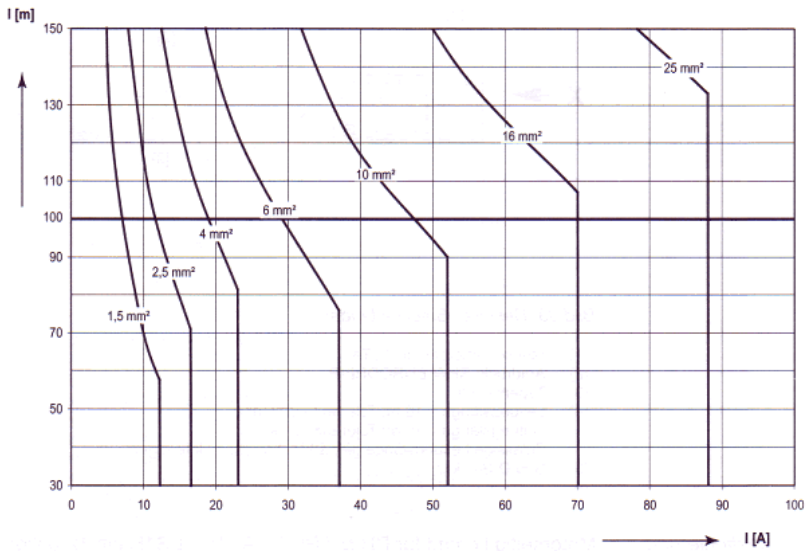
BECKHOFF AX5000: Accessories

Cables

General specification

Beckhoff offers pre-assembled motor and feedback cables for faster and flawless installation. Design, dimensioning and installation have significant influence on the function of a servo system. Beckhoff servo cables have been tested with regard to the material used, screening and connection, in order to guarantee proper function and compliance with statutory requirements such as EMC. The use of other may invalidate the warranty.

Wire cross-section depending on the cable length (according to EN60402)



Minimum wire cross-section depending on cable length and current

Line load for different types of installation:

WARNING

Fire hazard!
If several servo drives are operated at the same time the resulting total current of the configuration must be taken into account for dimensioning of the cables.
The information provides in this section should be regarded as guidance. It is not intended as a substitute for professional design based on the specific application.

Cable cross-section		Three-core non-metallic sheathed cable or conduit	Three-core non-metallic sheathed cable, stacked on wall	Three-core non-metallic sheathed cable, side by side, horizontal
[mm²]	[AWG]	[A]	[A]	[A]
1.5	16	12.2	15.2	16.1
2.5	12	16.5	21.0	22
4	10	23	28.0	30

6	10	29	36.0	37
10	8	40	50.0	52
16		53	66.0	70
25		67	84.0	88
35		83	104.0	114

Line load according to EN60204-1, Table 5, at an ambient temperature of 40°C

Two cable qualities are offered: Cables for fixed installation (static application), and cables for highly dynamic applications such as drag chains.

Cables for fixed installation

General data	Specification
Min. bending radius	18 x outside diameter
Max. horizontal velocity	180 m/min
Max. acceleration	5 m/s²
Max. no. of cycles	50,000
Max. tensile load	20 N/mm²
Operating temperature	-10°C to +80°C

Standards and specifications	Motor cable	Encoder cable
UL AWM-listed	80°C 1000 V	80°C 30 V
CSA AWM-listed	75°C 1000V	75°C 30 V
VDE (U_0 / U)	0.6 / 1 kV	---
Flame resistance	DIN EN 50265-2-1	
Oil resistance	UL 1581	
Silicone-free	yes	
CFC-free	yes	
Halogen-free	no	

Specification	Motor cable 4x1.5 + 2x(2x0.75) mm²	Encoder cable 7x(2x0.14) + 1x(2x0.5) mm²
Sheath	**Specification**	
Material	PVC according to UL AWM & CSA AWM	
Screen	tinned copper braid, optical cover ≥ 85 %	
Separator	polyester tape	
Diameter	11.3 mm ± 0.4 mm	7.6 mm ± 0.3 mm
Weight	kg / km	kg / km
Colour	orange RAL 2003	green RAL 6018
Power	**4x1.5 mm²**	**2x0.5 mm²**
Conductor material	bare copper Cl. 5 (IEC 60228)	tinned copper 19 x 0.18 mm
Insulation	TEO Flexene ® polymer compound according to UL AWM & CSA AWM	polypropylene, according to UL AWM & CSA AWM
Colour code	black (1 - 3) + green/yellow	see section "Feedback cables"
Signal	**2x(2x0.75) mm²**	**7x(2x0.14) mm²**
Conductor material	bare copper Cl. 5 (IEC 60228)	tinned copper 7 x 0.16 mm
Insulation	TEO Flexene ® polymer compound according to UL AWM & CSA AWM	polypropylene, according to UL AWM & CSA AWM
Structure	pair-wise twisted	
Screen per pair	tinned copper sheath, optical cover ≥ 85 %	---
Separator	fleece tape	---
Colour code	pair 1: black (5 - 6) pair 2: black (7 - 8)	see section "Feedback cables"
Electrical specification		
Test conditions	20°C	
Conductor resistance	IEC 60228 Cl. 5	0.5 mm²: ≤ 40 Ω/km 0.14 mm²: ≤ 140 Ω/km
Insulation resistance	≥ 2500 MΩ x km	
Operating voltage	≤ 1000 V	≤ 30 V
Test voltage: Power (conductor / conductor / screen) Signal (conductor / conductor / screen)	4 kV eff., 5 min. 2 kV eff., 1 min.	1500 VDC
Capacitance Power Signal	max. 150 pF / m max. 100 pF / m	max. 100 pF / m max. 120 pF / m

Cables for flexible installation / highly dynamic operation

General data	Specification
Min. bending radius	7 x outside diameter
Max. horizontal velocity	240 m/min
Max. acceleration	30 m/s²
max. moved horizontal length	20 m
max. vertical length	5 m
Max. no. of cycles	10 million
Max. tensile load	20 N/mm²
Operating temperature	-10°C to +80°C

Standards and specifications	Motor cable	Encoder cable
UL AWM-listed	80°C 1000 V	80°C 30 V
CSA AWM-listed	75°C 1000V	75°C 30 V
VDE	0.6 / 1 kV	---
Flame resistance	DIN EN 50265-2-1	
Oil resistance	UL 1581	
Silicone-free	yes	
CFC-free	yes	
Halogen-free	yes	

Specification	Motor cable 4x1.5 + 2x(2x0.75) mm²	Encoder cable 4x(2x0.14) + 1x(2x0.5) mm²
Sheath	**Specification**	
Material	TMPU halogen-free, accordingly UL AWM & CSA AWM	
Screen	tinned copper braid, optical cover ≥ 85 %	
Separator	polyester tape	
Diameter	12.2 mm ± 0.4 mm	7.6 mm ± 0.3 mm
Weight	____ kg / km	____ kg / km
Colour	orange RAL 2003	green RAL 6018
Power	**4x1.5 mm²**	**2x0.5 mm²**
Conductor material	bare copper Cl. 5 (IEC 60228)	tinned copper 19 x 0.18 mm
Insulation	TEO Flexene ® polymer compound according to UL AWM & CSA AWM	polypropylene, according to UL AWM & CSA AWM
Colour code	black (1 - 3) + green/yellow	see section "Feedback cables"
Signal	**2x(2x0.75) mm²**	**7x(2x0.14) mm²**
Conductor material	bare copper Cl. 5 (IEC 60228)	tinned copper 7 x 0,16 mm
Insulation	TEO Flexene ® polymer compound according to UL AWM & CSA AWM	polypropylene, according to UL AWM & CSA AWM
Structure	pair-wise twisted	
Screen per pair	tinned copper sheath, optical cover ≥ 85 %	---
Separator	fleece tape	---
Colour code	pair 1: black (5 - 6) pair 2: black (7 - 8)	see section "Feedback cables"
Electrical specification		
Test conditions	20°C	
Conductor resistance	IEC 60228 Cl. 5	0.5 mm²: ≤ 40 Ω/km 0.14 mm²: ≤ 140 Ω/km
Insulation resistance	≥ 2500 MΩ x km	
Operating voltage	≤ 1000 V	≤ 30 V
Test voltage: Power (conductor / conductor / screen) Signal (conductor / conductor / screen)	4 kV eff., 5 min. 2 kV eff., 1 min.	1500 VDC
Capacitance Power Signal	max. 150 pF / m max. 100 pF / m	max. 100 pF / m max. 120 pF / m

