BECKHOFF New Automation Technology

Function description | EN

AX5000

Digital compact servo drives
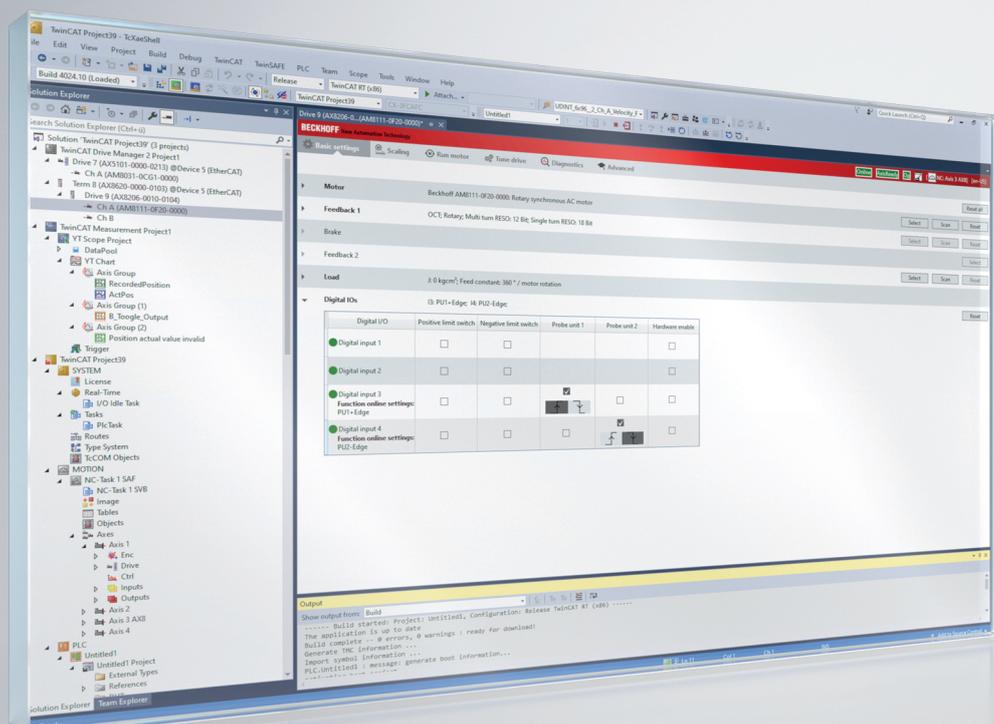
Table of contents

1 Foreword

1.1 Version numbers

Provision of revision levels

On request, you can obtain a list of revision levels for changes in the operating instructions.

- Send your request to: motion-documentation@beckhoff.de

Origin of the document

These operating instructions were originally written in German. All other languages are derived from the German original.

Product features

Only the product properties specified in the current operating instructions are valid. Further information given on the product pages of the Beckhoff homepage, in emails or in other publications is not authoritative.

1.2   Notes on the documentation

This description is intended exclusively for trained specialists in control and automation technology who are familiar with the applicable national standards.
For installation and commissioning of the components, it is absolutely necessary to observe the documentation and the following notes and explanations.
The qualified personnel is obliged to always use the currently valid documentation.

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

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.
We reserve the right to revise and change the documentation at any time and without notice.
No claims to modify products that have already been supplied may be made on the basis of the data, diagrams, and descriptions in this documentation.

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Patents

The EtherCAT Technology is covered, including but not limited to the following patent applications and patents:
EP1590927, EP1789857, EP1456722, EP2137893, DE102015105702
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2 For your safety

Read the section on safety and heed the notices to protect yourself against personal injury and material damages.

Liability limitations

All the components of the servo drive AX5000 are supplied in certain hardware and software configurations appropriate for the conditions of the application. Unauthorized modifications to the hardware and/or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH & Co. KG.

In addition, the following actions are excluded from the liability of Beckhoff Automation GmbH & Co. KG:

- Failure to comply with this documentation
- Untrained personnel
- Use of unauthorized spare parts

2.1 Staff qualification

Only technical personnel with knowledge of control and automation technology may carry out any of the illustrated work steps on the Beckhoff software and hardware, in particular on the servo drive AX5000.

The technical personnel must have knowledge of drive technology and electrical systems and must also know how to work safely on electrical equipment and machines.

This also includes:

- work preparation and
- securing of the working environment (e.g. securing the control cabinet against being switched on again).

The technical personnel must be familiar with the current and necessary standards and directives for the automation and drive environment.

2.2   Description of symbols

In this documentation the following symbols are used with an accompanying safety instruction or note. The safety instructions must be read carefully and followed without fail!

Symbols that warn of personal injury:

⚠ **DANGER**
Serious risk of injury!
This is an extremely dangerous situation. Disregarding the safety notice will lead to serious permanent injuries or even death.

⚠ **WARNING**
Risk of injury!
This is a dangerous situation. Disregarding the safety notice may lead to serious injuries.

⚠ **CAUTION**
Personal injuries!
This is a dangerous situation. Disregarding the safety notice may lead to minor injuries.

Symbols that warn of damage to property or equipment:

NOTICE
Warning of damage to property or the environment!
This notice indicates disturbances in the operational procedure that could damage the product or the environment.

Symbols indicating further information or tips:

Tip or pointer!

This notice provides important information that will be of assistance in dealing with the product or software. There is no immediate danger to product, people or environment.

UL note!

This symbol indicates important information regarding UL certification.

3   Asynchronous motors - Special functions

The following functions are integrated in the AX5000 servo drive for operating an asynchronous motor with encoderless control:

- Stall protection controller
- Acceleration controller

> **i** **Further documentation on asynchronous motors:**
>
> Further information on the function of asynchronous motors and their parameterization can be found in the AX5000 - System Manual Chapter 9 at:
> Electrical Installation -> Motors -> Motor Types -> Asynchronous Motors.

3.1   Stall protection controller

> **i** **Terminology**
>
> With reference to this documentation, the term KSR is often used for the functional description of the stall protection controller.

> **i** **Reference values of the acceleration and stall protection controllers Documentation:**
>
> P-0-0092; P-0-0093; P-0-0112; P-0-0115; P-0-0116; P-0-0117

3.2   General Information

Speed reduction due to sudden load increase at constant speed in a machining operation (e.g. penetration of a drill bit into solid material) is implemented from firmware v2.03 by means of stall protection controller (KSR) function.

Special feature asynchronous motor

This function is only suitable for asynchronous motors without feedback system. The stall protection controller replaces the current controller. The maximum torque of an asynchronous motor is also the breakdown torque. If the max. set torque is exceeded, an uncontrolled condition of the motor occurs. The result is an overcurrent error F2A1.

Typical torque / speed curve of an asynchronous motor
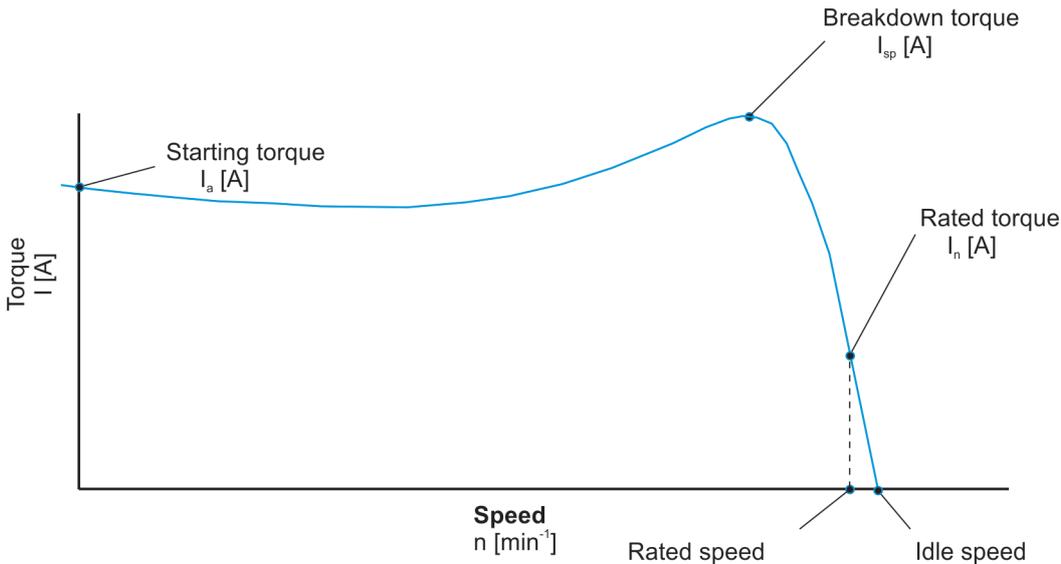
The diagram describes the characteristic curve at a rotary field frequency.

When operating with a stall protection controller, an attempt is always made to avoid the non-permissible range. A setpoint specification may not be adhered to as a result. If this is the case, your PLC must take appropriate measures to restore permissible operation.

Optimum configuration of application and motor
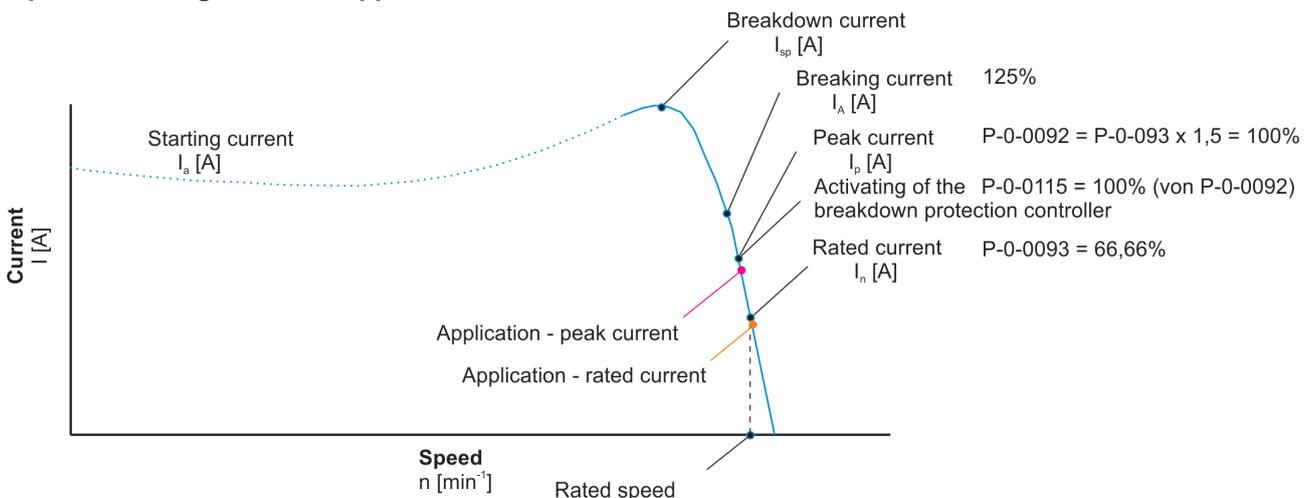
The image shows a rotary field frequency when the current is plotted against the speed.

If the application requires more current (torque), e.g. because the milling tool is becoming blunt, the current value moves to the left of the curve.

This applies mainly for the linear range (nominal current to cut-off current). The range beyond the stall current is not relevant, since it is not permitted.

With the AX5000, among others, the values

- P-0-0093 (nominal current) and
- P-0-0092 (peak current)*
  *calculated from P-0-0093 and the overload factor (for ASM mostly 1.5)

taken over from the motor database.

The response of the stall protection controller with respect to the current limit (P-0-0115) would be:

- The stall protection controller is activated.
- The rotary field frequency is reduced. As a result, the current value does not exceed the current limit (P-0-0115) and thus prevents the cut-off current* from being reached.

*The servo drive switches the motor torque-free. It would come to an uncontrolled standstill.

Operation in the field weakening
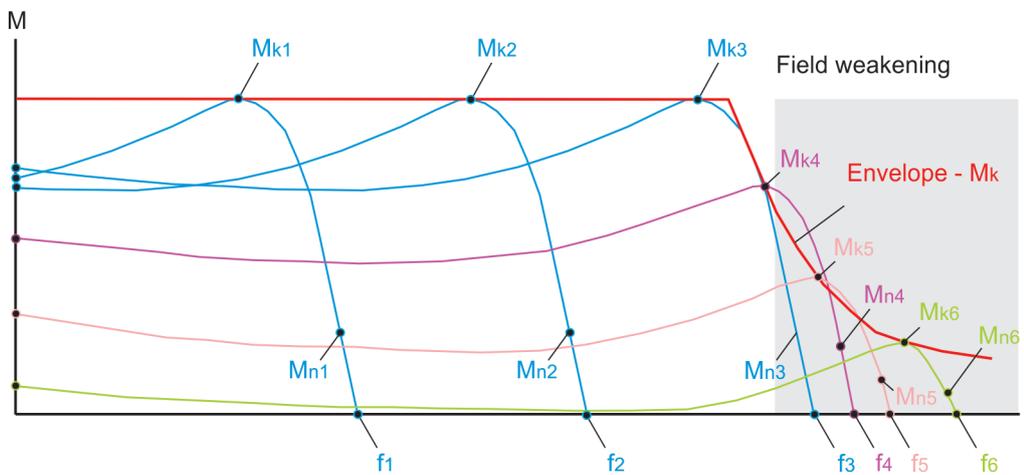
In the field weakening, the envelope follows the function M=1/n. In the linear range (Mk4 / Mk5), a decrease of the rotary field frequency causes a significant increase of the torque.

During operation of an asynchronous motor the torque curves may differ, depending on the rotary field frequency (f).

Behavior of the breakdown torques with changed field weakening:

- Until the field weakening is reached, the breakdown torques (Mk1 - Mk3) are equal.
- At the beginning of the field weakening, the breakdown torques (Mk4 and Mk5) decrease almost linearly.
- With increasing field weakening (Mk6 and further), the breakdown torque is very low and almost constant.

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3.2.1 Functionality from firmware v2.03

Mode of functioning of the stall protection controller

The stall protection controller attempts to avoid the impermissible range (actual current value I_{max} in %). This is defined in advance in parameter P-0-0115 (ASM: stall protection loop, torque limit value). If a machining procedure exceeds the I_{max} value, the servo drive reduces the set speed (reduction to ≤ 0 is possible). The mode of functioning is illustrated in detail in the following practical examples 1 and 2. The procedure concerned is always a machining procedure on a milling machine. A tool penetrates solid material on reaching the speed setpoint:

Practical example 1: Machining procedure with an actual current value Imax of 90%
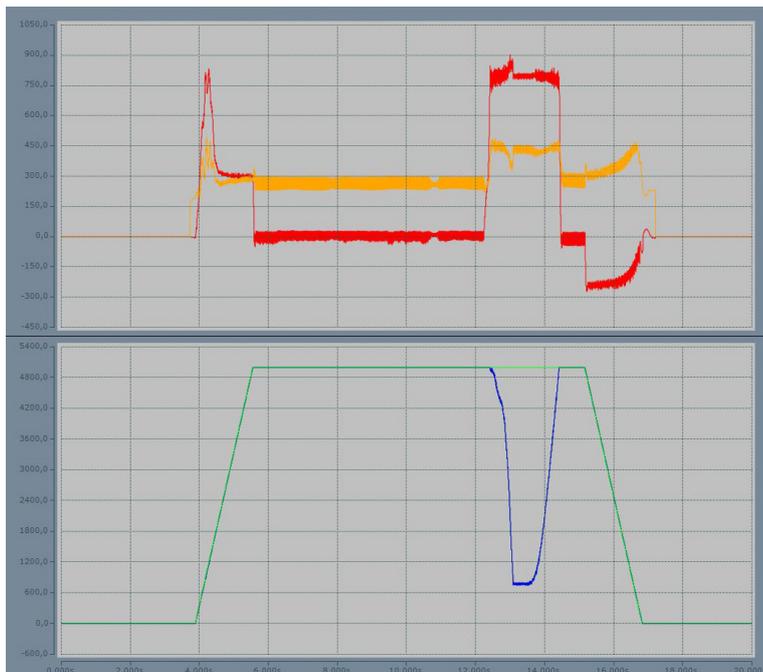
The value of the stall protection controller is set to 90% in example 1. As the tool penetrates the solid material, you can see by the blue characteristic curve that the speed drops dramatically at this point.

Result:

The limitation of the current to 90% by the stall protection controller is therefore insufficient to maintain the set speed.

Practical example 2: Machining procedure with an actual current value Imax of 100%
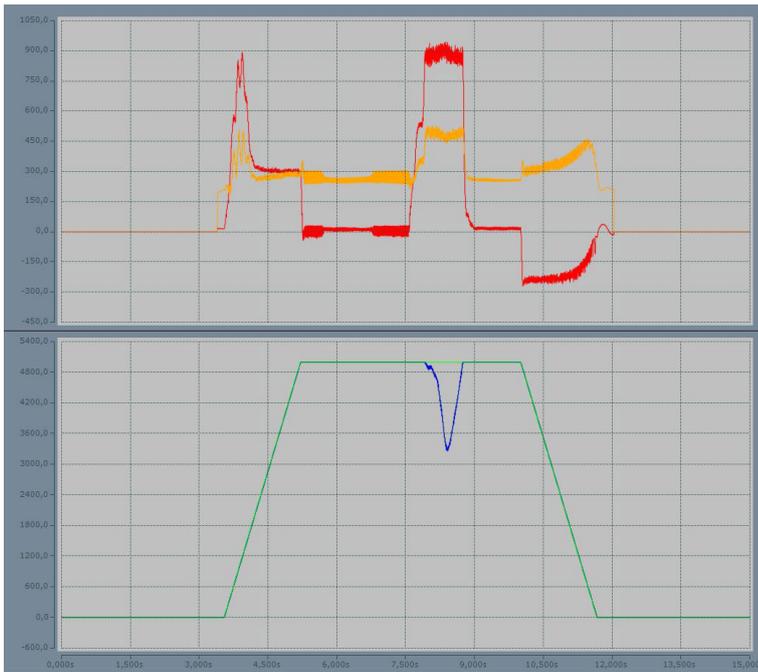
The value of the stall protection controller is set to 100% in example 2. As the tool penetrates the solid material, you can see by the blue characteristic curve that more current is available at this point and that the speed does not drop as dramatically as in example 1.