BECKHOFF AX5000: Accessories

Order key for motor and feedback cables

Z K 4 t u v - w w x y - z z z z				
t	**Servo drive series**			
		5	=	AX5000
u	**Function**			
		0	=	Motor cable
		1	=	Encoder cable EnDat, Hiperface, BiSS

		2	=	Encoder cable TTL, Sin/Cos with zero pulse
		3	=	Resolver cable
		4	=	Temperature cable AL2000
		5	=	Hall cable for AL2000
v	**Function**			
		0	=	Motor - drive
		1	=	Extension cable
		2	=	Motor - choke
		3	=	Choke - drive
		4	=	Motor - other side bluntly cut
		5	=	Drive - other side bluntly cut
		9	=	Raw material
ww	**Motor series**			
		0 0	=	AL2000/AM2000/AM3000/AM3500
		0 1 to 1 9	=	Beckhoff
		2 0 to 2 9	=	Alpha EnDat / Alpha resolver
		3 0 to 3 9	=	Lenze
		4 0 to 4 9	=	SEW
		5 0 to 5 9	=	Siemens
		6 0 to 9 9	=	Further
x	**Quality**			
		0	=	fixed installation / no motion
		1	=	dynamic / drag chain
		2	=	high dynamic / high-speed chain
y	**Cross-section [mm²]**			
		0	=	Feedback
		1 to 8	=	0.75=1 / 1.0=2 / 1.5=3 / 2.5=4 / 4.0=5 / 6.0=6 / 10=7 / 16=8
		9	=	special
z z z z	**Length in dm**			
		0001 to 9999	=	0.1 to 999.9 m

BECKHOFF AX5000: Accessories

Motor cables

Motor cable for AL2000 / AM2000 / AM3000 / AM3500

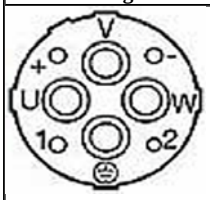
1.5 mm² and 2,5 mm²

Article number	Number of conductors and wire cross-section	Installation
ZK4500-0003-xxxx	4x1.5 + 2x(2x0.75) mm²	fixed installation
ZK4500-0004-xxxx	4x2.5 + 2x(2x0.75) mm²	fixed installation
ZK4500-0023-xxxx	4x1.5 + 2x(2x0.75) mm²	highly dynamic
ZK4500-0024-xxxx	4x2.5 + 2x(2x0.75) mm²	highly dynamic

Plug connector	Contact	Function	Core identification	Contact	Plug connector
	1	U	black with white labelling "1"	U	see "Y"
	2 / PE	PE	green/yellow	PE	
	3	W	black with white labelling "3"	W	
	4	V	black with white labelling "2"	V	
	A	Brake +	5	1	
	B	Brake -	6	2	
		Screen	Screen	3	
View X	C	Temp. +	7	4	
	D	Temp. -	8	5	

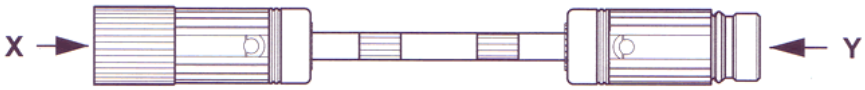
4 mm²

Article number	Number of conductors and wire cross-section	Installation

ZK4500-0015-xxxx	4x2 + 2x1 +2x1,5 mm²				highly dynamic
ZK4502-0015-xxxx	4x2 + 2x1 +2x1,5 mm²				highly dynamic
Plug connector	**Contact**	**Function**	**Core identification**	**Contact**	**Plug connector**
	U	U	black with white labelling "1"	U	see "Y"
	PE	PE	green/yellow	PE	
	W	W	black with white labelling "3"	W	
	V	V	black with white labelling "2"	V	
	+	Brake +	5	1	
	-	Brake -	6	2	
		Screen	Screen	3	
	1	Temp. +	7	4	
View X	2	Temp. -	8	5	

BECKHOFF AX5000: Accessories

Extension for motor cables



Extension cables enable a fixed connection to be used between the control cabinet and the drag chain and the highly dynamic version for the drag chain. The drag chain is regarded as a wear part, which means the drag chain can be replaced with worn cables as required.

Extension for motor cables AL2000 / AM2000 / AM3000 / AM3500

Article number	Number of conductors and wire cross-section	Installation
ZK4501-0003-xxxx	4x1.5 + 2x(2x0.75) mm²	fixed installation
ZK4501-0004-xxxx	4x2.5 + 2x(2x0.75) mm²	fixed installation
ZK4501-0023-xxxx	4x1.5 + 2x(2x0.75) mm²	highly dynamic
ZK4501-0024-xxxx	4x2.5 + 2x(2x0.75) mm²	highly dynamic

Plug connector	Contact	Function	Core identification	Contact	Plug connector
	1	U	black with white labelling	1	
	2 / PE	PE	green/yellow	2 / PE	
	3	W	black with white labelling	3	
	4	V	black with white labelling	4	
	A	Brake +		A	
	B	Brake -		B	
		Screen	Screen		
View X	C	Temp. +		C	View Y
	D	Temp. -		D	

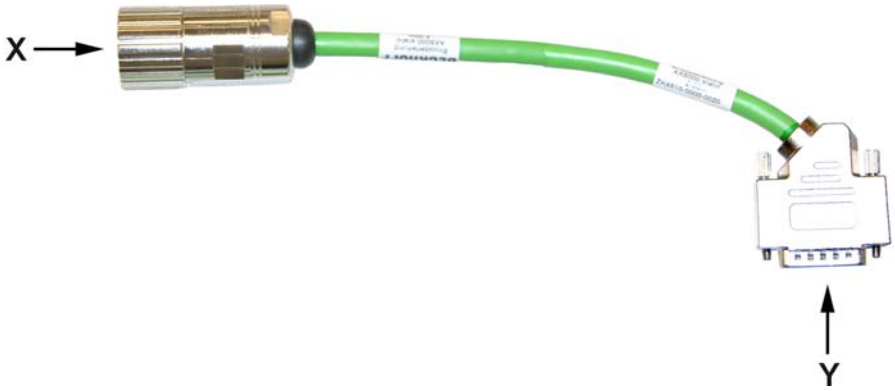
BECKHOFF AX5000: Accessories

Feedback cables for Beckhoff motors

CAUTION

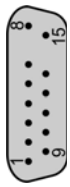
EMC-Safety!

At all cables, do not connect the wires marked with "n.c.".



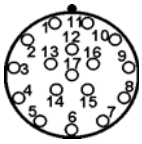
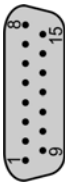
Encoder cable for AL2000 / AM3000 / AM3500 with EnDat-, BiSS or Hiperface interface and sine / cosine without zero pulse

Article number	Number of conductors and wire cross-section	Installation
ZK4510-0000-xxxx	7x(2x0.14) + 2x0.5 mm²	fixed installation
ZK4510-0020-xxxx	7x(2x0.14) + 2x0.5 mm²	highly dynamic

Circular plug 17-pole to motor	Contact	Function	Core identification		Contact	D-sub 15-pole to AX5000
				Rev. 02 05.06.2008		
 View X (female)	1	REFSIN	white	red / blue	9	 View Y (male)
	2	GND_5 V / 9 V	red/blue	white 0,5 mm²	2	
	3	REFCOS	green	green	11	
	4	U_{s-}5 V	grey / pink	brown 0,5 mm²	4	
	5	DX+ Data	grey	grey	5	
	6	U_{s-}9 V	brown / green	brown / green	6	
	7	n.c.			n.c.	
	8	CLK+ Clock	blue	blue	8	
	9	SIN	brown	grey / pink	1	
	10	GND_Sense	violet	violet	10	
	11	COS	yellow	yellow	3	
	12	U_{s-}5 V_Sense	black	black	12	
	13	DX- Data	pink	pink	13	
	14	n.c.			n.c.	
	15	CLK- Clock	red	red	15	
	16	n.c.			n.c.	
	17	n.c.			n.c.	