Result:

The consequence of the limitation of the current to 100% by the stall protection controller is that the set speed can be maintained better.

Key:

- Green characteristic curve: set speed
- Blue characteristic curve: actual speed
- Red characteristic curve: active current (maps the torque)
- Yellow characteristic curve: reactive current (maps the magnetization)

3.2.2   Configuration

Joint operation of the stall protection and the acceleration controller!

To use the stall protection and the acceleration controller together, the two IDNs P-0-0115 and P-0-0112 should have different values.

Activation and setting of the stall protection properties

To activate the control structure of the stall protection [item 3], go in the Drive Manager to Channel A → Configuration → Controller overview → V/f control [item 1].

The stall protection is parameterized via the Kp and I_{max} values [item 2].

Confirmation of the settings made

After actuating the stall protection button, a pop-up window appears [item 4] in which you have to confirm the activation of the current controller settings once again.

Conclusion of the configuration

The stall protection is now activated. The red coloring [item 5] indicates that the project is not yet online. To set the b stall protection to active, you have to activate the TwinCAT project.

Value range of Kp and Imax:

The values for the gain factor K_p and the actual current value I_{max} must be set in the *Stall protection control* settings [item 2].

4 Ballast calculation for single-axis drives

This documentation refers to single-axis drives. Further calculations are required for multi-axis drives and coupled axes.

Reaction of a servomotor during operation:

- In the acceleration phase, the servomotor draws energy from the DC link.
- In the braking phase, the servomotor (generator operation) feeds energy into the DC link.

The feedback causes an increase in the DC link voltage, which is limited by the maximum permissible DC link voltage of the servo drive (by a brake resistor). This limitation serves to protect the device. The excess energy is converted into heat in the brake resistor.

The power that is fed back can be calculated from the available kinetic energy. The result is offset pro rata against the total cycle time. The additional energy (E_c) is not taken into account. It serves as a reserve.

Example:

Default values

- 600 V nominal voltage (DC link) at 400 V_{AC} supply voltage
- 850 V switch-on point of the brake chopper[1].
- **Formula**

$E_c [Ws] = 0.5 \times C_{DC\ link} (850\ V^2 - 600\ V^2)$

Special case with an EL72xx servo terminal:

- 48 V nominal voltage (DC link)
- 55 V switch-on point of the brake chopper[1].

Formula

$Ec [Ws] = 0.5 \times CDC\ link (55\ V^2 - 48\ V^2)$

[1]: Below this threshold, the energy is stored in the DC link capacitors.

Additional storable energy of an AX5000 servo drive at 400 V_{AC} (EL72xx at 48 V_{DC}) supply voltage

Servo drives	DC link capacitance [µF]	Storable energy [Ws]
AX5101 – AX5106	235	42
AX5112	470	85
AX5118	940	170
AX5125	1175	212
AX5140	1485	270
AX5201 – AX5203	235	42
AX5206	470	85
AX5160 – AX5172	900	163
AX5190	1060	192
AX5191	2120	384
AX5192	3180	576
AX5193	4240	768
AX5021	705	128
Servo terminal		
EL7201	53	0.019

ℹ **Calculation of the load moment of inertia:**

For an exact determination of the inertia reduced to the motor shaft, please use the
Beckhoff TE5910 | TwinCAT3 Motion Designer.

4.1 Formulary

Symbol	Unit	Definition
ω	[rad/s]	Angular velocity
C_{zk}	[F]	Capacitance of the DC link capacitor
n	[1/min]	Motor speed
m	[kg]	Weight of the load
J_l	[kgm²]	Load moment of inertia (can be reduced to the motor shaft)
J_m	[kgm²]	Motor moment of inertia
J_{l+m}	[kgm²]	Mass moment of inertia of the load and the motor
M_{be}	[Nm]	Acceleration torque
t_{be}	[s]	Acceleration time
P_{meanAC}	[W]	Mean acceleration power
M_{br}	[Nm]	Braking torque
t_{br}	[s]	Deceleration time
P_{meanBR}	[W]	Mean braking power
E_{br}	[Ws]	Braking energy
P_{erf}	[W]	Required continuous power of the braking resistor
T_{total}	[s]	Total cycle time
i	[1]	Gear ratio
Ec	[Ws]	Energy that can be stored in the DC link capacitors
E_{pot}	[Ws]	Potential energy of a load
P_{lower}	[W]	Power required to reduce potential energy
t_{absenk}	[s]	Time during which the load is reduced
g	[m/s²]	Gravitational constant
h	[m]	Height at which the load is positioned / height difference of the lifting movement

Angular velocity:

$$\omega = \frac{2 \cdot \Pi \cdot n}{60}$$

Acceleration torque (from 0 → ω):

$$M_{be} = J_{l+m} \cdot \frac{\triangle\omega}{t_{be}}$$

Braking torque (from ω → 0):

$$M_{br} = J_{l+m} \cdot \frac{\triangle\omega}{t_{br}}$$

Mean drive power during the acceleration phase (from 0 → ω):

$$P_{mittelBE} = M_{be} \cdot \frac{\omega}{2}$$

Mean drive power during the brake phase (from ω → 0):

$$P_{mittelBr} = M_{br} \cdot \frac{\omega}{2}$$

Generated braking energy (from ω → 0):

$$E_{br} = J_{l+m} = \frac{\omega^2}{2}$$

If a gear unit is used, load inertia relating to the motor shaft is reduced by i².

Selecting the braking resistor:

The mean braking power of the individual braking operations must be considered in relation to the total cycle time.

$$P_{erf} = \frac{P_{mittelBr1} \cdot t_{br1} + P_{mittelBr2} \cdot t_{br2} + P_{mittelBr3} \cdot t_{br3} + \ldots}{T_{gesamt}}$$

Special case: lifting axes:

Speed n

Braking

Driving

Rotation to the

right

II   I

III   IV

Rotation to the

right   Torque M

Driving

Braking

Rotation to the
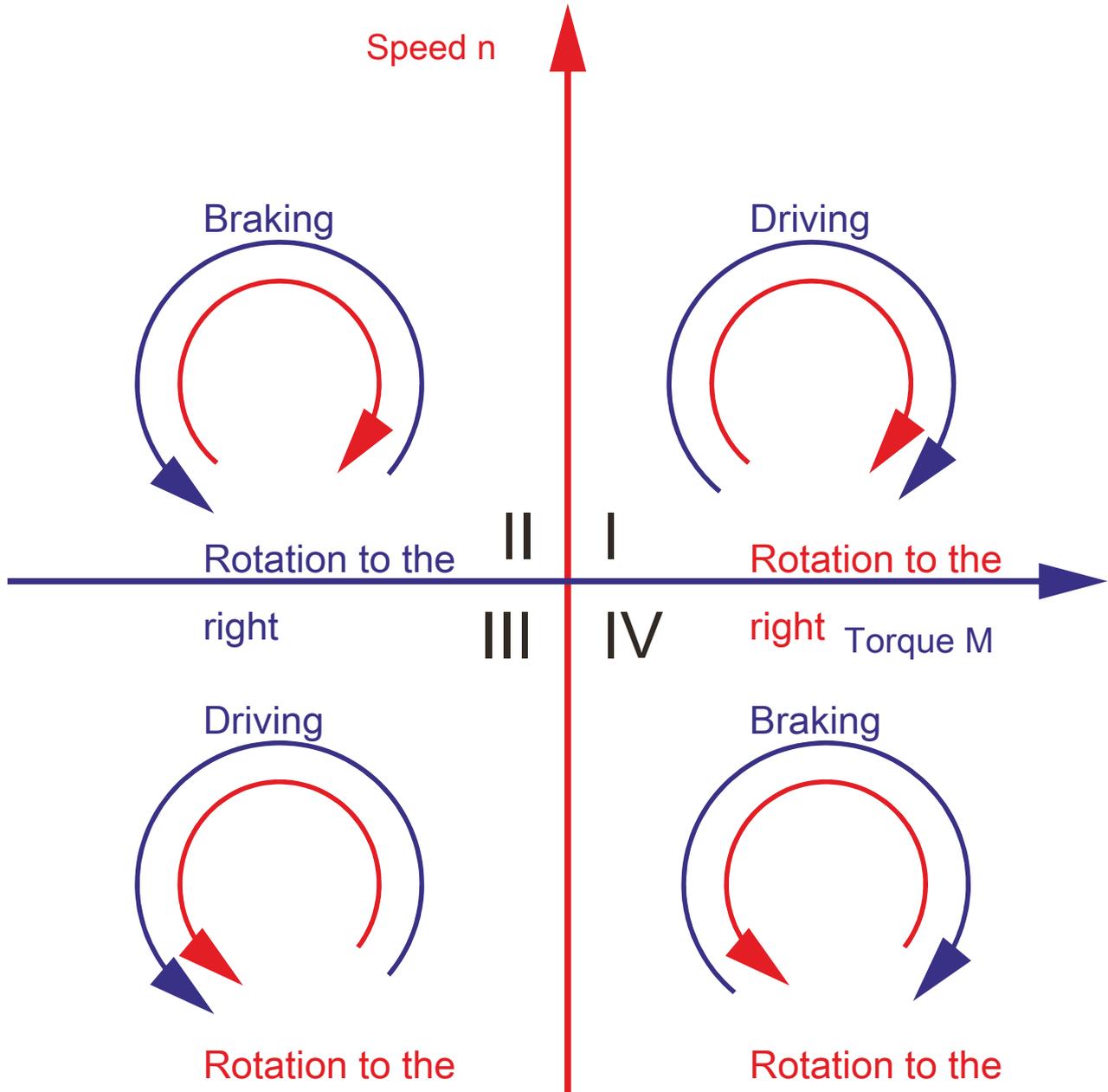
Rotation to the

For vertical axes, in addition to the kinetic energy, the potential energy (caused by the mass) must be taken into account.

Behavior at standstill

The load is in the 1st quadrant. This means that no braking power occurs. The braking power only occurs in quadrants 2 and 4. When the load is lowered, the potential energy must be dissipated by the servo drive:

$$E_{pot} = m \cdot g \cdot h$$

It depends on the respective height difference and the mass to be moved. The lowering time must also be taken into account for the calculation of the mean power.

$$P_{absenk} = \frac{E_{pot}}{t_{absenk}}$$

Continuous power of the entire cycle

To calculate the cycle, the power for lowering and the remaining power values are included in the calculation.

$$P_{erf} = \frac{P_{absenk} \cdot t_{absenk} + P_{mittelBr1} \cdot t_{br1} + P_{mittelBr2} \cdot t_{br2} + P_{mittelBr3} \cdot t_{br3} + \ldots}{T_{gesamt}}$$

4.2   Example for horizontal travel drive

The task

A travel drive is to be accelerated and decelerated twice within a total cycle time of 50 s. Calculate the brake resistor to be used for an AX5112 servo drive.

Default values

- Speed 3000 rpm
- Acceleration and braking time 0.5 s
- Moment of inertia reduced to the motor shaft 0.02 kgm²
- Motor moment of inertia 0.0024 kgm²

Procedure

1. Calculation of the angular velocity

$$\omega = \frac{2 \cdot \Pi \cdot n}{60} = 314 \;\; 1/s$$

2. Calculation of the required braking torque

$$M_{br} = J_{I+m} \cdot \frac{\omega}{t_{br}} = 14{,}07 \;\; Nm$$

3. Calculation of the mean braking power for each braking process

$$P_{mittelBr} = M_{br} \cdot \frac{\omega}{2} = 2209 \;\; W$$

4. Calculation of the required continuous power

$$P_{erf} = \frac{P_{mittelBr1} \cdot t_{br1} + P_{mittelBr2} \cdot t_{br2}}{T_{gesamt}} = 44{,}18 \;\; W$$

Since the internal brake resistor already offers a continuous power of 90 W, it is sufficient for this application.

If the result is calculated for ten braking operations, it corrects itself as follows:

Required continuous power for ten braking operations

$$P_{erf} = \frac{P_{mittelBr1} \cdot t_{br1} + P_{mittelBr2} \cdot t_{br2}}{T_{gesamt}} = 220{,}90 \;\; W$$

For this value it is recommended to use an external brake resistor AX2090-BW50-0300 with 300 W continuous power.

4.3   Example for a vertical travel drive

The task

A load of 1000 kg is to be lowered by 1 m within 6 s.

Procedure

1. Calculation of the potential load

$$E_{pot} = 1000 \ kg \cdot 9{,}81 \ m/s^2 \cdot 1 \ m = 9810 \ Ws$$

2. Calculation of the lowering time

$$P_{absenk} = \frac{9810 \ Ws}{6 \ s} = 1635 \ Ws$$

---

i **Differentiation between peak and continuous load:**

Long braking times (> 1 s) no longer represent a peak load but a continuous load. Therefore, the continuous load must be added directly when calculating the braking power.

Please note:

For very short braking times (<1 s), the time can be considered in relation to the total cycle time.^t

---

5   Acceleration pre-control

The lag error of an axis during acceleration can be minimized with the aid of the acceleration pre-control. This can, for example, shorten the cycle times of handling axes or improved the path fidelity of CNC axes.

The meaning of the parameters in conjunction with the acceleration pre-control is explained in the following chapters.

> **i** **Reference variables for the acceleration pre-control**
>
> P-0-0010, P-0-0071, P-0-0505, P-0-0556, S-0-0348

Requirements

The acceleration pre-control can only be used if the AX5000 is operated in

- 11: position control feedback 1 lag less

or

- 12: position control feedback 2 lag less mode.

The AX5000 receives a new set position value cyclically (e.g. every 2 ms) and interpolates between the new set values with the cycle time of the position controller (default value 250 µs).
The acceleration results from the second derivative of the position. In the case of linear interpolation of the set values the value of the second derivative is always zero.

Therefore cubic interpolation must be set in the AX5000 (P-0-0556):

P-0-0010	Feature flags	
	Enable adjusted velocity controller gain scaling	0: disabled
	Enable adapted axis state machine	1: enabled
	View enlarged error history	1: enabled
	Enable excessive position deviation monitoring	1: enabled
	View extended software versions list (P-0-0320)	1: enabled
	Enable extended power management	1: enabled
	Consider the 'Additive position command value' (S-...	1: enabled
	rsvd	1
	rsvd	1: enabled
	Enable phase clamping	1: enabled
	Explicit modulo init data saving required	1: Yes
	Probe unit: Hardware delay compensation	1: enabled
	Feedback value sampling point: Adjusted to Sync1	1: Yes
	Set data length of P-0-0070 to 4 byte	1: Yes
	Extended thermal motor model (P-0-0062)	1: Yes
	Velocity controller gain in 'Nm/(rad/s)|N/(m/s)'	0: No
	Acceleration feed forward gain (S-0-0348) in '%'	1: Yes
	reserved	0

If cubic interpolation is active, the cycle time of the position controller in the AX5000 (P-0-0004) must not be shorter than 250 µs, otherwise an error message (F330) will appear.

The acceleration pre-control should be used if possible with a firmware version ≥ FW v2.10 build 8. The function has already been implemented in previous versions, but not with the functionality described here.

In parameter P-0-0010 "Feature Flags", the associated bit must be activated so that the scaling of the pre-control takes place in %:

A value for the current is calculated from the acceleration, depending on the motor and the load conditions. For this, it is important that the correct values for the mass inertia of the motor and the load are entered in parameter P-0-0071:

The mass inertia of the motor is read automatically from the electronic name plate during the configuration.

S P-0-0071	PS	047	Mechanical motor data		
			Rotor moment of inertia (BitSize 32,OffSet 0)	4.75	*0.0001 kgm^2
			Load moment of inertia (BitSize 32,OffSet 32)	23.00	*0.0001 kgm^2

If the exact value of the load inertia is not known it should be estimated. In most servo applications the ratio of the load inertia to the motor inertia has a value of between 3 and 10.

Procedure
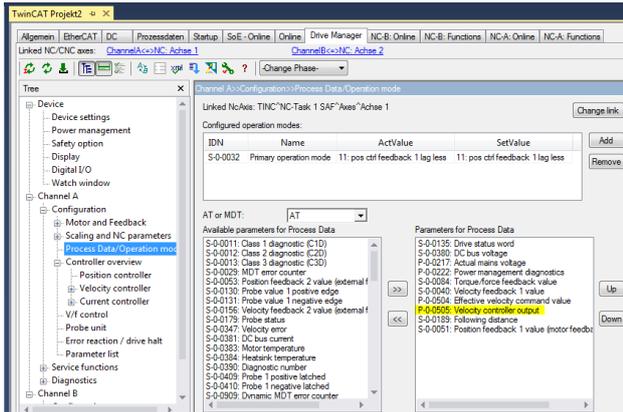
First of all, optimise the axis with the linear interpolation. To do this, record the current, velocity command value, actual velocity and lag error with the oscilloscope.

Then activate the cubic interpolation as shown above and add the parameter P-0-0505 to the process data:
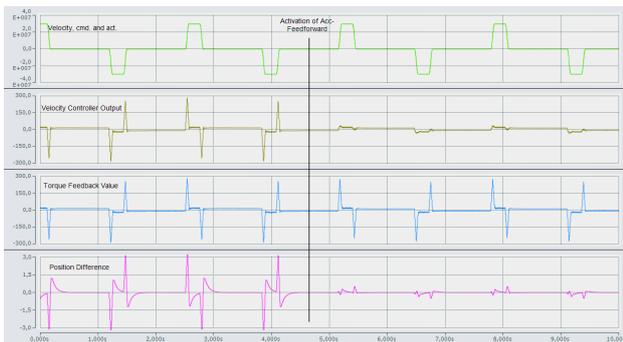
If you record the value of the "velocity controller output" with the oscilloscope, you will obtain a picture similar to the one shown here:

The value of the "velocity controller output" (P-0-0505) is largest during the acceleration and braking phases.
In the second part of the picture the acceleration pre-control is active. As a result, the velocity controller is relieved and the value of the "velocity controller output" reduced.
At the same time the lag error becomes smaller.
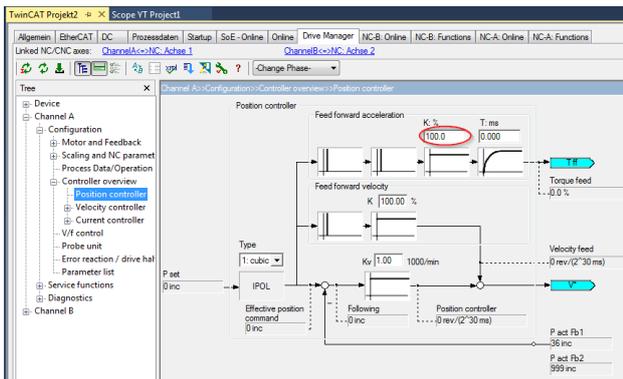
If the moment of inertia is set correctly, a value of 100% is usually ideal for acceleration pre-control (S-0-0038, "acceleration feedforward gain"):

This can be checked and corrected if necessary using the oscilloscope recording.
The criterion for this is the size of the lag error and possibly the value of the "velocity controller output".

6 Operation of encoders with EnDat interface and battery-backed absolute position

6.1 Description of the problem

With these encoders, in contrast to other encoders, the absolute position, i.e. the number of revolutions, is not mechanically recorded with the aid of a gear unit, but is stored in a battery-backed memory. If the power supply to the encoder fails when the servo drive is switched off, because the battery is empty or the connection to the battery is interrupted, the encoder irrevocably loses the absolute position. In order to prevent possible damage to an axis, this case must be taken into account and given special treatment. The displayed error must not be able to be acknowledged with the normal error reset. To do this, there must be a way to reset the error and re-reference the axis and put it into operation after battery power is restored to the encoder.

6.2 Message from encoder

If during operation the battery voltage of the encoder becomes too low or fails completely, it issues a warning, which the AX5000 displays as battery warning 0xED61. The position is still valid and operation can continue.

In this case, please search for the cause!

To reset the warning, a restart of the AX5000 is required, description see below.

If the AX5000 is restarted without the battery voltage having returned, the encoder has lost its absolute position and reports an error. The AX5000 reports this as an error:

F87E Feedback "AX572x": Feedback battery error

It remains in the "Error Pre-Op" state

This error is also reported if the battery voltage at the encoder has been interrupted when the AX5000 is switched off.

The error cannot be acknowledged with the normal reset command, S-0-0099, but appears repeatedly during the transition from Pre-Op to Safe-Op.

6.3 Resetting the error message and warning

If the AX5000 displays the error "F87E Feedback battery error" in the "Error Pre-Op" state, it is essential first to find the cause and remedy the problem: is the cable to the battery interrupted or is the battery voltage too low?

The following steps must be carried out to reset the error in the encoder and in the AX5000 so that the axis can move again:

1. Resetting EtherCAT error
2. Set parameter P-0-0357 Enhance error handling, bit 0 = "1: Yes":

P-0-0357	Enhanced error handling	
	Ignore and reset feedback battery error for one PreOp->SafeOp transition	1: Yes
	Reset feedback battery warning for one PreOp->SafeOp transition	0: No

3. Set the drive to the "Op" state.
4. Bit 0 in P-0-0357 is automatically reset.

> **i** Attention, the axis must be referenced!

To reset the warning,

5. set the drive to the Pre-Op state.

6. Set bit 1 = "1: Yes" in parameter P-0-0537.

P-0-0357	Enhanced error handling	
	Ignore and reset feedback battery error for one PreOp->SafeOp transition	0: No
	Reset feedback battery warning for one PreOp->SafeOp transition	1: Yes

7. Set the drive to the "Op" state.

8. Bit 1 in P-0-0357 is automatically reset.

6.4 Emergency mode

Normal operation of the axis

It is the responsibility of the application programmer not to enable normal operation of the axis until the battery has been replaced or reconnected and the axis has been re-referenced.

If the axis must be moved before the cause of the error can be corrected, special care must be taken because the absolute position is invalid. For example, allow only jogging mode!

Follow the steps above to reset the error. The AX5000 reports the warning ED61 "Feedback battery warning", but it can be enabled and the axis can be moved.

6.5 Additional error message

If bit 0 or 1 is set in parameter P-0-0357, although no error and no warning are present in the encoder, the AX5000 outputs the error message *F87F, Feedback "AX572x" Parameter error in P-0-0537*. This prevents that a bit remains permanently active and thus a battery error of the encoder is not detected.

7   Change to compatible type

> **Further documentation:**
>
> The steps shown in this functional description refer to a configuration in the TwinCAT 3 development environment.
> **Further information can be found at:**
> www.beckhoff.com → Automation → TwinCAT 3 → Documentation

Change to Compatible Type in the case of AX5000 servo drive

With the *Change to Compatible Type* function, TwinCAT offers an exchange of the AX5000 servo drive (larger range of functions or performance, see above) and/or the revision, taking into account the links in the task.

Breakdown of the EtherCAT revisions
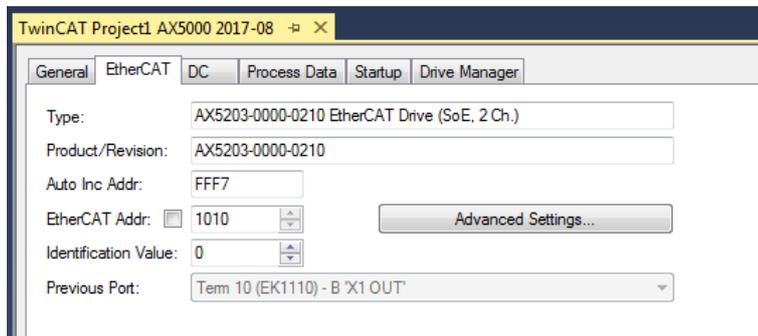
If the AX5000 servo drive is inserted by means of a device scan in the TwinCAT configuration the Solution Explorer displays the EtherCAT revision of the device (see picture, left). The user can change the device name.

Depending on the hardware and firmware version of the AX5000 servo drive, there is an assignment of different EtherCAT revisions to the appropriate firmware.

In the table below the EtherCAT revisions of hardware 1 and 2 are allocated to the firmware versions (V1.00 – V2.10).

Example hardware 1 device:
The EtherCAT revision number AX5yxx-0000-**0004** (hardware 1) was created to:
operate a firmware V1.00 b0010 (final build).

Example hardware 2 device:
The EtherCAT revision number AX5yxx-0000-**0202** (hardware 2) was created to:
operate a firmware V2.05 b0008* (final build).

AX5000 - Hardware 1			AX5000 - Hardware 2		
Order key	EtherCAT revision	Firmware (final build)	Order key	EtherCAT revision	Firmware (final build)
AX5yxx-0000-0000	AX5yxx-0000-**0004**	V1.00 b0010	AX5yxx-0000-0200[1]	AX5yxx-0000-**0200**	V2.03 b0026*
AX5yxx-0000-0000	AX5yxx-0000-**0006**	V1.01 b0008	AX5yxx-0000-0200[1]	AX5yxx-0000-**0201**	V2.04 b0016*
AX5yxx-0000-xxxx	AX5yxx-0000-**0007**	V1.02 b0007	AX5yxx-0000-0200[1]	AX5yxx-0000-**0202**	V2.05 b0008*
AX5yxx-0000-xxxx	AX5yxx-0000-**0008**	V1.03 b0001	AX5yxx-0000-0200[1]	AX5yxx-0000-**0203**	V2.06 b0028*
AX5yxx-0000-xxxx	AX5yxx-0000-**0009**	V1.04 b0005	**Order key**	**EtherCAT revision**	**Firmware (final build)**
AX5yxx-0000-xxxx	AX5yxx-0000-**0010**	V1.05 b0011	AX5yxx-0000-0202[1]	AX5yxx-0000-**0210**	V2.10 b0014*
AX5yxx-0000-xxxx	AX5yxx-0000-**0011**	V1.06 b0030	AX5yxx-0000-0202[1]	AX5yxx-0000-0211	V2.11 (no release)
AX5yxx-0000-xxxx	AX5yxx-0000-**0012**	V1.07 b0016	AX5yxx-0000-0202[1]	AX5yxx-0000-0212	V2.12 (no release)

1) Operation of the EtherCAT revisions 020x with firmware versions V2.03 - V2.06 is permitted. Operation of the EtherCAT revision with FW version V2.10 is permitted. The full functionality of a firmware can only be guaranteed with the corresponding EtherCAT revision (e.g. firmware V2.06 b0023 with EtherCAT revision 203).

*Due to continuous software development, the firmware versions listed in the table may be obsolete.

Example scenarios for the handling of the *Change to Compatible Type* function

Scenario	Example and feasibility of the Change to Compatible Type
Firmware Update:	**Initial situation:** There is a TwinCAT configuration. **Intention:** A firmware update is to be carried out on the AX5000 servo drive. **Explanation:** The new firmware uses a more recent EtherCAT revision. Following the update the TwinCAT configuration is no longer identical to the EtherCAT revision of the modified servo drive. **Result:** A *Change to Compatible Type* can be performed.
Service case: Device replacement – deviating performance	**Initial situation:** There is a service case. The AX5203 servo drive on the machine is defective. **Intention:** The defective servo drive is to be replaced. No identical replacement device is available, but one from the same series with a higher performance (AX5206). **Explanation:** The AX5203 is replaced by the AX5206. The configuration has to be adapted due to the different performances. **Result:** A *Change to Compatible Type* can be performed.
Service case: Device replacement – backward compatible	**Initial situation:** An AX5000 servo drive with current firmware (V2.06 b0023) is to be installed in the machine. **Problem:** The configured servo drive in TwinCAT has an older EtherCAT revision (0012). **Request of the application:** The new functions of the firmware V2.06 b0023 are not required. The servo drive is to be operated with the old configuration. **Result:** **No** *Change to Compatible Type* is necessary.
Service case: Device replacement – upwardly compatible	**Initial situation:** An AX5000 servo drive with an EtherCAT revision 0200 and a current firmware V2.06 b0023 is configured in TwinCAT. **Problem:** An AX5000 servo drive with an EtherCAT revision 0011 and a firmware V1.06 b0028 is installed in the machine. **Explanation of the problem:** Newer EtherCAT revisions include new or changed functions. The interfaces of the EtherCAT revisions have been extended. This has the consequence that an older EtherCAT revision cannot serve a newer one. The AX5000 servo drive cannot be controlled. **Result:** A Change to Compatible Type is **not** possible. A downgrade of the servo drive or a reinstallation must be carried out.

7.1   Functional description

ℹ **Data backup!**
Beckhoff Automation GmbH & Co. KG recommends that you make a backup of your TwinCAT project and the data of your configuration before executing the function.

Step 1

- Right-click on a created servo drive (in our example *Drive_X1*) in the I/O configuration.
- Select the *Change to Compatible Type* function in the context menu.
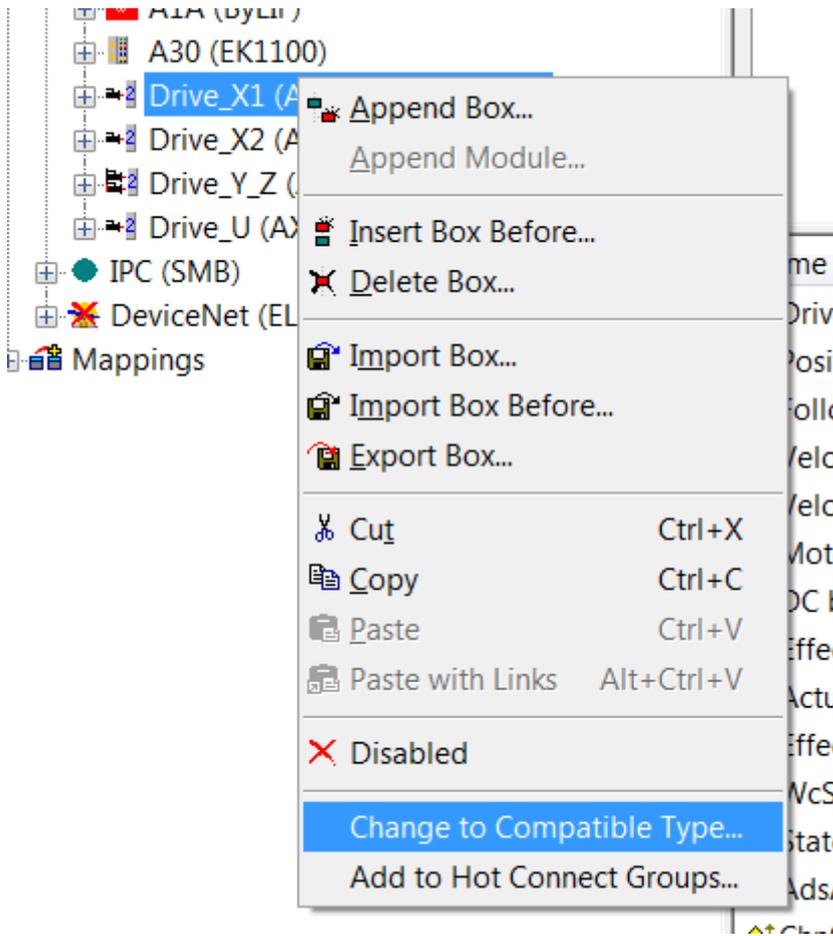
Step 2

A list appears showing the compatible servo drives that are suitable for the execution of the *Change to Compatible Type* function.

- Select a suitable servo drive from the list (**Step 2**).

- Confirm with "OK"
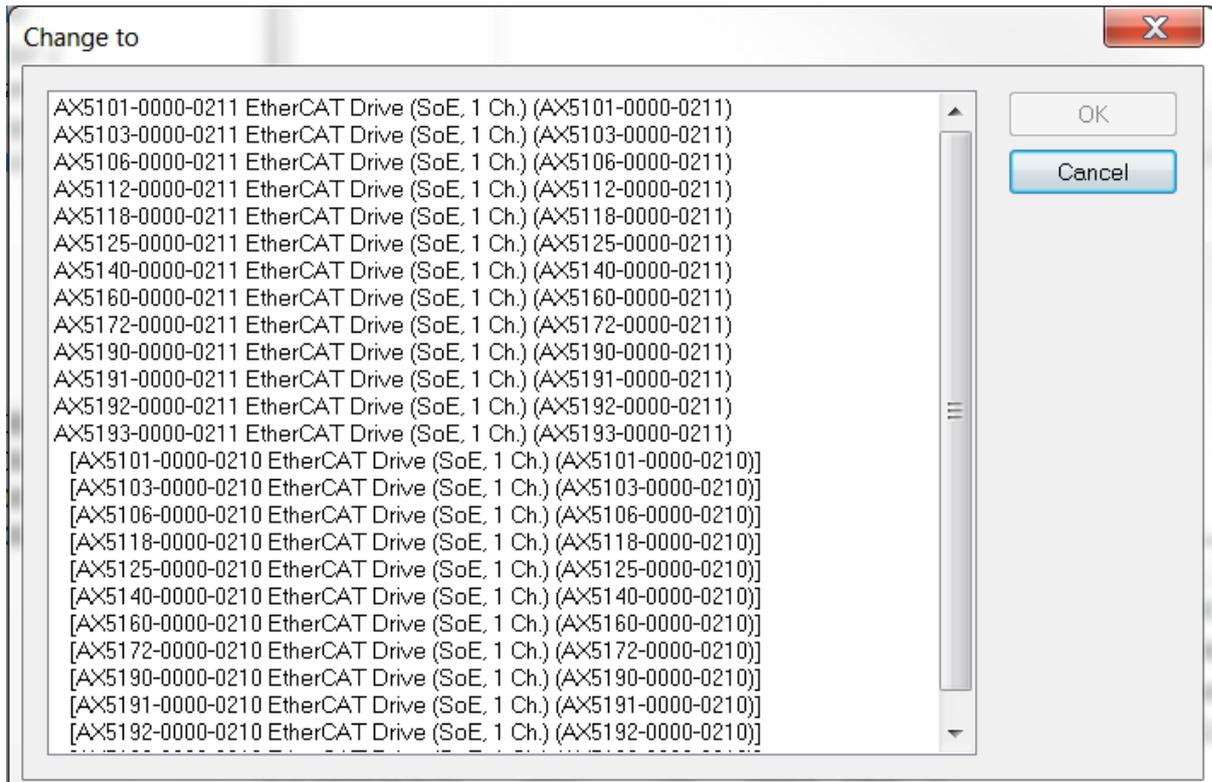
- In the next step, start the function by left-clicking on "OK".
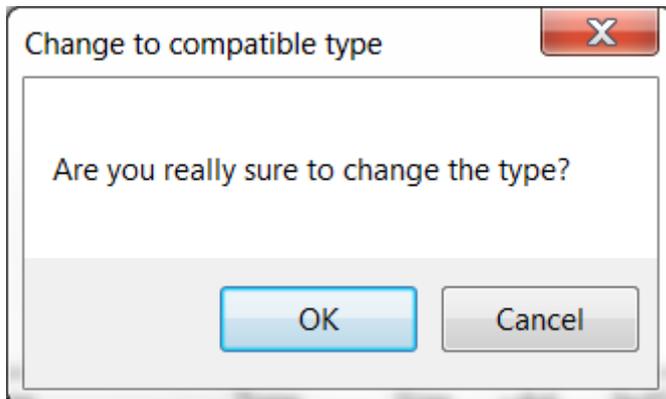
ⓘ **Use of the *Change to Compatible Type* function.**

Only servo drives with identical hardware conditions (HW1 or HW2) and the same number of channels (1- or 2-channel devices) can be updated or changed.
A *downgrade* of the servo drive to older EtherCAT revisions (e.g. AX5206-0000-0210 to AX5206-0000-0203) is not possible!