Encoder cable for AL2000 with sine / cosine encoder with zero pulse

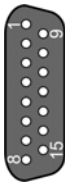
Article number	Number of conductors and wire cross-section	Installation
ZK4520-0020-xxxx	7x(2x0.14) + 2x0.5 mm²	highly dynamic

		Function				
Circular plug 17-pole to motor	Contact	SIN / COS	TTL	Core identification	Contact	D-sub 15-pole to AX5000
 View X (female)	1	REFSIN	---	red / blue	9	 View Y (male)
	2	GND_5 V / 9 V	GND_5 V / 9 V	white 0,5 mm²	2	
	3	REFCOS	---	green	11	
	4	U_{s-}5 V	U_{s-}5 V	brown 0,5 mm²	4	
	5	---	B +	grey	5	
	6	U_{s-}9 V	U_{s-}9 V	brown / green	6	
	7	REF Z	REF Z	white / yellow	7	
	8	---	A +	blue	8	
	9	SIN +	---	grey / pink	1	
	10	GND_Sense	GND_Sense	violet	10	
	11	COS +	---	yellow	3	
	12	U_{s-}5 V_Sense	U_{s-}5 V_Sense	black	12	
	13	---	B -	pink	13	
	14	Z +	Z +	brown / yellow	14	
	15	---	A -	red	15	
	16	n.c.	n.c.		---	
	17	n.c.	n.c.		---	

Resolver cable for AM2000 / AM3000 / AM3500

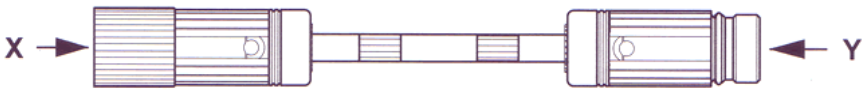
Article number	Number of conductors and wire cross-section	Installation
ZK4530-0010-xxxx	4x2x0,25 mm²	dynamic

Circular plug 12-pole to motor	Contact	Function	Core identification	Contact	D-sub 15-pole to AX5000
	1	n.c.		n.c.	

 View X (female)	2	Temerature (only PTC, Klixon or Bimetal!) Switchpoint: 1178 Ω	blue	1	 View Y (female)
	3	COS - (S3)	yellow	3	
	4	SIN - (S4)	brown	4	
	5	REF - (R2)	pink	5	
	6	GND_Temp.	red	9	
	7	COS + (S1)	green	10	
	8	SIN + (S2)	white	11	
	9	REF + (R1)	grey	12	
	10	n.c.		n.c.	
	11	n.c.		n.c.	
	12	n.c.		n.c.	

BECKHOFF AX5000: Accessories

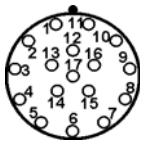
Extension for feedback cables for Beckhoff motors



Extension cables enable a fixed connection to be used between the control cabinet and the drag chain and the highly dynamic version for the drag chain. The drag chain is regarded as a wear part, which means the drag chain can be replaced with worn cables as required.

Encoder cable extension for AL2000 / AM2000 / AM3000

Article number	Number of conductors and wire cross-section	Installation
ZK4511-0000-xxxx	7x(2x0.14) + 2x0.5 mm²	fixed installation
ZK4511-0020-xxxx	7x(2x0.14) + 2x0.5 mm²	highly dynamic

Plug connector	Contact	Function	Core identification	Contact	Plug connector
 View X (female)	1	1 : 1 connection as in extended cable		1	 View Y (male)
	2			2	
	3			3	
	4			4	
	5			5	
	6			6	
	7			7	
	8			8	
	9			9	
	10			10	
	11			11	
	12			12	
	13			13	
	14			14	
	15			15	
	16			16	
	17	n.c.		17	

Extension for resolver and Hall cables for AL2000 / AM2000 / AM3000

Article number	Number of conductors and wire cross-section	Installation
ZK4531-0000-xxxx		fixed installation
ZK4531-0020-xxxx		highly dynamic

Connector motor side	Contact	Function	Core identification	Contact	Connector clutch side
 View X (female)	1	1 : 1 connection as in extended cable		1	 View Y (male)
	2			2	
	3			3	
	4			4	
	5			5	
	6			6	
	7			7	
	8			8	
	9			9	
	10			10	
	11			11	

12 12

BECKHOFF AX5000: Accessories

Special motor connections

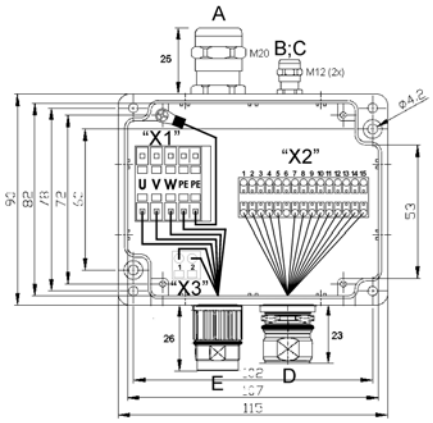
Linear motors of the AL2xxx series

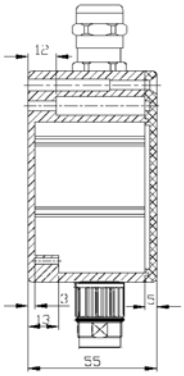
Connector box

With the Beckhoff AL2250 connector box you can simply connect the motor, encoder and thermal protection contact cables of the AL2000 linear motor range with the trailing cable motor and encoder cables of the AX5000, AX2500 and AX2000 range of servo drives

Appropriate use

The connector box is just for connection to the motor, encoder and thermal protection contact cables of the AL2000 linear motor range with the trailing cable motor and encoder cables of the AX5000, AX2500 and AX2000 range of servo drives.





Description of connections:

A: Cable bushing and fuse for the linear motor cable.
B: Cable bushing and fuse for the linear motor encoder cable.
C: Cable bushing and fuse for the linear motor thermal protection contact cable.
D: Connecting socket for the standard feedback cable to the servo drive.
E: Connecting socket for the standard motor cable to the servo drive.
X1: Terminal strip for the linear motor connection cable. (The side for connection to "E" is already wired)
X2: Terminal strip for the encoder and thermal protection contact connection cable. (The side for connection to "D" is already wired)
X3: Thermal protection contact connection. Contacts "1" and "2" are bridged on the board with contacts "7" and "14" of "X2". (The connection to "E" is already wired).

Installation

WARNING

Caution – Risk of injury through electric shock!

Remove the motor and feedback lines from the connector box to the servo drive when you open the connector-box.

Note

Attaching the connector box!

The linear motor cables are not for trailing cables, hence the connector box has to be fixed on the moving part of the linear motor.

Unscrew the cover and fix the connector box with 2 M4 screws on the carriage of the linear motor.

Motor cable:

Strip the wires of the motor cable and fit wire end sleeves.

Twist the screen of the motor cable and solder on a cable with a minimum diameter of 1.5 mm^2. Fit wire end sleeves or a cable lug to the free end. Place the nut of socket "A" over the motor cable and feed the wires through the socket "A" in the box and screw the nut onto socket "A". Fit the shielded and PE cables with a "PE" connection and the power wires on connection "X1".

Encoder cable:

Strip the wires of the encoder cable and fit wire end sleeves.

Twist the screen of the encoder cable and solder on a cable with a minimum diameter of 0.75 mm^2. Fit wire end sleeves or a cable lug to the free end. Place the nut of socket "B" over the encoder cable and feed the wires through the socket "B" in the box and screw the nut onto socket "B". Fit a "PE" connection to the shielded cable. Wire the signal wires to the "X2" connection as per the table.