Step 3

The following settings are now changed for the selected servo drive in the TC Drive Manager:

- **EtherCAT \ Slave \ Info:**
  Physical devices, product code, revision number, serial number, type.

- **Settings / StateMachine:**
  CheckRevisionNo (if changed)

- **ProcessData:**
  The missing Sync Manager is added (if available).

Step 4

Once steps 1 – 4 have been completed, the changes are adopted into the startup list in parameter P-0-0010. These are then compared with the Beckhoff-AX5xxx.xml defined standard configurations.

---

i **Aborting and restarting the function!**

It is possible at all times to stop and restart the function.

- **To stop the function:**
  Click *Cancel* in step 3. The procedure is now aborted.

- **To restart the function:**
  First make a backup of your data. Then begin with step 1 of this functional description.

7.2 Term definitions

Order key

The order key identifies the product. It is attached to the name plate on the outside and consists of a 14-character combination of letters and numbers.

---

i **Further information on the order key can be found in the:**
AX5000 - System manual under Product identification!

Beckhoff distinguishes the AX5000 servo drives between **H**ard**W**are 1 - devices and **H**ard**W**are 2 - devices.

Firmware (version):

The firmware is the software of the AX5000 servo drive. This is identified accordingly with Firmware - v1.xx or Firmware - v2.xx. A breakdown of the firmware revisions to the hardware versions of the device can be found in the chapter: Change to Compatible Type [▶ 29]".

Revision No. / EtherCAT revision ≠ order key

Each firmware has an assigned Revision No. or EtherCAT revision. This is saved on the E²Prom of the AX5000 servo drive and can be read via the TwinCAT System Manager. The revision no. is shown in the last 8 characters of the *Product / Revision* : **e.g. AX5106-0000-0203**

The first 4 characters are always zero.

Builds:

As soon as a firmware is released it is given a version number (V) and a build (b). If changes or optimizations take place within a firmware version, the builds are incremented. Each firmware has a latest current version.

ESI – Device - Description:

An **E**therCAT **S**lave **I**nformation is a device description in *xml format. It is required in order to carry out online or offline configurations in TwinCAT. ESI files can be requested by manufacturers and are provided for download.

There may be several ESI device descriptions in one *xml file.

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i **Structure of the ESI file in the *xml format:**
*xsd is a format that describes the structure of a device description (ESI) in the *xml file. If the EtherCAT slave information is updated, the *xsd and *xml files should always be updated as well. This way you can ensure that the required information from the device description is transferred fully.

---

8 Digital inputs and outputs

The AX5000 servo drive can be used to activate various functions via digital inputs and outputs. The functions are assigned via eight inputs (0-7); input 7 can be configured as output. The individual functions are described in this chapter.

> **i** **Reference values for the digital inputs and outputs:**
>
> P-0-0251; P-0-0315; P-0-0400; P-0-0401; P-0-0402; P-0-0800

Overview of inputs and outputs with assignable functions
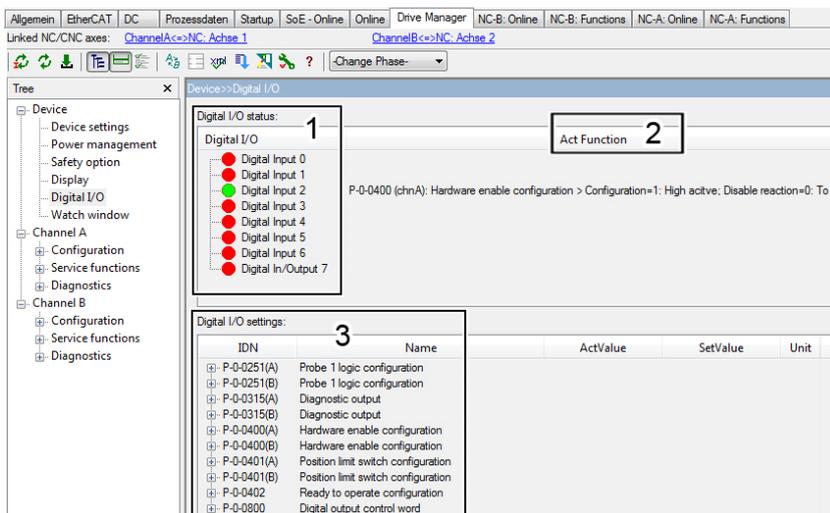
In the „*Digital I/O status*" section (1), the TC3 Drive Manager provides an overview of all inputs and outputs at the AX5000 servo drive. Inputs at which no voltage is present (low) are shown in red. Inputs at which voltage is present (high) are shown in signal green.

The „*ActFunction*" window (2) shows whether and where a function is active. The „*Hardware enable configuration*" is assigned to input 2.

The functions that can be assigned to the inputs and outputs are shown in the „*Digital I/O settings*" section (3). The functions listed under (3) are described later in this chapter.

8.1 Diagnostic output

The parameter P-0-0315 enables configuration of a diagnostic outputs at the AX5000 servo drive. For dual-channel devices this parameter is configurable for both channels (A and B).
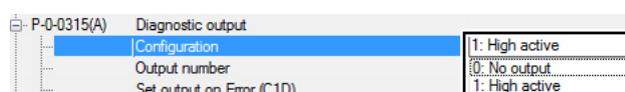
Configuration

0: No output
No diagnostic output function is selected.

1: High active
A diagnostic output function is selected.

Default value: 0 No output

Output number
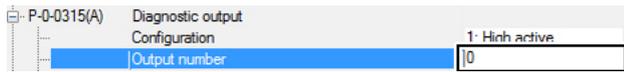
„*Digital output 7*" can be configured as digital output with the function „*Diagnostic output*" under this setting in parameter P-0-0315.

Default value: 0 No

Set output on Error (C1D)
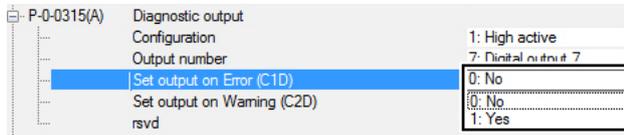
0: No
The specified output *(Digital output 7)* does not respond to a C1D error.

1: Yes
The specified output *(digital output 7)* responds to a C1D error.

The error is displayed on the AX5000.

Default value: 0 No

Set output on warning (C2D)
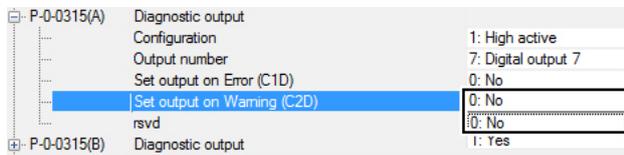
0: No
The specified output *(digital output 7)* does not respond to a C2D warning.

1: Yes
The specified output *(digital output 7)* responds to a C2D warning.

The error is displayed on the AX5000.

Default value: 0 No

8.2   Hardware-Enable

A hardware enable for the AX5000 servo drive can be configured in the TC3 Drive Manager. This function is active in addition to the software enable from the controller via the bus system. The two functions are connected via an AND link. The settings for this input function are made in parameter P-0-0400.

Configuration

0: No hardware enable
No hardware enable function is selected.
1: High active
A hardware enable function is selected.

Default value: 0 No hardware enable

Input number
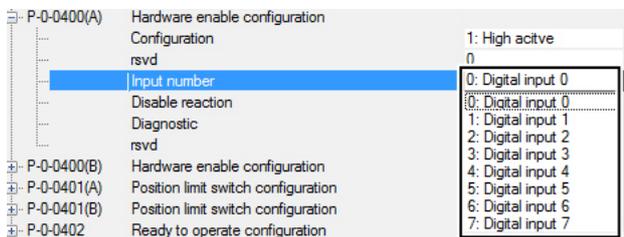
Under this setting in parameter P-0-0400 you can specify which digital input is to be configured with the function „*Hardware enable*". You can assign the function to one of eight digital inputs (0-7).

Default value: 0 Digital input 0

Disable reaction
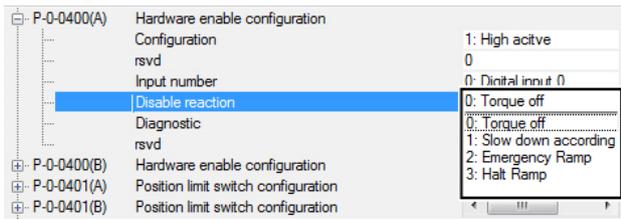
Default value: 0 Torque off

0: Torque off
The servo drive de-energizes the axis.
1: Slow down according to P-x-0356
(only asynchronous motors)
The servo drive brakes the axis with the deceleration ramp set in parameter
P-x-0356 (rotor slow down procedure parameter).
2: Emergency ramp
The servo drive brakes the axis with the deceleration ramp set in parameter S-0-0429 (emergency stop deceleration).
3: Halt ramp
The servo drive brakes the axis with the deceleration ramp set in parameter S-0-0372 (drive halt acceleration bipolar)

Diagnostics

Default value: 0 Error

0: Error
If axis control is active (enabled) and the hardware enable input is switched off, the AX5000 servo drive reports error message F102 (loss of the hardware enable).
3: Silent
If axis control is active (enabled) and the hardware enable input is switched off, the AX5000 servo drive reports no error.

8.3 Limit switch monitoring

⚠ DANGER
Serious injuries caused by moving axes!
The limit switch monitoring in the AX5000 servo drive is purely functional and **not** suitable for personal protection!
Notwithstanding active limit switch monitoring a fault in the drive system may:
- disable the protection functions of the limit switch
- prevent braking of the axes through EStop and axis stop ramps.
In other words, the axes may **not** respond. This could cause serious injury.
Before commissioning ensure that all external personal protection measures were applied.

The parameter P-0-0401 enables configuration of two limit switches per axis. For dual-channel devices this parameter is configurable for both channels (A and B).
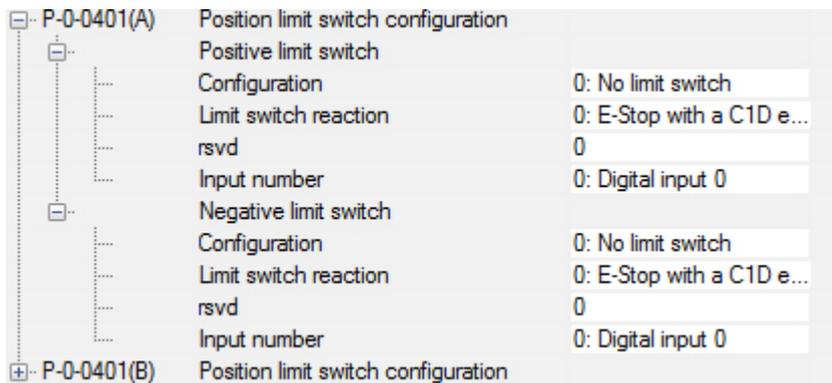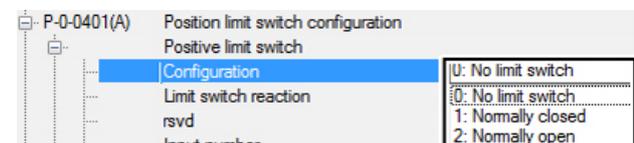
Configuration

Default value: 0 No limit switch

0: No limit switch
No limit switch is configured / available.
1: Normally closed (wire-break protection)
The limit switch is closed if it was not reached by the axis.
2: Normally open
The limit switch is open if it was reached by the axis.

Limit switch reaction

Default value: 0 E-Stop with a C1D error

0: E-Stop with a C1D error
Braking of the axis with the emergency stop ramp (S-0-0429) and triggering of an error message (FCD0, FCD1). The error is displayed on the AX5000.

1: E-Stop with a C2D warning
Braking of the axis with the emergency stop ramp (S-0-0429) and triggering of a warning (ECD0, ECD1). The error is displayed on the AX5000.

2: Axis halt with a C2D warning
Braking of the axis with the halt ramp (S-0-0372) and triggering of an error message (FCD0, FCD1). The error is displayed on the AX5000.

Input number

Under this setting in parameter P-0-0401 you can specify which digital input is to be configured with the function „*Position limit switch*". You can assign the function to one of eight digital inputs (0-7).

Configuration of the positive and negative limit switch

The positive and negative limit switch can be configured in parameter P-0-0401. The selectable settings are identical for both limit switch versions and are described in this chapter for the positive limit switch only.

8.4   Ready to operate

In the AX5000 configuration this device can be integrated in the ready-chain of the machine. This function requires a digital input and a digital output. Activation of this function and allocation to the respective input and output is realized in parameter P-0-0402. Since only digital input no. 7 can optionally be configured as output, only digital output no. 7 is offered as output number.

8.5   Digital output control word

Digital output 7 can be configured as „*user output*" at the AX5000 servo drive for signal output from the PLC.

Default value: 0 no output

1: user output (P-0-0802)
Digital output 7 can be controlled via parameter P-0-0802
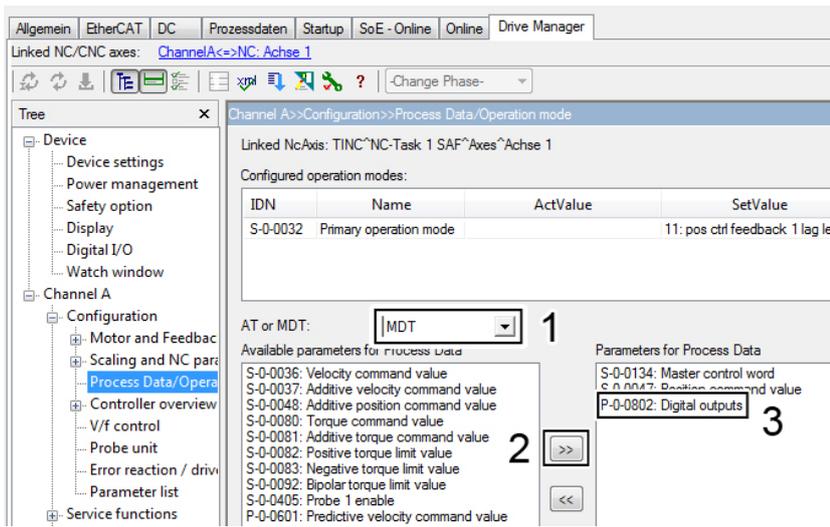
The parameter P-0-0802 (3) can now be mapped in the **M**aster**D**ata**T**elegram (1) process data of the AX5000 servo drive and linked to a PLC variable.

Proceed as follows:

- Adding parameters from „*Available parameters for process data*" to the „*Parameters for process data*" via the button (2).

Bit 7 of this variable controls the state of digital output 7.

9 Extended commutation monitoring

In order to be able to detect a commutation error even more reliably and to switch off in the event of an error, the commutation monitoring function has been extended in firmware 2.13. The function and its setting options are described below.

9.1 Associated settings in P-0-0010

To enable the extended commutation monitoring, bit 21, Commutation angle error, in parameter P-0-0010, Feature Flags, must be "1 Enabled":

S P-0-0010	IP	006	Feature flags	
			Adjusted velocity controller gain scaling (BitSize 1,OffSet 0)	1: Enabled
			Adapted axis state machine (BitSize 1,OffSet 1)	1: Enabled
			View enlarged error history (BitSize 1,OffSet 2)	1: Enabled
			Excessive position deviation monitoring (BitSize 1,OffSet 3)	1: Enabled
			View extended software versions list (P-0-0320) (BitSize 1,OffSet 4)	1: Enabled
			Extended power management (BitSize 1,OffSet 5)	1: Enabled
			Consider the 'Additive position command value' (S-0-0048) (BitSiz...	1: Enabled
			rsvd (BitSize 1,OffSet 7)	
			rsvd (BitSize 1,OffSet 8)	
			Phase clamping (BitSize 1,OffSet 9)	1: Enabled
			Explicit modulo init data saving required (BitSize 1,OffSet 10)	1: Enabled
			Probe unit: Hardware delay compensation (BitSize 1,OffSet 11)	1: Enabled
			Feedback value sampling point: Adjusted to Sync1 (BitSize 1,Off...	1: Enabled
			Set data length of P-0-0070 to 4 byte (BitSize 1,OffSet 13)	1: Enabled
			Extended thermal motor model (P-0-0062) (BitSize 1,OffSet 14)	1: Enabled
			Velocity controller gain in 'Nm/(rad/s)|N/(m/s)' (BitSize 1,OffSet 15)	1: Enabled
			Acceleration feed forward gain (S-0-0348) in '%' (BitSize 1,OffSet ...	1: Enabled
			rsvd (BitSize 1,OffSet 17)	
			Advanced parametrization introduced with FW 2.10 (BitSize 1,Off...	0: Enabled
			Revised Control Mode of P-0-0451 (BitSize 1,OffSet 19)	1: Enabled
			rsvd (BitSize 1,OffSet 20)	
			Commutation angle error (P-0-0069) (BitSize 1,OffSet 21)	**1: Enabled**
			Enable one phase device protection (BitSize 1,OffSet 22)	1: Enabled
			Enable new basic field weakening limit calcultation (BitSize 1,Off...	1: Enabled
			rsvd (BitSize 40,OffSet 24)	

When creating a new configuration, this is the default setting.

9.2 Parameter P-0-0069, Commutation monitoring

The three conditions for the occurrence of the commutation error described under "Commutation error" are still valid. In addition, the AX5000 uses an internal calculation model to constantly calculate the current commutation angle error. If this exceeds the set limit value for the set time, the commutation error is also triggered. The setting options can also be found in parameter P-0-0069. The default settings are shown here:

P-0-0069	Commutation monitoring		
	Velocity limit	300	1/min
	nRsvd0	0.0	
	Maximum commutation angle error	1.00	rad
	Fault tolerance time	3	ms
	Low pass frequency	30	Hz

Parameter	Meaning
Velocity limit	The calculation of the model only starts when the velocity value set for "Velocity limit" is exceeded.
Maximum commutation angle error	If the deviation of the commutation angle exceeds this limit value, the commutation error is triggered (1rad = 57°).
Fault tolerance time	The commutation error is triggered if the deviation exceeds the limit value for longer than the set time.
Low pass frequency	The calculated deviation is filtered with a low-pass filter. Higher frequency values provide for faster response, lower frequency values for more tolerant behavior.

9.3   Possible cause for the error triggering

The calculation model for calculating the current commutation angle error requires the values for the inductance and the resistance of the motor winding. The correct values in parameter P-0-0066 are therefore very important:

P-0-0066	Electric motor model		
	Winding resistance (phase to phase) (Bit Size 32,Of...	2.47	Ohm
	Winding inductance (phase to phase) (Bit Size 32,...	25.00	mH

The effective inductance decreases with increasing current. For Beckhoff motors this relationship is stored in parameter P-0-0075:

P-0-0075	Motor inductance characteristic
	Iq (Bit Size 320,Off Set 0)
	Lq (Bit Size 320,Off Set 320)

For third-party motors these values are usually not known. Especially in the case of linear motors that accelerate very dynamically with a multiple of the nominal current, it is therefore possible that the model calculates with an incorrect value for the inductance during acceleration and as a result delivers a too large deviation of the commutation angle.

The options described in the next section can be used to determine whether the fault is actually always detected at high currents.

9.4   Diagnostic options

Add parameter P-0-0081, Estimated commutation error, to the process image and record it using ScopeView:
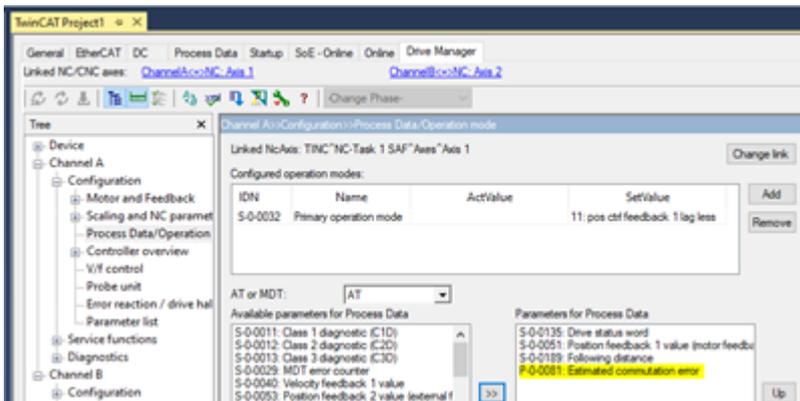
> ℹ **P-0-0081 does not map the angle, but the sine of the angle.**

The value for "Low pass frequency"(P-0-0069) affects the recording. At the maximum value of 1000 Hz the calculated deviation is displayed (and evaluated) almost unfiltered. In this way, you can also detect possible short-term deviations.

The following recording shows an example where an incorrect value for the motor inductance is active. For the recording the value for "Low pass frequency" was set to 1000 Hz. Only then are the peaks of the "Estimated commutation error" visible during acceleration.
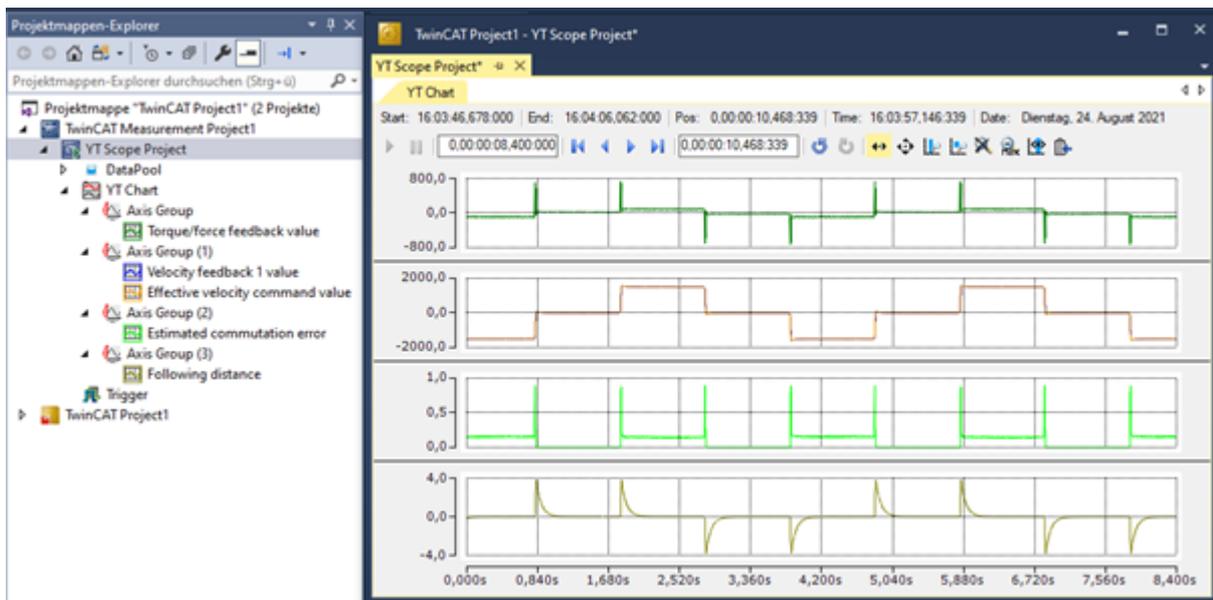
For comparison: if the value for the inductance is correct, the maximum value of the "Estimated commutation error" is 0.7.

9.5   Remedy for frequent commutation error

Make sure that the commutation error is not caused by a poorly adjusted velocity controller and a resulting oscillating axis.

If the "Estimated commutation error" value is consistently significantly different from zero, check the commutation angle. Possibly an incorrect offset was determined and entered, or the "Wake & Shake" routine does not provide reliable values.

If the "Estimated commutation error" only becomes significantly larger at large current values, typically at large acceleration, check whether the current-dependent values of the inductance are entered in parameter P-0-0075. If these are not available to you - especially for third-party motors - you can reduce the value of the inductance in P-0-0066. (The value of the inductance is used in the configuration of the motor to calculate the gain of the current controller. In operation only the described motor model uses it.)

You can also set the monitoring to be more tolerant by increasing the value for "Max. commutation error". The adjustable maximum value of 1.57 corresponds to a deviation of the angle of 90°. With this deviation, the motor has no more power/torque, but does not run away. The case of positive feedback with a deviation >90° is also detected with this setting and an error is triggered.

10 Field weakening

i ● **Available from firmware v2.12**

The field weakening function is available from firmware v2.12.

This documentation applies to the AX5000 servo drive. The chapters contain information on how to parameterize field weakening via the corresponding IDNs.

You can then check the status of the function and interpret error messages. Finally, information is provided about different IDNs that are important for the function.

10.1 Function

NOTICE
Check the settings and ensure they are correct
When activating field weakening, check that the correct commutation angle is set.
Incorrect settings in the function have a negative influence on the performance characteristics of the servomotor and can shorten the service life.

Servomotors can be operated above the nominal speeds by selectively manipulating the magnetic field. The maximum adjustable torque decreases with increasing speed.

When field weakening is used, a functional distinction is made between synchronous motors and asynchronous motors. The aim of the function is to map speeds above the nominal speed.

Please read up on the function and its effects before parameterizing it.

10.1.1 Synchronous motors

In synchronous motors, a magnetic field is established against the permanent magnets in the rotor so that the servomotor induces lower voltage at the same speed. This enables the servomotor to accelerate to higher speeds.

10.1.2 Asynchronous motors

Asynchronous motors require a reduction of the existing positive [d] current to induce lower voltage. The use of field weakening is common with asynchronous motors.

10.2   Requirement

All Beckhoff servomotors are suitable for this function. For advice on third-party motors please contact Beckhoff after-sales service. Observe the maximum permissible mechanical speeds.

10.3   Parameter description

The following information explains which S-parameters and P-parameters are involved in the function. The commissioning scenarios serve as examples. The configuration is always dependent on the application and various environmental and operational conditions.

Parameter	Name	Description
S-0-0196	Motor rated current	Configuration of the nominal motor current
P-0-0093	Configured channel current	Configuration of the channel continuous current
P-0-0445	Basic field weakening parameter	Configuration of the "Basic Mode" of the field weakening
P-0-0446 available from FW v2.13	Basic field weakening limits	Currently valid actual value of the field weakening current and the maximum permissible speed
P-0-0459	Actual torque / force generating current	Actual value of the torque-forming current component
P-0-0460	Actual flux generating current	Actual value of the field-forming current
P-0-0465	Effective q current command value	Setpoint of the torque-forming current component
P-0-0469	Actual absolute voltage	Display of the total voltage provided by the current controller
P-0-0470	Voltage controller command value	Setpoint of the total voltage for the field weakening
P-0-0471	Effective d current command value	Setpoint of the field-forming current

10.3.1   P-0-0445

ℹ **Functional description from firmware v2.12:**

The description of the parameter for field weakening applies to newly configured machines and systems with firmware version v2.12 or higher and the Basic Field Weakening setting.

When updating from older firmware versions to newer firmware versions, the original field weakening configuration is retained.

The original configuration of the field weakening can still be used with the compatibility mode in parameter P-0-0455.

P-0-0445	Basic field weakening parameter			
	Field weakening current ratio	60.00	60.00	%
	Field weakening voltage utilization	80.00	80.00	%
	rsvd	0	0	
	Voltage controller integral action time	5.00	5.00	ms

Current ratio

Synchronous motors

Via this setting in the parameter you configure which current can be impressed for the reduction of the induced voltage.

The total current is limited according to the formula $I_{max} \leq \sqrt{I_d^2 + I_q^2}$.

The field weakening current [I_d] reduces the available torque-forming current [I_q] via the calculation.

ℹ **Example**

If the default value is 60%, 80% of the torque is available for the speed controller.

Usable current flow [q] =. $q = \sqrt{100\,\%^2 - 60\,\%^2} = 80\,\%$

For the percentage specification of the "Current ratio", the smaller value from the nominal motor current S-0-0196 or the channel nominal current P-0-0093 is selected as the reference value.

The resulting maximum field weakening current is displayed in parameter P-0-0446. This value refers to the maximum channel current in P-0-0092.

Asynchronous motors

A flow-forming current [d] is defined for operation. The current ratio indicates to what extent this current may be reduced in order to maintain the voltage limit.

The value in % by which the flux-forming current [d] may be reduced is now entered in the input mask of the current ratio.

Voltage utilization

ℹ **Scope:**

The following settings apply to synchronous motors and asynchronous motors.

Voltage utilization indicates the maximum available voltage in relation to the current DC link voltage. In the input mask you can determine what percentage of the currently available total voltage is utilized at the voltage limit.

The higher the voltage utilization percentage, the higher the torque that can be set at a given speed. The difference to 100% is the control value reserve for the current control loop.

rsvd	Reserved input window. No purpose here.
Integral Action time	The "Integral Action time" is the integral action time of the voltage regulator within the field weakening. The field weakening voltage regulator is superimposed on the current controller. A dynamic range should be maintained when setting the integral action time.

10.3.2   P-0-0455

Mode SM		2: Basic
Mode ASM		0: Disabled
Min mains voltage for field weakening		1: Compatibility
Max mains voltage for field weakening		2: Basic
Max field weakening current		0.000

Mode SM   Selection for synchronous servomotors

Value	Selection	Information
0	Disabled	Field weakening disabled
		Alternative:
		◦ No servomotor connected
1	Compatibility	Firmware version v2.10 or earlier:
		◦ Field weakening enabled
2	Basic	From firmware version v2.12:
		◦ Field weakening enabled
		◦ Activation of an additional voltage regulator

Mode ASM   Selection for asynchronous servomotors

Value	Selection	Information
1	Compatibility	Firmware version v2.10 or earlier:
		◦ Field weakening enabled
2	Basic	From firmware version v2.12:
		◦ Field weakening enabled
		◦ Activation of an additional voltage regulator

10.4 Scope view

All current curves shown refer to the configured peak current in parameter P-0-0092.

Position	Information
1	**Setpoint for the voltage regulator**
	DC [V] x P-0-0445 / √3
	If the voltage requirement of the servomotor is lower than the setpoint, the voltage regulator is inactive. When the setpoint is reached, the field-weakening current is set via the voltage regulator.
2	Effective voltage
3	**DC link voltage**
	Increase during braking due to recuperation:
	Since the setpoint of the voltage regulator is calculated from the instantaneous value of the DC link voltage, the setpoint increases accordingly.
4	**Torque-forming and flux-weakening current**
	If the voltage requirement of the servomotor falls below the setpoint, the voltage regulator becomes inactive again.
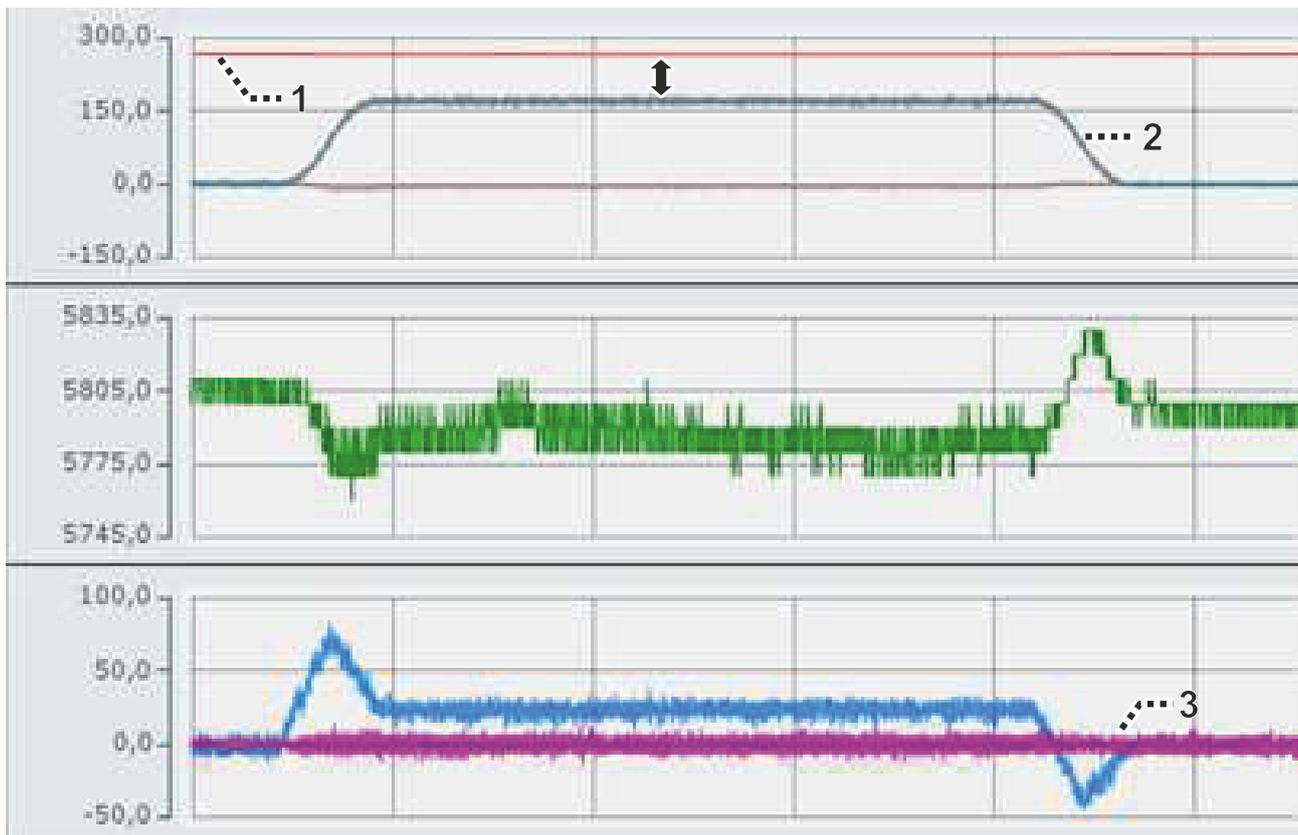
Position	Information
1	Setpoint for the voltage regulator
2	The voltage requirement of the servomotor is lower than the setpoint of the voltage regulator. The voltage regulator remains inactive.
3	No field weakening current is required

BECKHOFF

Position	Information
1	Setpoint for the voltage regulator
2	The voltage requirement of the motor exceeds the setpoint. The voltage regulator intervenes and impresses a flow-weakening current.
	When the maximum flux-weakening current value that was entered is reached, the voltage requirement of the motor rises above this value.
	The voltage regulator is in control value limit mode and cannot prevent the increase
	A higher field-weakening current is required, which can be configured via the current ratio parameter.