Connection pin	Signal description	MES AL2200	LIKA SMS-V1	SIKO LE100	NJ* LIA 1Vss
X1-PE	PE / GND	shield	shield	shield	wh / gn
X2-1	COS -	red	orange	green	red
X2-2	GND	white	black	black	white

X2-3	SIN -	yellow	blue	orange	yellow
X2-4	+ 5V DC	brown	red	brown	brown
X2-5	DATA + / Z +	---	white	blue	grey
X2-6	n.c.	---	---	---	---
X2-7	PTC	---	---	---	---
X2-8	Clock+	---	---	---	---
X2-9	COS +	blue	green	yellow	blue
X2-10	GND sense	grey	---	---	---
X2-11	SIN +	green	yellow	red	green
X2-12	+ 5V sense	pink	---	---	---
X2-13	DATA - / Z -	---	---	violet	pink
X2-14	PTC	---	---	---	---
X2-15	Clock-	---	---	---	---

Thermal protection contact cable

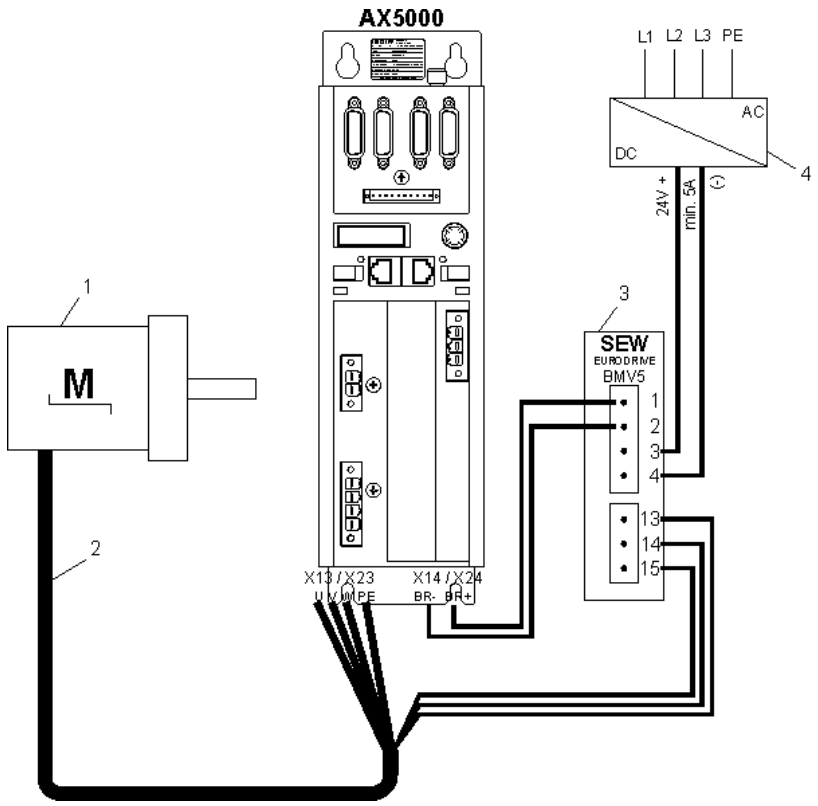
Strip both wires of the thermal protection contact cable and fit wire end sleeves.

Twist the screen of the thermal protection contact cable and solder on a cable with a minimum diameter of 0.75 mm^2. Fit wire end sleeves or a cable lug to the free end. Place the nut of socket “C” over the thermal protection contact cable and feed the wires through the socket “C” in the box and screw the nut onto socket “C”. Fit a “PE” connection to the shielded cable. Fit both thermal protection contact wires to contacts “7” and “14” of connection “X2”.

Retighten the connector box cover.

SEW motors from the “DFS / CFM” range with stopping brake

The stopping brake of the SEW motors has to be connected via a brake rectifier, to guarantee the “quick activation of the brake”. A 3 wire connection cable is required for this. The following schematic diagram shows the correct connections of the motors to the AX5000.



1 = SEW servo motor of the DFS/ CFM range
2 = Motor brake cable ZK4500-4xxx
3 = SEW- BMV5 brake rectifier
4 = Power supply unit with 5A minimum output current

BECKHOFF AX5000: Appendix

Fault management

Fatal errors

General

Fatal errors are error types requiring reinitialisation of the connected AX5000 feedback systems. This requires a change in communication state of the EtherCAT State Machine from Operational (Op) to ErrorSafe-Operational (ErrSafe-Op), which takes place automatically. ErrSafe-Op is a special case of Safe-Op. Two-channel devices only have one communication unit, which means that both channels are disabled. In this particular case, the change from Op to ErrSafe-Op results in the working counter of the SyncUnit becoming invalid, since the AX5000 can no longer supply valid actual values, resulting in all servo drives in this SyncUnit being disabled.

Requirement

The measures described in this section assume the following software versions.

- TwinCAT v2.10 b1329 or later versions
- Firmware v1.05 b0009 or later versions

Special features for two-channel devices

By default, a fatal error totally disables a two-channel device, including the error-free channel. If such a behaviour is not permitted in the application, the default behaviour can be changed with the following parameterisation of IDN P0-0350.

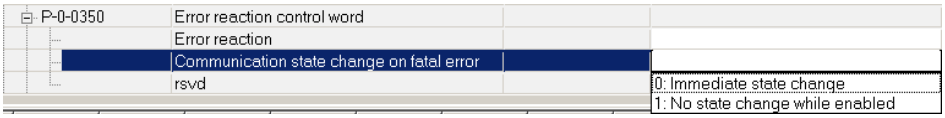
P-0-0350: Change of communication state in the event of fatal errors

0: Immediate state change (default)

If the servo drive is in “Op” state when the fatal error occurs, it immediately changes from “Op” to “ErrSafe-Op” and sets the error bit in the EtherCAT state.

1: No change in communication state while the other channel is enabled

In this case the AX5000 initiates the state change from Op to ErrSafe-Op in the event of a fatal error on one channel only once the error-free channel has been deactivated. The error-free channel can therefore continue to operate until it is deactivated.



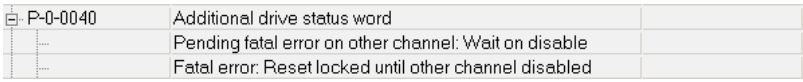
PLC

The IDN P-0-0040 is used in order to be able to diagnose in the PLC whether a fatal error situation has occurred that will lead to a state change next time the channel is deactivated. This IDN should be read acyclically in the PLC with block “FB_SoERead”. Cyclic evaluation is not meaningful, since the AX5000 no longer supplies valid inputs in ErrSafe-Op state after a fatal error, and therefore no valid information is transferred cyclically.

xxxx00: Both channels are error-free.

xxxx01: The other channel has a fatal error. As soon as this channel is deactivated, the communication state changes from “Op” to “ErrSafe-Op”.

xxx1x: This channel has a fatal error. As soon as the other channel is deactivated, the communication state changes from “Op” to “ErrSafe-Op”. An error reset is not possible.

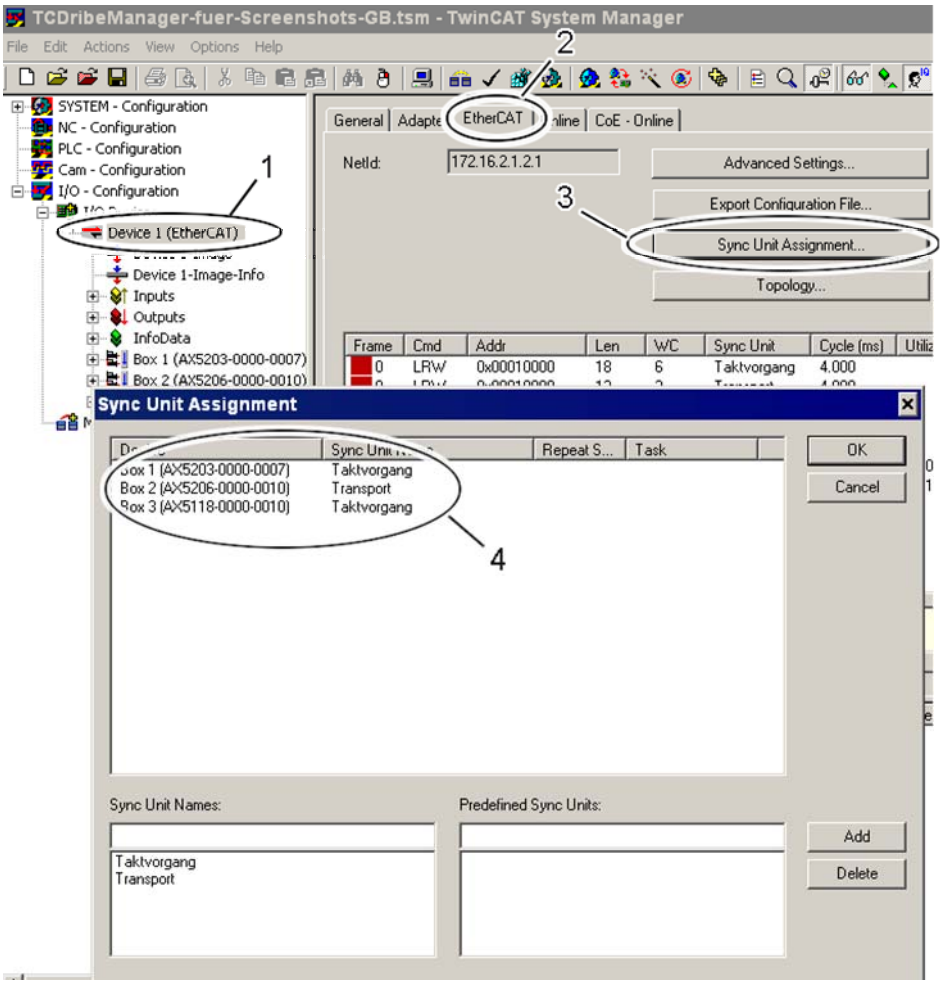


SyncUnit diagnostics

The individual servo drives should be consolidated in meaningful groups, depending on the application. Each of these groups is allocated to a SyncUnit. Since each group has its own working counter, the individual groups can continue to operate independently in the event of fatal errors. For particularly critical applications, each AX5000 can be allocated a separate Sync Unit. However, this step should only be implemented in cases where it is actually required, because each further Sync Unit results in additional data traffic on the EtherCAT strand.

Allocation of servo drives to a Sync Unit

Start the TwinCAT System Manager and left-click on the associated EtherCAT strand (1). Select the “EtherCAT” tab (2) and left-click on “Sync Unit Assignment” (3). The “Sync Unit Assignment” submenu appears. Section (4) shows the servo drives and their allocation to the Sync Units. Servo drives AX5203 and AX5118 belong to Sync Unit “Cycle Process”, 5206 belongs to Sync Unit “Transport”.

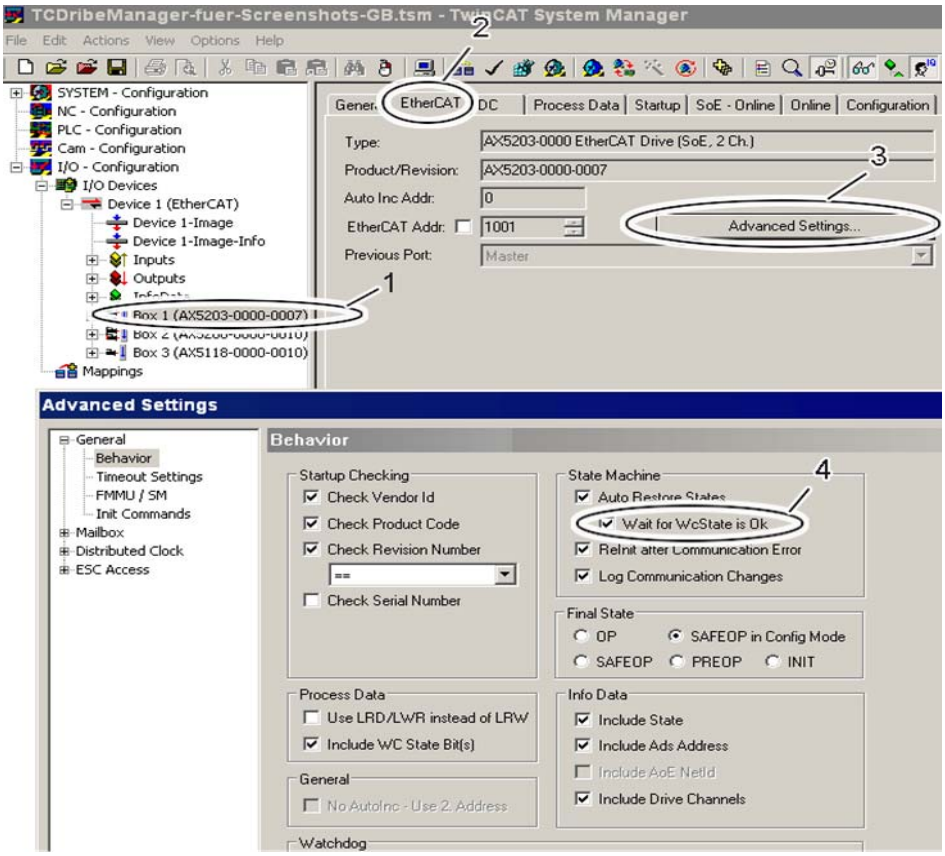


Reinitialisation, troubleshooting and reset

1. Analyse and rectify the fatal error.
2. Carry out an error reset via IDN S-0-0099. To this end the blocks “FB_SoEReset” or “FB_SoEReset_ByDriveRef” are available in the PLC.
3. Automatic change of communication state from “ErrSafe-Op” to “Op”.
4. NC axis reset. To this end the block “NC_Reset” is available in the PLC.

Re 3.

In order for the communication state to automatically switch back to “Op”, flag “Wait for WcState is OK” must be activated on the corresponding AX5000. This is automatically the case for new configurations. In existing configurations it may have to be set accordingly.
Start the TwinCAT System Manager and left-click on the associated servo drive (1). Select the “EtherCAT” tab (2) and left-click on “Advanced Settings....” (3). The “Advanced Settings” submenu appears. Select the flag “Wait for WcState is OK” with the left mouse button (4).



BECKHOFF AX5000: System description

The Beckhoff automation system

More and more customers are looking for automation systems from one source in order to

- have a single contact,
- simplify the interfaces between the components,
- ensure fast and trouble-free commissioning, and
- have access to worldwide service and support from one source.

Beckhoff offers this solution:

- Industrial PC as real-time automation platform

- Real-time software packages

TwinCAT NC PTP
for point-to-point movements

TwinCAT NC I
for interpolated movements of up to 3 axes

TwinCAT CNC
for interpolated movements of up to 32 axes

- High-end servo drive
AX2000: single-axis drive, up to 70 A rated current

AX2500: multi-axis system, up to 8 axes

AX5000: EtherCAT Drive

- Rotational and linear servo motors

AM2000: Servomotors

AM3000: Servomotors, pole-wound

AM3500: Servomotors with high moment of inertia

AL2000: Linear motors

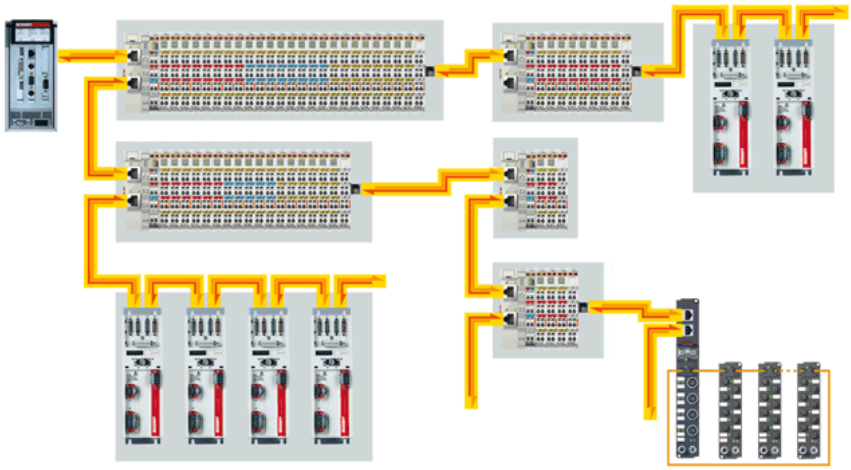
AL3000: Ironless linear motors

The AX5000 servo drive is a component of the Beckhoff automation system. It is not designed for stand-alone operation. The AX5000 is the first drive developed specifically for EtherCAT. This enables the outstanding features of EtherCAT to be fully utilised:

- Outstanding performance
- Low-cost
- Simple diagnosis
- Safety over EtherCAT

BECKHOFF Fieldbus Components: EtherCAT basics

System structure



In analogy to the Beckhoff Bus Terminals the EtherCAT terminal system is a modular I/O system consisting of electronic terminal blocks. An I/O station consists of an EtherCAT coupler and almost any number of terminals. Since up to 65535 devices can be connected, the size of the network is almost unlimited.