11 Gantry Brake

> ℹ **Available from firmware v2.10**
>
> The Gantry Brake function is available from Firmware v2.10.

This documentation applies to the AX5000 servo drive. In the chapters you will find information on how to parameterize a Gantry Brake via the corresponding IDNs.

You can then check the status of the function and interpret error messages. Finally, information is provided about different IDNs that are important for the function.

11.1 Function

NOTICE
Preventing a delay in the Gantry Brake
By configuring the function, you can reduce the delay in case of error.
A delay due to mechanical stress in the Gantry Brake can lead to damage to the axes used.

A Gantry Brake is an axis with two or more rigidly coupled motors. These motors must be moved synchronously with each other. If the drives are not moved synchronously, the mechanics may jam or be damaged. Synchronous movement must be maintained at the best possible level even in the event of a drive error. For this reason, it is important that all drives on the Gantry Brake react to the occurrence of a drive error with almost no time delay. The function described here makes it possible for all drives of the Gantry Brake to react to an error with almost no time delay. The communication time that normally exists from the faulty drive to the NC or CNC and from there to all other drives is eliminated by this function. The function is parameterized via parameter P-0-0340 "Error propagation configuration" and P-0-0341 "Gantry brake configuration".

The figure below shows two AX5yxx servo drives that are wired to each other via the digital inputs and outputs on connection X06.

AX5yxx   **AX5yxx**

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

DigOut 7   DigIn 0

DigIn 0   DigOut 7

Possibilities for error coupling:

- Internal coupling with a delay time of < 100 µs; only possible with two-channel servo drives
- External coupling via jumper on connection X06 of the servo drive. The delay time is < 100 µs.
- External coupling via NC or CNC. The delay time is equal to four EtherCAT cycles.

11.2 Parameter description

In the following you will find information about which P-parameters are involved in the function. The commissioning scenarios serve as examples. The configuration is always dependent on the application and environmental and operational conditions.

Parameter	Name	Description
P-0-0340	Error propagation configuration	Parameterization of which error types are displayed on which communication channel and how to react to received error types
P-0-0341	Gantry brake configuration	Switching the function on and off

11.2.1 P-0-0340

With the help of the parameter "Error propagation configuration", you can set which error types are to be sent to other Gantry axis. If "Yes" is selected for an error type, the occurrence of this error type is reported.

IDN	Name	ActValue	SetValue
⊞ P-0-0322	Device component hardware Ids		
⊞ P-0-0323	Memory usage		
P-0-0324	ProductCode/RevisionNo	AX5106-0000-0210	
P-0-0325	Compile time and date	Jul 20 2016 , 16:25:12	
P-0-0326	Release notes		
⊟ P-0-0340	Error propagation configuration		
⊟	Propagate error types		
	Torque off	1: Yes	1: Yes
	Shorted coils brake	1: Yes	1: Yes
	Open loop ramp	1: Yes	1: Yes
	Closed loop ramp	1: Yes	1: Yes
	Nc handling	1: Yes	1: Yes
	Lost feedback	1: Yes	1: Yes
	Propagate errors	8: to: Digital output 7	8: to: Digital output 7
	React on propagated error	4: with: Closed loop ramp	4: with: Closed loop ramp
	Receive propagated errors	7: from: Digital input 6	7: from: Digital input 6

Propagate errors   The selection of the error transmission is defined by this parameter.

```
8: to: Digital output 7
0: No
8: to: Digital output 7
9: to: Other channel of same device
```
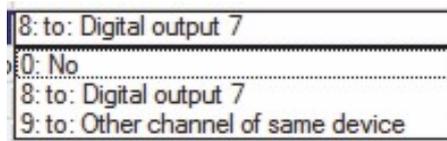
Value	Description
8: to: Digital output 7	Error transmission takes place to another servo drive via a wire connection
9: to: Other channel of same device	Error transmission takes place internally from channel A to channel B, or from channel B to channel A, of the same AX52xx servo drive.

Receive propagated errors   The receiving channel of an error is defined with this parameter. You can choose between the digital inputs 0 to 7.

```
7: from: Digital input 6
0: No
1: from: Digital input 0
2: from: Digital input 1
3: from: Digital input 2
4: from: Digital input 3
5: from: Digital input 4
6: from: Digital input 5
7: from: Digital input 6
8: from: Digital input 7
9: from: Other channel of same device
```
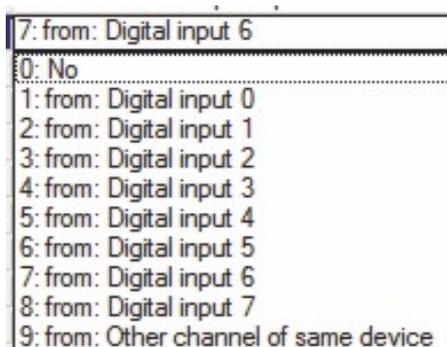
Value	Description
8: from: Digital input 7	Contact can be used as input and as output at the same time; do not select if output is required
9: from: Other channel of same device	Error transmission takes place internally from channel A to channel B, or from channel B to channel A, of the same AX52xx servo drive

11.2.2   P-0-0341

Use the "Gantry brake configuration" parameter to configure the Gantry Brake function in the control loop of the servo drive. Instead of "Emergency stop deceleration" in parameter S-0-0429, for each braking operation the force is limited to the value set in parameter P-0-0341 "Gantry brake configuration".

> **ℹ** **Error state "Torque Off"**
>
> If an axis switches to the error state "Torque Off", the Gantry Brake can only be moved with the error-free axis. Due to the mechanical design, the force usually has to be limited in this case.
>
> Switching off the speed controller I component reduces the tendency of the control to oscillate, leaving a braking force proportional to the speed deviation.

IDN	Name	ActValue	SetValue
P-0-0325	Compile time and date	Jul 20 2016 , 16:25:12	
P-0-0326	Release notes		
⊞ P-0-0340	Error propagation configuration		
⊟ P-0-0341	Gantry brake configuration		
	Use 'Gantry-Brake' instead of the 'closed loop ramp'	0: No	0: No
	Brake torque	20.0	20.0

The Gantry Brake is activated if the device or the channel of an AX52xx receives an error.

Reaction of the servo drive   Reaction to the error < 100 µs:

- Switch to speed control
- Set the speed setpoint to 0 rpm
- Switch off the I-portion of the speed controller
- Limit the torque setpoint to P-0-0341
  For example: 20% of P-0-0094 "Configured channel peak torque / force"

12 Comissioning a Generic Encoder with BISS-C Interface

12.1 Preface

BISS-C is an open standard for communication with a rotary or linear feedback device and is used by various encoder manufacturers.

The AX5000 does support this interface in general. Due to the many possible variations we now offer a generic encoder XML file for rotary encoders and for linear encoders that can be used and adjusted to many different encoders with BISS C interface.

Please use firmware version ≥ 2.06 build 27 or ≥ 2.10 build 14.

The following instructions explain the different settings.

12.2 Encoder-Interface

If the encoder provides a digital (BISS-C) interface AND an analogue Sine/Cosine interface, it must be connected to X11/ X21 of the AX5000.

If the encoder provides digital (BISS-C) signals only, the option card AX572x is required and the encoder must be connected to X41/ X42.

Please note:

- Default clock frequency for the pure digital BISS-C interface is 5MHz. If you want to use a digital encoder that requires lower clock frequencies, there are certain restrictions. Please see below chapter "Restrictions for Clock Frequency" for details.

- X11/ X21 will output more clock edges than necessary to read the position telegram. With some encoders this will cause problems.

12.3   Wiring

Correct wiring, of course, is essential to run any feedback device correctly. Depending on wether or not there are sense lines for the power supply there are 2 or 4 wires for the supply voltage:

Signal	Description
AX5000	Encoder
Us_5V	+5V Power Supply
GND_5V	GND for the +5V Power Supply
Us_5V Sense	+5V Sensor connection (optional)
GND_Sense	0V Sensor connection (optional)

For the position infomation there are the following signals. Incremental Sine/ Cosine signals are not provided by every encoder.

Signal	Description
AX5000	Encoder
DX + (Data)	Data +, (also "SLO +")
DX – (Data)	Data -, (also "SLO -")
CLK + (Clock)	Clock signal, (also "MA +")
CLK – (Clock)	Clock signal, (also "MA -")
SIN +	(optional) Sine +
REFSIN	(optional) Sine -
COS +	(optional) Cosine +
REFCOS	(optional) Cosine -

Please refer to the AX5000 "Startup Manual" or "System Manual" for correct wiring!

12.4   Required Data for Comissioning

Before you start commissioning the encoder, make sure you do have the following information about it:

	Encoder feature	Example
1	What power supply does the encoder need? In case it is 5 V: Does it provide connections for the sense line?	5 V with sense line
2	Maximum current consumption of the encoder? The AX5000 can provide a max. of 250 mA per feedback channel.	150 mA
3	Pure digital interface or sine/ cosine signals provided?	with sine/ cosine signals
4	Maximum clock frequency for the BISS-C communication	10 MHz
5	For a rotary encoder: Number of singleturn bits and number of multiturn bits For a linear encoder: Number of position bits	rotary, 19 bits ST, 12 bits MT
6	For a rotary encoder: Number of sine periods per revolution For a linear encoder: Length of signal period	rotary: 2048
7	For a linear encoder: Resolution of the digital interface	

Screenshots in the following explanation show the configuration for the above example.

BECKHOFF

12.5 Selecting the Feedback

Use the "Select Feedback" button and choose either "Rotational" or "Linear Motorfeedbacks". Choose "BISS_C Generic 5V 1Vpp" if you do have an encoder with Sine/ Cosine signals. Choose "BISS_C Generic 5V" if you want to run an encoder with digital position interface only:
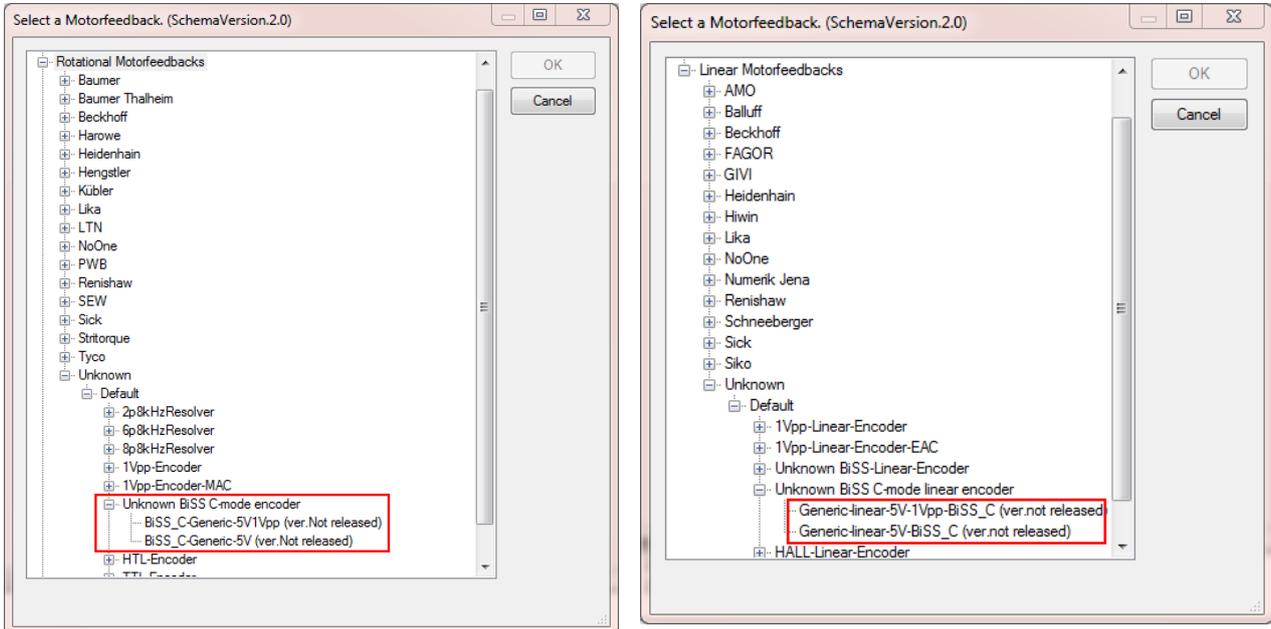
12.6 Adjusting Encoder specific Settings

Parameter P-0-0150 defines the details of the primary feedback ("Feedback 1"). Details of a secondary feedback ("Feedback 2") are defined in P-0-0180. The following description will only mention P-0-0150. P-0-0180 has the same structure and can be adjusted in the same way.

The settings of the feedback parameter must be adjusted to the specific encoder. In the "Motor and Feedback" window click "Feedback 1" to get the detailed parameter view.

Then open the structure of P-0-0150 to see the details and follow below instructions for adjusting.
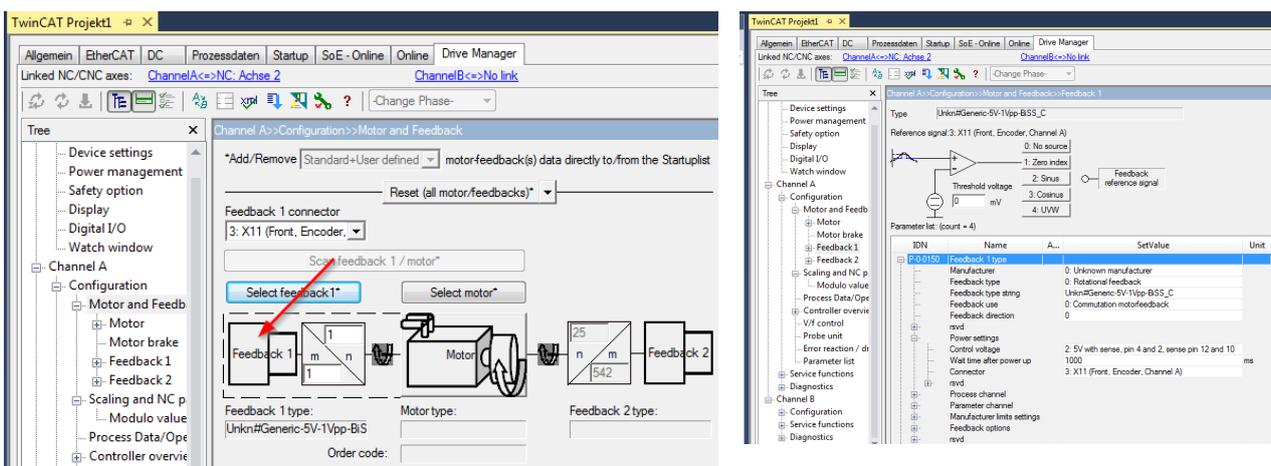
12.7   Definition of Parameter P-0-0150

12.7.1   Feedback Type string

The name of the encoder is not important for operation. It may be changed to remember what encoder you are using:

P-0-0150	Feedback 1 type	
	Manufacturer	0: Unknown manufact...
	Feedback type	0: Rotational feedback
	Feedback type string	MyBiSS_C-Encoder
	Feedback use	0: Commutation motorf...
	Feedback direction	0: Positive direction

12.7.2   Power Settings

Please choose the correct power supply accoding to the datasheet of your encoder. Correct voltage and "sense" setting is essential.

	Power settings	
	Control voltage	2: 5V with sense, pin 4 and 2, sense pin 12 and 10
	Wait time after power up	0: off ms
	Connector	1: 8V/11V, pin 6 and 2
	rsvd	2: 5V with sense, pin 4 and 2, sense pin 12 and 10
	Process channel	3: 5V without sense, pin 4 and 2

"Wait time after power up" is a delay after switching the power supply on, before the AX5000 starts communicating with the encoder. If you do not know the correct value, keep the default.

The "Connector" should be correct if the correct encoder has been chosen. If not, please correct!

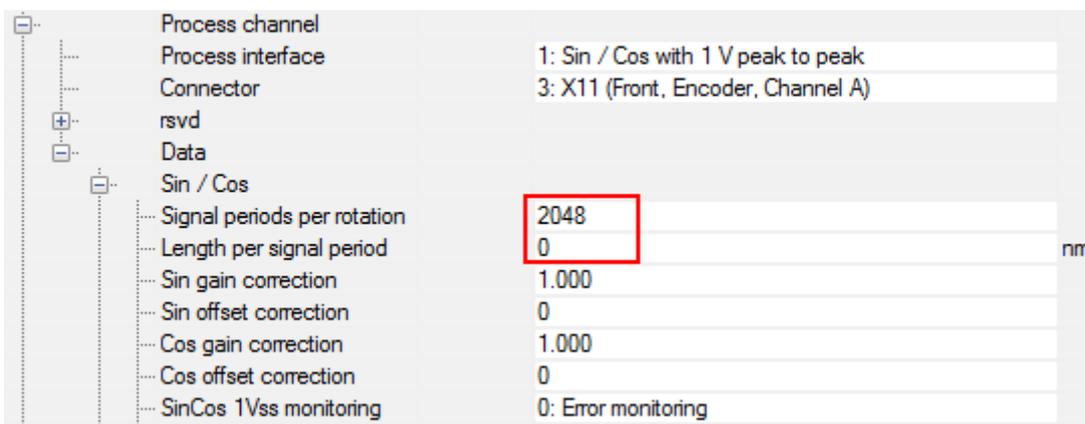|	Power settings	
	Control voltage	2: 5V with sense, pin 4 and 2, sense pin 12 and 10
	Wait time after power up	1000 ms
	Connector	3: X11 (Front, Encoder, Channel A)
	rsvd	

12.7.3   Process Channel

"Process interface" is "1: Sin / Cos with 1 V peak to peak" in case the encoder provides those signals. In case of pure digital communication it is " 5: Digital interface".