EtherCAT is designed for operation without switch. In this case the EK1100 coupler is used. For applications requiring a switch Beckhoff will shortly provide a solution in the form of the EK1000 that can process the EtherCAT UDP protocol in passing.

The electronic terminal blocks are attached to the EtherCAT coupler. The contacts are made as the terminal clicks into place, without any other manipulation. This means that each electronic terminal block can be individually exchanged. It can be placed on a standard mounting rail.

Suitable EtherCAT terminals are available for common digital and analog signal types encountered in the world of automation. Fieldbus devices, e.g. for PROFIBUS, CANopen or DeviceNet, are integrated via local fieldbus master/slave terminals. Removal of the fieldbus master saves PCI slots in the PC. Any Ethernet devices can be connected decentralised via switch terminals.

The fine granularity of the EtherCAT terminals enables bit-precise composition of the required I/O channels. The digital EtherCAT terminals are designed as 2-, 4-, or 8-channel terminals. The standard analog signals of ± 10 V, 0 ... 10 V, 0 ... 20 mA and 4 ... 20 mA are all available as 1-, 2-, 4-, and 8-channel variants within a standard housing. The EtherCAT Terminal system offers different connection options for optimum adaptation to the respective application. The ELxxxx EtherCAT terminals include electronics and connection level in a single enclosure. The ESxxxx type EtherCAT terminals feature a pluggable connection level. The ES series Bus Terminals enable the complete wiring to be removed as a plug connector from the top of the housing for servicing.

Free choice of topology – maximum wiring flexibility: with or without switch, line or tree topologies, can be freely selected and combined. Address assignment is automatic, no IP address setting is required.

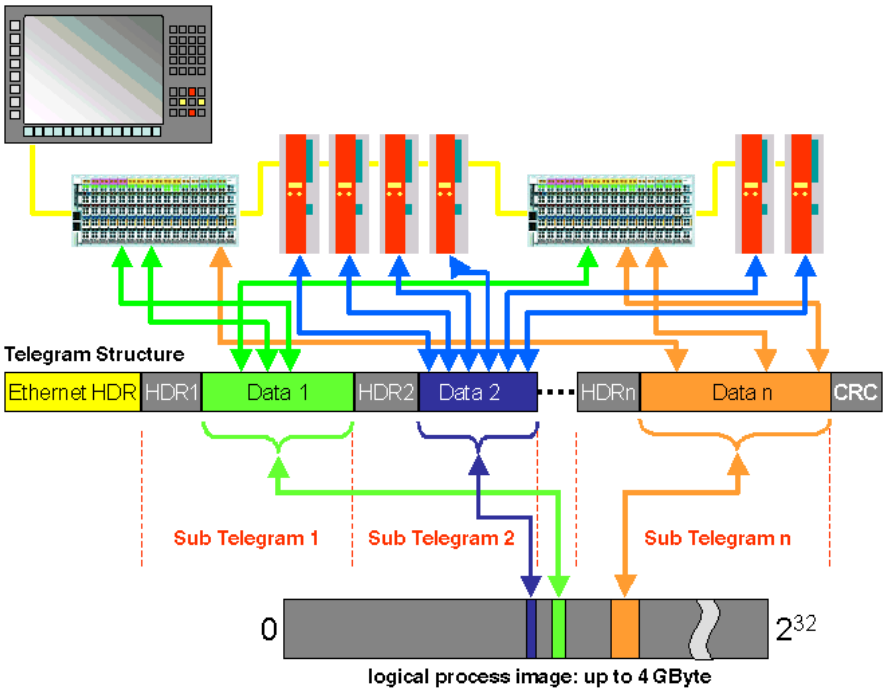
BECKHOFF Fieldbus Components: EtherCAT Basics

System Properties

Protocol

The EtherCAT protocol is optimised for process data and is transported directly within the Ethernet frame thanks to a special Ether-type. It may consist of several sub-telegrams, each serving a particular memory area of the logical process images that can be up to 4 gigabytes in size. The data sequence is independent of the physical order of the Ethernet terminals in the network; addressing can be in any order. Broadcast, Multicast and communication between slaves are possible. Transfer directly in the Ethernet frame is used in cases where EtherCAT components are operated in the same subnet as the control computer.

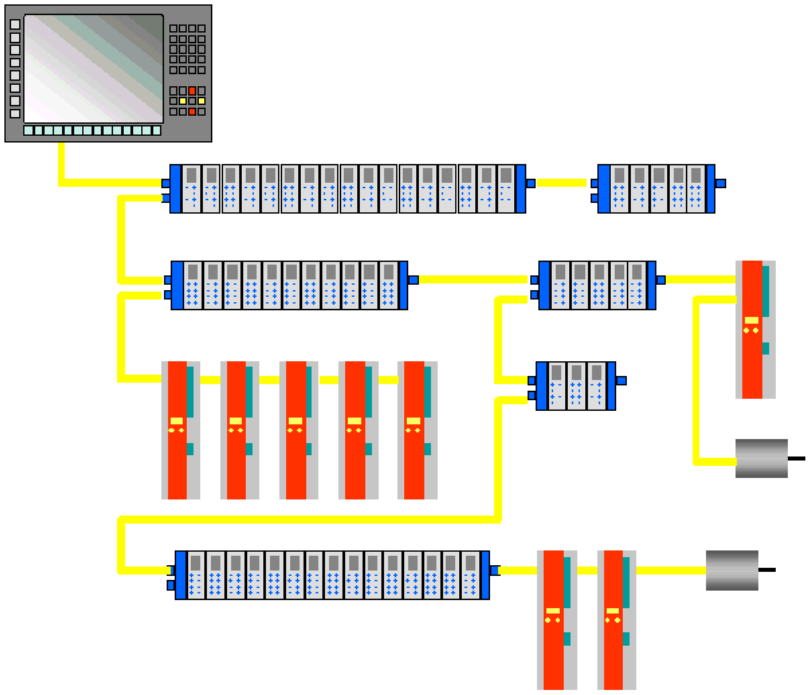
However, EtherCAT applications are not limited to a subnet: EtherCAT UDP packs the EtherCAT protocol into UDP/IP datagrams. This enables any control with Ethernet protocol stack to address EtherCAT systems. Even communication across routers into other subnets is possible. In this variant, system performance obviously depends on the real-time characteristics of the control and its Ethernet protocol implementation. The response times of the EtherCAT network itself are hardly restricted at all: the UDP datagram only has to be unpacked in the first station.



Protocol structure: The process image allocation is freely configurable. Data are copied directly in the I/O terminal to the desired location within the process image: no additional mapping is required. The available logical address space is with very large (4 GB).

Topology

Line, tree or star: EtherCAT supports almost any topology. The bus or line structure known from the fieldbuses thus also becomes available for Ethernet. Particularly useful for system wiring is the combination of line and branches or stubs. The required interfaces exist on the couplers; no additional switches are required. Naturally, the classic switch-based Ethernet star topology can also be used.



Maximum wiring flexibility:
with or without switch, line or tree topologies, can be freely selected and combined. The complete bandwidth of the Ethernet network - such as different optical fibres and copper cables - can be used in combination with switches or media converters.

Distributed Clocks

Accurate synchronisation is particularly important in cases where spatially distributed processes require simultaneous actions. This may be the case, for example, in applications where several servo axes carry out coordinated movements simultaneously.

The most powerful approach for synchronisation is the accurate alignment of distributed clocks, as described in the new IEEE 1588 standard. In contrast to fully synchronous communication, where synchronisation quality suffers immediately in the event of a communication fault, distributed aligned clocks have a high degree of tolerance vis-à-vis possible fault-related delays within the communication system.