Doublecheck the connector setting.

In case of a rotary encoder with digital interface only you are done with the process channel.

Process channel	
Process interface	1: Sin / Cos with 1 V peak to peak
Connector	3: X11 (Front, Encoder, Channel A)
rsvd	
Data	
Sin / Cos	
TTL	

In case of an encoder with sin / cos signals or a linear encoder please proceed to "Data/ Sin / Cos":

Process channel	
Process interface	1: Sin / Cos with 1 V peak to peak
Connector	3: X11 (Front, Encoder, Channel A)
rsvd	
Data	
Sin / Cos	
Signal periods per rotation	2048
Length per signal period	0 nm
Sin gain correction	1.000
Sin offset correction	0
Cos gain correction	1.000
Cos offset correction	0
SinCos 1Vss monitoring	0: Error monitoring

For a **rotary encoder** with sin/ cos signals please set the correct number of "Signal periods per rotation".

For a **linear encoder** please set the "Length per signal period" in nm. This is required also in case there are no sin/ cos signals. Together with the "Signal periods per rotation" this value defines one rotation. If you run a linear motor with a linear encoder you should set these values to get

Pole pitch = Length per signal period x Signal periods per rotation

Example:

Linear motor pole pitch = 24 mm

Length per signal period = 20000 nm (20 µm)

- → Signal periods per rotation = 24 mm / 20000 nm = 1200

12.7.4 Parameter Channel

Parameter channel	
Parameter interface	6: BiSS C-Mode unidirectial
Connector	3: X11 (Front, Encoder, Channel A)
Identifier	0
Bit resolution singleturn position	19
Bit resolution multiturn position	12
Number of clockcycles to get singleturn position or...	19
Number of clockcycles to get multiturn position	12
Digital name plate	0: No digital name plate
Commutation mode	2: Commutation offset 0 deg
Adjustable commutation offset (mechanical)	0.0
Linear resolution about digital interface	0

Parameter	Explanation
Parameter interface	6: BISS C-Mode unidirectional (Do not change!)
Connector	Doublecheck where you connected the encoder.
Identifier	Not used, keep 0.
Bit resolution singleturn position	**For a rotary encoder:** Get number of singleturn bits from encoder datasheet. **For a linear encoder:** Number of position bits.
Bit resolution multiturn position	**For rotary encoder:** Get number of multiturn bits from encoder datasheet. **For a linear encoder:** 16
Number of clockcycles to get singleturn position or absolute position	**For a rotary encoder:** Get from encoder datasheet (usually same value as "Bit resolution singleturn position"). **For a linear encoder:** 0
Digital nameplate	Keep "0: No digital namplate".
Commutation mode	Will be set later, when you do the motor commissioning
Adjustable commutation offset	Keep 0.0
Linear resolution about digital interface [nm]	For rotary encoder: Keep 0 For linear encoder: Get the number from the encoder datasheet (in nanometer).

12.7.5   Parameter Channel / Data / BISS

Most encoders will run with the preset default values.

Do not change any settings unless you are sure that your specific encoder requires that!

Some explanations (referring to the numbers in the picture):

1. The settings are the same for most common encoders and will be preset.
2. Mcd (multi cycle data) is not used here. Keep values 0.
3. Use "Min. clock speed" and "Max. clock speed "from encoder datasheet if available. If you need to change this, see below chapter "Restrictions for Clock Frequency".
4. Register mode is not used. Keep settings as preset.
5. Keep values 0 (except in some cases for "Pretrigger time encoder to sync" as described below).

12.8 Restrictions for Clock Frequency

Firmware ≥ v2.10 build 0015 allows setting different frequency values.

> **ℹ** **Possible values of the clock frequency to be set: 2000, 2500, 3333, 5000 [kHz].**
>
> **The clock frequency can be changed in the parameter P-0-0150 under:**
>
> Parameter channel → Data → BISS → Sensor mode: Max. clock speed

If other values are set, the software will use the next possible lower value. Lower clock frequency causes longer data transmission time.

Communication signals between AX5000 and encoder look like this:
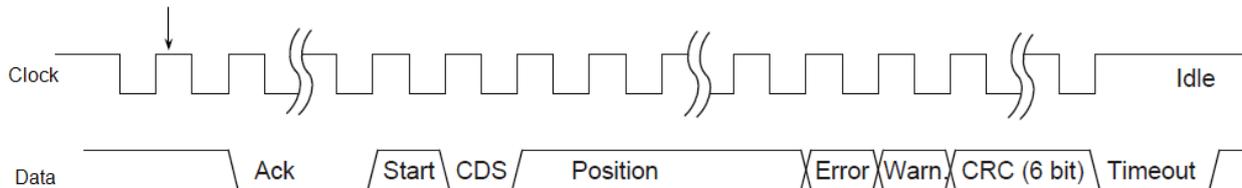
During the "Ack" period the encoder prepares for transferring the actual position value. With the rising edge at "Start" it signals to be ready and then starts transferring data.

Due to its internal cycles the AX5000 needs the position at certain point of time after it has started reading. This means the time from the first rising edge of the clock signal to the last CRC bit must not exceed 18µs.

Example:

Clock frequency: 3.333 MHz => Bit time = 1/ 3.333MHz = 0.3 µs

Number of bits to be transferred for a position telegram:

Example 1	Example 2	
4 µs	8 µs	Preparing time of encoder ("Ack")
Number of bits		
1	1	Start
1	1	CDS (Cyclic data slave, not used, always 0)
26	32	Position
1	1	Error (status)
1	1	Warning (status)
6	6	CRC
1	1	Stop/ Timeout
37	43	Number of clock cycles for complete telegram

Example 1	Example 2
Transmission time = 4 µs + 37 x 0.3 µs = 15.1 µs < 18 µs	Transmission time = 8 µs + 43 x 0.3 µs = 20.9 µs > 18 µs
◦ The encoder in this example can be run at 3.333 MHz clock frequency.	◦ For this case it is possible to set a value for "Pretrigger time encoder to sync" to start reading of the encoder earlier in the cycle: 20.9 µs - 18 µs = 2.9 µs ◦ Set "Pretrigger time encoder to sync" = 4µs (1µs margin).

ℹ The value for the pretrigger must not exceed 15 µs!

12.9 Troubleshooting

Most errors in this context are caused by wrong wiring. Please double check that if you get any feedback errors! To find out more details you may try one or more of the following steps.

12.9.1 Try analog signals only

If you do have an encoder with BISS C interface and analogue signals you may choose a setup without using the digital interface. Choose "Unknown/ 1Vpp..." with the correct sense settings and resolution.
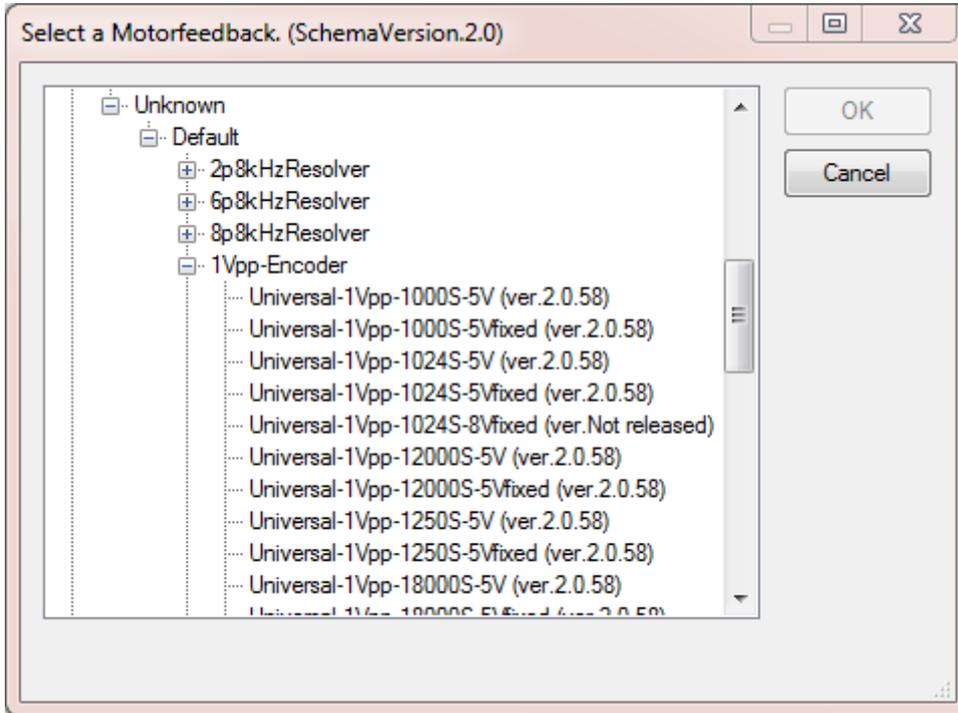
If you get errors related to the sense line (e.g. F705, F707, F879,...), please double check the wiring of the sense lines or choose a setting without sense line ("5Vfixed"). If you do not get erros related to the power supply but to the signal amplitude, check wiring of the sine/ cosine signals. If possible you may use a hardware oscilloscope to look at the signals.

> **ℹ** **If the AX5000 senses a feedback error it switches the encoder power supply off!**

When you get correct 1Vpp signals, i.e. no error related to that, you may double check the resolution: Does the position count one revolution when you turn the encoder one rev.? Dou you see the correct distance when you move the linear encoder?

12.9.2 Change BISS settings

If the analogue signals do not cause an error or there are no analogue signals, but you get feedback errors related to the digital signals (e.g. F717, F718, F72x,...) please doublecheck the wiring and the number of position bits.

If you are not sure about that number you may try changing values for "Bit resolution singleturn position" and "Number of clockcycles to get singleturn position".

13 Internal velocity filters

⚠ WARNING
Warning, risk of injury from uncontrolled movements!
When working with the described filters there is always a danger of the motor performing uncontrolled movements due to impermissible parameterization. Make sure that your application allows these movements and secure the entire danger zone against inadvertent entry; ensure that no persons are in the danger zone.

ℹ **Application of the Velocity Observer!**

Above a frequency of 300 Hz noise can become problematic. First and second-order filters are often ineffective in this case. The Velocity Observer of the AX5000 servo drive provides the velocity controller with a speed signal available without resonance-induced oscillations over the widest possible frequency range. It is available in FW v2.06 in Basic mode (third order) and in FW v2.10 in Advanced mode (fifth order).
Further information can be found in chapter: „Velocity Observer" of this function manual.

The control quality describes the capacity of the drive system to follow the setpoint values highly dynamically, with low losses and fail-safe. The control quality depends on many factors. On the mechanical side these could be soft drive trains with belt drive, or resonance points caused by the natural ageing of components or special features of the mechanical structure. Without the use of filters the only possibility is to reduce the loop gain and to adapt it to the worst condition. However, this adaptation affects the total application and lowers the dynamics of the drive system. The application and the parameterization of the internal speed and current filters act, for example, specifically on a resonant frequency, hence allowing a high loop gain and thus a highly dynamic drive system. The filters described here serve to eliminate or attenuate unwanted noise or resonant frequencies. The main control loops of a servo drive are the position controller, the velocity controller and the current controller. With the exception of the position controller, software filters can be inserted before the controllers. The characteristic of these special software filters is realized by means of a 1st and 2nd order IIR filter with time-discrete transfer function.

13.1 Basic principles

The drive system receives the input parameter "Speed n = 40 rpm" from the PLC. If the drive system is operating under optimum conditions, the motor achieves this speed with very good control quality. The different characteristics of the drive system also cause sources of resonance among other things, which are always disturbing. They often manifest themselves in oscillating shafts or hum frequencies. Overlaid signal oscillations of the encoder systems can similarly create high frequency noise, thus reducing the control quality.

The following test provides information about possibly existing interference frequencies: Drive through the necessary operating speed range and make a scope recording of the actual active current (IDN S-0-0084). On the basis of the curve of the graph you can judge whether or not there are points of interference.

Drive system

Input parameter → Servo drive Mechanic Motor → Output parameter
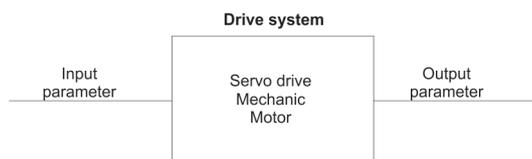
13.2 1st and 2nd order IIR filter – Infinite Impulse Response Filter

A general digital filter with time-discrete transfer function has been implemented for the current command value filter.

The following filters can be selected in the TCDriveManager:

- Notch filter
- Phase correction filter 1st order (PD T1 or lead lag)
- Low-pass filter 1st order (PT1)
- Phase correction filter 2nd order (Bi Quad)
- Low-pass filter 2nd order (PT2)
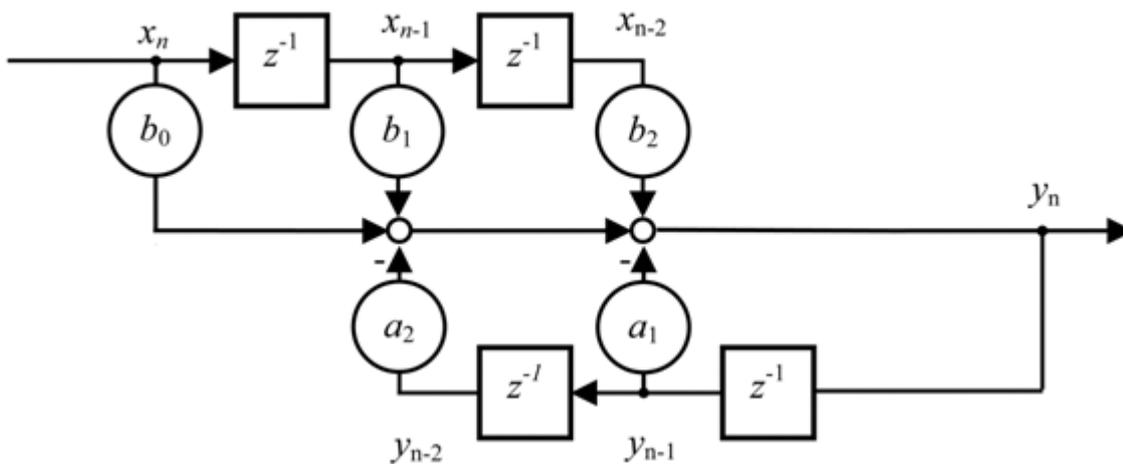
The coefficients b_0, b_1, b_2, and a_1, a_2 determine the characteristic of all the filters described and can also be directly specified.

13.3 Notch filter (band-stop filter)
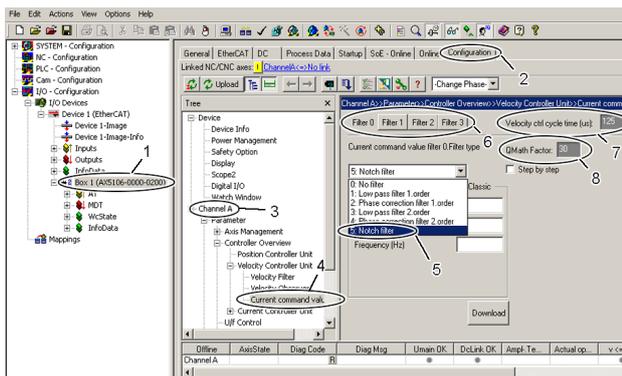
The notch filter is designed as a narrow-band filter for the attenuation of resonance frequencies. Select a servo drive (1) in the TwinCAT System Manager, start the TCDriveManager (2), click on the respective axis (3) and select the "Current command value filter" (4).

A maximum of four filters are evaluated, which can be parameterised independently of one another. In area (6), activate the filter that you would like to occupy with the notch filter. The cycle time of the velocity controller is indicated in field (7). The "QMath Factor" (8) determines the scaling of the filter input parameter. With the current filter implementation the maximum possible resolution is achieved with the default value "30".

Now select "Notch filter" (5) from the drop-down menu.

BECKHOFF

13.3.1   Parameterisation of the filter

⚠ WARNING
Warning, risk of injury from uncontrolled movements!
Impermissible attenuation values lead to a strong phase shift, which can result in uncontrolled acceleration of the motor and other instable states.

There are two different methods of parameterising the filter.

"Classic" method
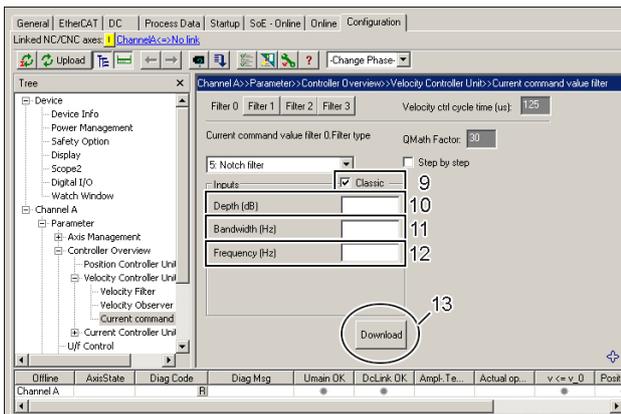
This variant is activated by checking the "Classic" checkbox (9).

The parameters "Depth" (10), "Bandwidth" (11) and "Frequency" (12) must now be determined and entered; see the diagram "Bode Plot" below for this. The parameters entered lead internally to the calculation of the coefficients b_0, b_1, b_2, and a_1, a_2 (see the above diagram "1st and 2nd order IIR filter" for this).

Click on the "Download" button (13) to conclude the parameterisation. If you are online these parameters are loaded directly into the AX5000 and activated. If you are offline they are only written into the start-up list.