With EtherCAT, the data exchange is fully based on a pure hardware machine. Since the communication utilises a logical (and thanks to full-duplex Fast Ethernet also physical) ring structure, the mother clock can determine the run-time offset to the individual daughter clocks simply and accurately - and vice versa. The distributed clocks are adjusted based on this value, which means that a very precise network-wide timebase with a jitter of significantly less then 1 microsecond is available.

However, high-resolution distributed clocks are not only used for synchronisation, but can also provide accurate information about the local timing of the data acquisition. For example, controls frequently calculate velocities from sequentially measured positions. Particularly with very short sampling times, even a small temporal jitter in the displacement measurement leads to large step changes in velocity. With EtherCAT new, extended data types are introduced as a logical extension (time stamp and oversampling data type). The local time is linked to the measured value with a resolution of up to 10 ns, which is made possible by the large bandwidth offered by Ethernet. The accuracy of a velocity calculation then no longer depends on the jitter of the communication system. It is orders of magnitude better than that of measuring techniques based on jitter-free communication.

Performance

EtherCAT reaches new dimensions in network performance. Protocol processing is purely hardware-based through an FMMU chip in the terminal and DMA access to the network card of the master. It is thus independent of protocol stack run-times, CPU performance and software implementation. The update time for 1000 I/Os is only 30 µs - including terminal cycle time. Up to 1486 bytes of process data can be exchanged with a single Ethernet frame - this is equivalent to almost 12000 digital inputs and outputs. The transfer of this data quantity only takes 300 µs.

The communication with 100 servo axes only takes 100 µs. During this time, all axes are provided with set values and control data and report their actual position and status. Distributed clocks enable the axes to be synchronised with a deviation of significantly less than 1 microsecond.

The extremely high performance of the EtherCAT technology enables control concepts that could not be realised with classic fieldbus systems. For example, the Ethernet system can now not only deal with velocity control, but also with the current control of distributed drives. The tremendous bandwidth enables status information to be transferred with each data item. With EtherCAT, a communication technology is available that matches the superior computing capacity of modern Industrial PCs. The bus system is no longer the bottleneck of the control concept. Distributed I/Os are recorded faster than is possible with most local I/O interfaces. The EtherCAT technology principle is scalable and not bound to the baud rate of 100 MBaud – extension to GBit Ethernet is possible.

Diagnostics

Experience with fieldbus systems shows that availability and commissioning times crucially depend on the diagnostic capability. Only faults that are detected quickly and accurately and which can be precisely located can be corrected quickly. Therefore, special attention was paid to exemplary diagnostic features during the development of EtherCAT.

During commissioning, the actual configuration of the I/O terminals should be checked for consistency with the specified configuration. The topology

should also match the saved configuration. Due to the built-in topology recognition down to the individual terminals, this verification can not only take place during system start-up, automatic reading in of the network is also possible (configuration upload).

Bit faults during the transfer are reliably detected through evaluation of the CRC checksum: The 32 bit CRC polynomial has a minimum hamming distance of 4. Apart from breaking point detection and localisation, the protocol, physical transfer behaviour and topology of the EtherCAT system enable individual quality monitoring of each individual transmission segment. The automatic evaluation of the associated error counters enables precise localisation of critical network sections. Gradual or changing sources of error such as EMC influences, defective push-in connectors or cable damage are detected and located, even if they do not yet overstrain the self-healing capacity of the network.

Integration of standard Bus Terminals from Beckhoff

In addition to the new Bus Terminals with E-Bus connection (ELxxxx), all Bus Terminals from the familiar standard range with K-Bus connection (KLxxxx) can be connected via the BK1120 or BK1250 Bus Coupler. This ensures compatibility and continuity with the existing Beckhoff Bus Terminal systems. Existing investments are protected.

BECKHOFF EtherCAT: Installation and Wiring

EtherCAT Wiring

The cable length between two EtherCAT devices must not exceed 100 m.

Cables and connectors

For connecting EtherCAT devices only Ethernet cables that meet at least the requirements of category 5 (CAT5) according to EN 50173 or ISO/IEC 11801 should be used. EtherCAT uses 4 wires for signal transfer.

EtherCAT uses RJ45 connectors. The pin assignment is compatible with the Ethernet standard (ISO/IEC 8802-3).

Pin	Core coloring	Signal	Description
1	yellow	TD +	Transmission Data +
2	orange	TD -	Transmission Data -
3	white	RD +	Receiver Data +
6	blue	RD -	Receiver Data -

Due to automatic cable detection (auto-crossing) symmetric (1:1) or cross-over cables can be used between EtherCAT devices from Beckhoff.

The following Beckhoff cables are suitable for cabling of EtherCAT systems:

- ZB9010 (industrial Ethernet/EtherCAT cable, fixed installation, CAT5e, 4-wires)
- ZB9020 (industrial Ethernet/EtherCAT cable, drag chain suitable, CAT5e, 4-wires)
- ZS1090-0003 (RJ 45 connector, 4-pin, IP 20, for field-assembly)
- ZS1090-0005 (RJ 45 connector, 8-pin, (GigaBit suitable), IP 20, for field-assembly)
- ZK1090-9191-0001 (0.17m EtherCAT patch cable)
- ZK1090-9191-0005 (0.5m EtherCAT patch cable)
- ZK1090-9191-0010 (1.0m EtherCAT patch cable)
- ZK1090-9191-0020 (2.0m EtherCAT patch cable)
- ZK1090-9191-0030 (3.0m EtherCAT patch cable)
- ZK1090-9191-0050 (5.0m EtherCAT patch cable)

E-Bus supply

Attention

Attention! Malfunction possible!

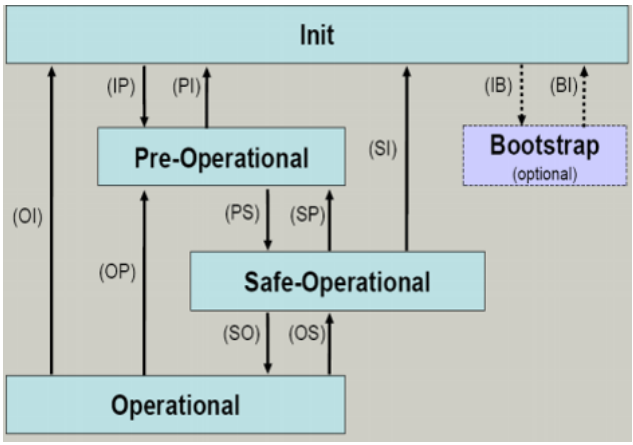
The same ground potential must be used for the E-Bus supply of all EtherCAT terminals in a terminal block!

BECKHOFF Fieldbus Components: EtherCAT Basics

EtherCAT State Machine

The state of the EtherCAT slave is controlled via the EtherCAT State Machine (ESM). A distinction is made between the following states (see. Fig. 1):

- Init
- Pre-Operational
- Safe-Operational and
- Operational
- Boot



Init

After switch-on the EtherCAT slave in the *Init* state. No mailbox or process data communication is possible. The EtherCAT master initializes sync manager channels 0 and 1 for mailbox communication.

Pre-Operational (Pre-Op)

During the transition between *Init* and *Pre-Op* the EtherCAT slave checks whether the mailbox was initialized correctly.

In *Pre-Op* state mailbox communication is possible, but not process data communication. The EtherCAT master initializes the sync manager channels for process data (from sync manager channel 2), the FMMU channels and, if the slave supports configurable mapping, PDO mapping or the sync manager PDO assignment. In this state the settings for the process data transfer and perhaps terminal-specific parameters that may differ from the default settings are also transferred.

Safe-Operational (Safe-Op)

During transition between *Pre-Op* and *Safe-Op* the EtherCAT slave checks whether the sync manager channels for process data communication and, if required, the distributed clocks settings are correct. Before it acknowledges the change of state, the EtherCAT slave copies current input data into the associated DP-RAM areas of the EtherCAT slave controller (ECSC).

In *Safe-Op* state mailbox and process data communication is possible, although the slave keeps its outputs in a safe state, while the input data are updated cyclically.

Operational (Op)

Before the EtherCAT master switches the EtherCAT slave from *Safe-Op* to *Op* it must transfer valid output data.

In the *Op* state the slave copies the output data of the masters to its outputs. Process data and mailbox communication is possible.

Boot

In the *Boot* state the slave firmware can be updated. The *Boot* state can only be reached via the *Init* state.

In the *Boot* state mailbox communication via the *file access over EtherCAT* (FoE) protocol is possible, but no other mailbox communication and no process data communication.

BECKHOFF AX5000: EtherCAT

EtherCAT as drive bus

EtherCAT technology overcomes these inherent limitations of other Ethernet solutions: the Ethernet packet is no longer received, then interpreted and copied as process data at every connection. The EtherCAT devices read the data addressed to them while the telegram passes through the device. Similarly, input data are inserted while the telegram passes through. The telegrams are only delayed by a few nanoseconds. Since an Ethernet frame reaches the data of many devices both in send and receive direction, the usable data rate increases to over 90%. The full-duplex features of 100BaseTx are fully utilised, so that effective data rates of > 100 Mbit/s (>90% of 2 x 100 Mbit/s) can be achieved.

The option of being able to use EtherCAT both for drive applications and for fast I/O signals was one of its main development aims right from the start. In existing systems, short cycle times and high synchronicity (as required for control loops that are closed via the bus) could only be realised with special drive buses. The SERCOS profile for servo drives according to IEC61491 was implemented in order to make the drive functionality compatible with existing standards and facilitate commissioning and optimised operation of the AX5000 through the user.

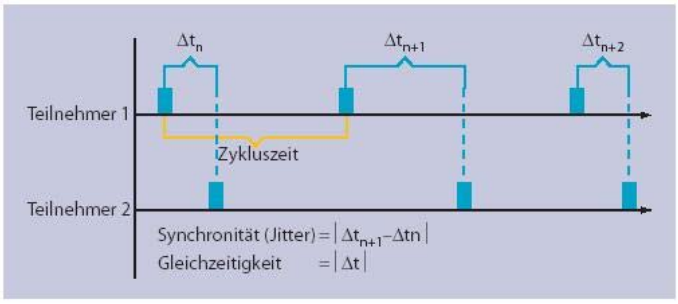
Special drive technology requirements

- Cycle time
- Synchronicity

- Simultaneity

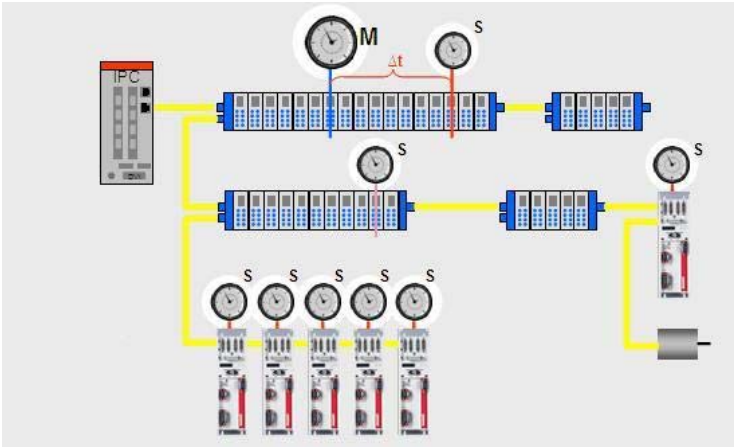
Typical values for the necessary cycle times lie between 1 and 4 milliseconds when position is specified cyclically, with position control in the drive. One microsecond is often quoted as an adequate value for synchronicity in drive technology.

While synchronicity describes the temporal jitter during processing of the functions in the device involved (drives and controllers), simultaneity defines the measure of temporal offset of these functions. Synchronicity is important for the individual devices, so that their own subordinate control loops can synchronise with the cyclic signal with the required precision. Simultaneity moreover enables distributed devices to work on a common task with absolutely identical timebase.



Distributed clocks - EtherCAT slave controller features

EtherCAT uses an approach based on distributed clocks for synchronisation control: All devices have an independent clock as a basis for running local cycles and events. The crucial factor is that all clocks run at the same speed and have the same base time. A special control integrated in the EtherCAT Slave Controller (ESC) ensures that all clocks are guided by a reference clock and are synchronised irrespective of temperature and production tolerances.



Multi-protocol capability

Further important criteria for a fieldbus system that is to support drive technology are the communications protocol and profile used, which are responsible for compatibility and efficient data exchange between the controller and the drive. Instead of re-inventing the wheel, EtherCAT uses proven technology for this purpose.

None of the available protocols on their own support all communication requirements of modern fieldbuses (process data, parameter data, parallel TCP/IP, firmware updates, routing to subordinate bus systems, etc.). EtherCAT therefore introduces multi-protocol capability, consolidating the different protocols in a standardised mailbox. This enables quick and full conversion of existing devices to EtherCAT. The protocols relevant for drive technology are *CANopen over EtherCAT (CoE)* and *Servo Profile over EtherCAT (SoE)*. They enable the advantages of EtherCAT in terms of transfer characteristics to be combined with proven, profile-specific drive functions. The *Ethernet over EtherCAT (EoE)* and *File Access over EtherCAT (FoE)* protocols provide options for integrating a web server in the drive, for example, or for efficiently exchanging firmware or cam plate tables via the bus.

Servo Profile over EtherCAT

The *Servo Profile over EtherCAT (SoE)* protocol enables the proven SERCOS device profile to be used, which is tailored for demanding drive technology and standardised in IEC 61491. The SERCOS service channel, and therefore access to all parameters and functions residing in the drive, is mapped to the EtherCAT mailbox. Here too, the focus is on compatibility with the existing protocol (access to value, attribute, name, units etc. of the SERCOS identifiers) and expandability with regard to data length limitation. The process data (for SERCOS in the form of AT and MDT data) are transferred via the EtherCAT Slave Controller. The associated mapping is done SERCOS-compliant via the identifiers S- 0-0015, S-0-0016 and S-0-0024. For synchronisation - like for the CoE protocol - the synchronisation features of the EtherCAT Slave Controller are utilised as described above. This also includes - with associated quality improvements - those of standard SERCOS, so that implementation is correspondingly easy. The EtherCAT Slave State Machine explained above can also be mapped easily to the phases of the SERCOS protocol. "Pre-operational" corresponds to SERCOS, phase 2, and enables service channel communication without process data exchange. "Safe operational" is comparable with phase 3. Synchronisation is carried out as required, although for EtherCAT inputs that are already valid have to be transferred. "Operational" exactly corresponds to phase 4 for normal, cyclic data exchange. As the name suggests, the EtherCAT Slave State Machine refers to a slave and - unlike SERCOS - therefore enables individual drives to be parameterised and started up independent of other devices.

Conclusions

While EtherCAT is not a pure drive bus, it meets the associated requirements at least one order of magnitude better than familiar, specialised systems. Drive, I/O and communication buses therefore no longer have to be separated. Even demanding tasks, such as measurement technology applications, can be integrated and enable new functionalities to be utilised with classic control technology. Because proven communication profiles are used, migration of existing devices and applications can easily be accomplished. For drive technology in particular, a small number of profiles have been developed and tried and tested over years. It also means that the complete tool chain and existing experience with the parameterisation of associated drives is maintained.

IDNs used

This is a example for the structure and description of an IDN. A list and description of all relevant IDNs can be found in the separate IDN description (chm).

S-0-0001, Control unit cycle time (TNcyc)

Description:	
	The control unit cycle time defines the cyclic intervals during which the control unit makes new command values available. The control unit cycle time shall be transferred from the master to the slave during CP2 and becomes active in the slave during CP3. The control unit cycle time should be an integer multiple of the communication cycle time. tNcyc = tScyc * n [n =1,2,3,4...]

Parameter structure:	

Attributes:	
Unit:	us
Default value:	500
Min value:	62
Max value:	20000
Data length:	16
Format:	binary
Cyclic transfer:	No
Write protected:	SafeOp, Op
Decimal point:	0
Device parameter:	Yes

BECKHOFF Automation: Appendix

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