"Classic" method – step by step
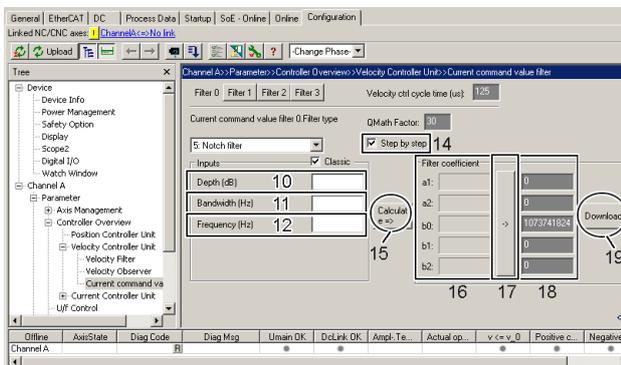
The "Step by step" extension enables you to calculate and enter the coefficients b_0, b_1, b_2, and a_1, a_2 yourself (see the above diagram "1st and 2nd order IIR filter"). Among other things you can now compare the values calculated by the software with your own values and see how changing the parameters affects the coefficients.

The "Step by step" extension is activated by checking the "Step by step" checkbox (14). You can now enter the parameters (10) to (12) as described in the previous section, after which you click on the button (15). Subsequently, you can read off the calculated coefficients in area (16). If you wish to accept these coefficients, click on the button (17); they are now entered automatically into area (18).

Alternatively you can also determine the coefficients yourself and enter them in area (18).

If you finally click on the "Download" button (19), the values are always taken from area (18). If you are online these parameters are loaded directly into the AX5000 and activated. If you are offline they are only written into the start-up list. The calculated values from area (16) and the parameters (10) to (12) remain visible for information purposes.

"Low-pass and high-pass filter" method
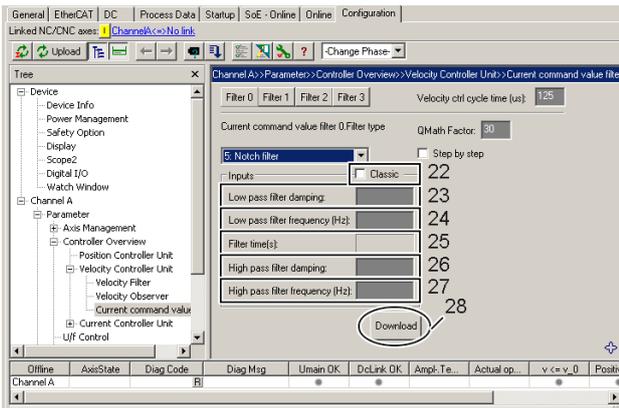
This variant is activated by unchecking the "Classic" checkbox (22).

You must now determine and enter the parameters "Low pass filter damping" (23), "Low pass filter frequency" (24), "High pass filter damping" (26) and "High pass filter frequency" (27); the "Filter time" (25) is calculated by the software in relation to the "Low pass filter frequency" (24). If you wish to emulate the classic method, you must enter the centre frequency plus half the bandwidth in field (24) and the centre frequency minus half the bandwidth in field (27). The depth (10) is determined with the damping (23) or (26); see the diagram "Bode Plot" below for this. The parameters entered lead internally to the calculation of the coefficients b_0, b_1, b_2, and a_1, a_2 (see the above diagram "1st and 2nd order IIR filter" for this).

Using the methods described you can also map any unbalances of the notch filter, among other things.

Click on the "Download" button (28) to conclude the parameterisation. If you are online these parameters are loaded directly into the AX5000 and activated. If you are offline they are only written into the start-up list.

"Low-pass and high-pass filter" method – step by step

● **Expert hint!**

The software calculates the coefficients independently using the parameters entered. If you have sufficient experience in control technology you can also determine the coefficients yourself and thus affect the behaviour of the filter.

The method is the same as in the "Classic method" – step by step.

Bode Plot
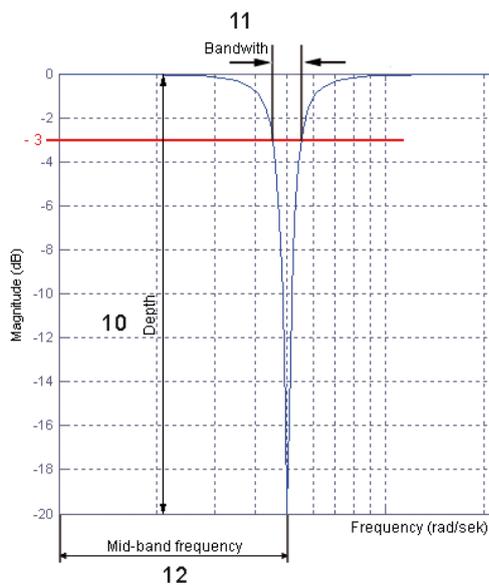
13.4   1st order low pass filter
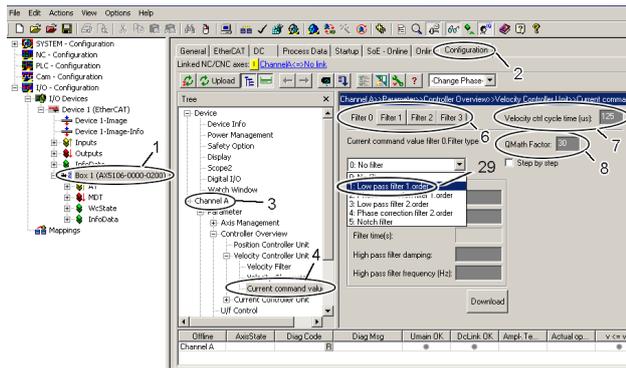
The 1st order low pass filter attenuates all frequencies above the specified limit frequency. Select a servo drive (1) in the TwinCAT System Manager, start the TCDriveManager (2), click on the respective axis (3) and select the "Current command value filter" (4).

A maximum of four filters are evaluated, which can be parameterised independently of one another. In area (6), activate the filter that you would like to occupy with the low pass filter. The cycle time of the velocity controller is indicated in field (7). The "QMath Factor" (8) determines the scaling of the filter input parameter. With the current filter implementation the maximum possible resolution is achieved with the default value "30".

Now select "Low pass filter 1. order" (29) from the drop down menu.

13.4.1   Parameterisation of the filter

⚠ WARNING
Warning, risk of injury from uncontrolled movements!
Impermissible damping values lead to a strong phase shift, which can result in uncontrolled acceleration of the motor and other instable states.

This filter is parameterised with the parameter "Limit frequency" (30). The time constant (31) is calculated from the limit frequency according to the following equation
"Time constant [s] = 1 / (2*Pi*Limit frequency [Hz])".

Determination of the limit frequency
The following test provides information about possibly existing interference frequencies: Drive through the necessary operating speed range and make a scope recording of the actual active current (IDN S-0-0084). A frequency analysis shows possibly existing resonance points.

i   **Phase shift**

With this filter you have no influence on the damping and any resulting phase shift. If you are not sure whether a phase shift is permissible, please use the "Phase correction filter 1. order"
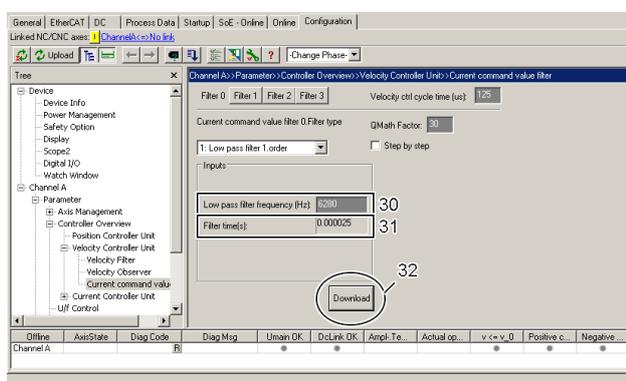
Click on the "Download" button (32) to conclude the parameterisation. If you are online these parameters are loaded directly into the AX5000 and activated. If you are offline they are only written into the start-up list.

Example:
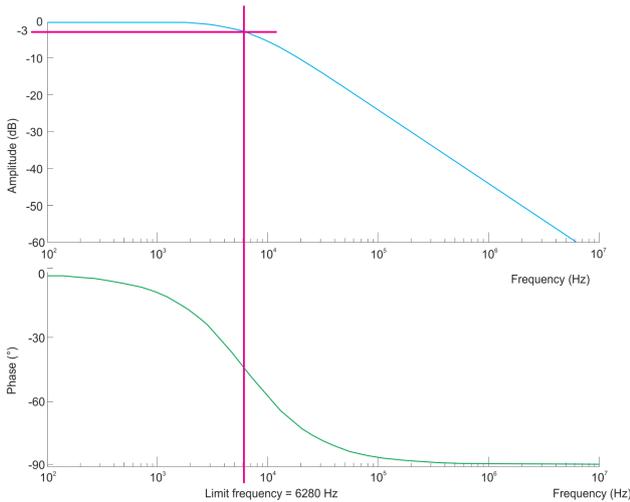
With this example the frequency response of the PT1 filters has been illustrated for clarity. The Bode plot (logarithmic frequency curve) shows the amplitude over frequency in the upper area and the associated phase shift over frequency in the lower area. Seen together, it is recognisable that a phase shift results from the damping of the amplitude.

Parameter inputs in the TCDriveManager:

Limit frequency = 6280 Hz
(Time constant = 0.025343)

**"1st order low pass filter" – method – "step by step"**

Expert hint!

The software calculates the coefficients independently using the parameters entered. If you have sufficient experience in control technology you can also determine the coefficients yourself and thus affect the behaviour of the filter.

The method is the same as in the "Notch filter classic method" – "step by step".

13.5 1st order phase correction filter
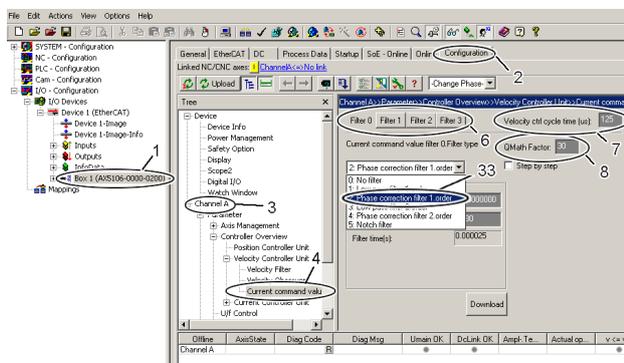
The 1st order phase correction filter attenuates all frequencies above the limit frequency entered. Select a servo drive (1) in the TwinCAT System Manager, start the TCDriveManager (2), click on the respective axis (3) and select the "Current command value filter" (4).

A maximum of four filters are evaluated, which can be parameterised independently of one another. In area (6), activate the filter that you would like to occupy with the phase correction filter. The cycle time of the velocity controller is indicated in field (7). The "QMath Factor" (8) determines the scaling of the filter input parameter. With the current filter implementation the maximum possible resolution is achieved with the default value "30".

Now select "Phase correction filter 1. order" (33) from the drop down menu.

13.5.1 Parameterisation of the filter

| ⚠ WARNING |
|---|
| **Warning, risk of injury from uncontrolled movements!** |
| Impermissible damping values lead to a strong phase shift, which can result in uncontrolled acceleration of the motor and other instable states. |
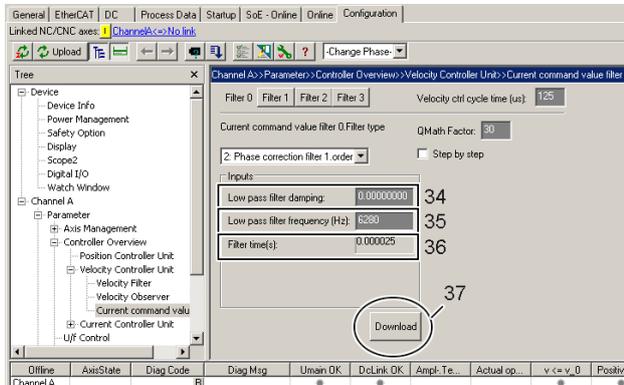
This filter is parameterised with the parameters "Limit frequency" (35) and "Damping" (34). The time constant (36) is calculated from the limit frequency according to the following equation --> "Time constant [s] = 1/ (2*Pi*Limit frequency [Hz])".

Determination of the limit frequency
The following test provides information about possibly existing interference frequencies: Drive through the necessary operating speed range and make a scope recording of the actual active current (IDN S-0-0084). A frequency analysis shows possibly existing resonance points.

Click on the "Download" button (37) to conclude the parameterisation. If you are online these parameters are loaded directly into the AX5000 and activated. If you are offline they are only written into the start-up list.

The limitation of the damping of the amplitude ensures that the phase shift returns to zero. The limited damping is adequate for most drive applications.

Example:
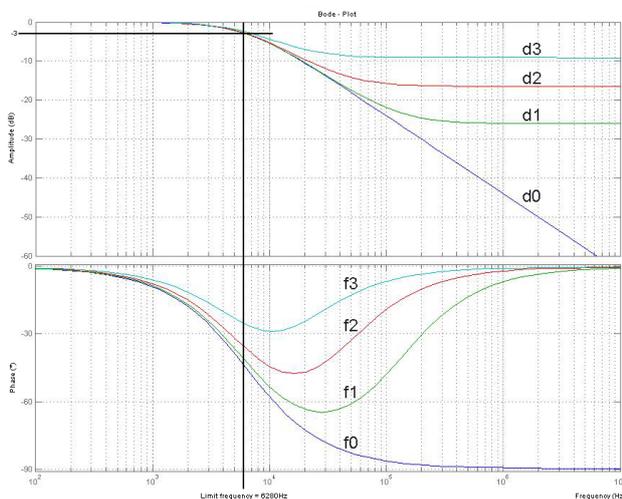
With this example the frequency response of the PT1 filters has been illustrated for clarity. The Bode plot (logarithmic frequency curve) shows the amplitude over frequency in the upper area and the associated phase shift over frequency in the lower area. Seen together, it is recognisable that a phase shift results from the damping of the amplitude.

Parameter inputs in the TCDriveManager:

Time constant = 0.000025 s
(Limit frequency = 6280 Hz)
Damping:
d0 = 0
d1 = 0.05
d3 = 0.15
d4 = 0.35

**"Phase correction filter 1. order" – method – "step by step"**

ℹ **Expert hint!**

The software calculates the coefficients independently using the parameters entered. If you have sufficient experience in control technology you can also determine the coefficients yourself and thus affect the behaviour of the filter.

The method is the same as in the "Notch filter classic method" – "step by step".

14 I*t calculation in the AX5000 servo drive

i ● **Reference variables for the I*t calculation:**

P-0-0052; P-0-0090; P-0-0091; P-0-0092; P-0-0093

The I*t calculation serves as a protective function for the output stage of the AX5000 servo drive. The max. permissible overcurrent time area (I*t$_{max}$) depends on the size of the devices. The servo drive can supply the peak current for the time t$_{max}$. The value is then limited to the nominal current on expiry of t$_{max}$.

In earlier firmware revisions the max. permissible overcurrent time area could not be used fully. From firmware v2.06 (build 18) the complete overcurrent time area of the servo drive is now available.

The overcurrent time area of the servo drive depends on the peak and nominal current of the different device sizes:

$$I \cdot t_{max} = (peak\ current - rated\ current) \cdot t_{max}$$

If the demanded overcurrent is smaller than the peak current, it can be supplied for a longer time. The possible time t$_{Appl}$ can be calculated as follows:

$$t_{Appl} = \frac{(peak\ current - rated\ current) \cdot t_{max}}{applications\ current - rated\ current}$$

The calculation is influenced by the following parameters:

Number	Name	Note
P-0-0052	Time limitation for peak current	= 0 for max. utilization of the I*t area
P-0-0090	Channel peak current	Dependent on the size
P-0-0091	Channel rated current	Dependent on the size
P-0-0092	Configured channel peak current	Dependent on the application
P-0-0093	Configured channel rated current	Dependent on the application
S-0-0112	Amplifier rated current	Dependent on the size
t$_{max}$	Max. time for I$_{peak}$	device-related 3 s[1] or 7 s[2]

[1]: 3 s for servo drives > AX5140 (see electrical data in the AX5000 system manual)

[2]: 7 s for servo drives from the AX52xx and AX5101 – AX5140 series.

On changing status from Pre-Op to Op, the firmware in the AX5000 checks whether the value set in parameter P-0-0052 is permissible. A parameter error appears if the value is impermissible.

With the inserted parameters, the equation mentioned above looks like this:

$$t_{Appl} = \frac{(P\text{–}0\text{–}0090 - P\text{–}0\text{–}0091) \cdot t_{max}}{I_{Appl} - P\text{–}0\text{–}0091}$$

The current is limited to the value of P-0-0091 on expiry of the time t$_{Appl}$.

Meaning of the parameter P-0-0052:

P-0-0052 should generally be set to 0 so that the AX5000 supplies the overcurrent for the maximum possible time.

For reasons of compatibility, the default value is not zero, but 3000 ms. Two cases must be distinguished when setting P-0-0052:

1) P-0-0052 = 0

$$t_{Appl} = \frac{(P{-}0{-}0090 - P{-}0{-}0091) \cdot t_{max}}{I_{Appl} - P{-}0{-}0091}$$

The current I_{Appl} is always supplied for the max. possible time (max. 1000 s).

2) 0 < P-0-0052 ≤ P-0-0052$_{max}$ (compatibility mode)

$$t_{Appl} = \frac{(P{-}0{-}0092 - P{-}0{-}0093) \cdot P{-}0{-}0052}{I_{Appl} - P{-}0{-}0093}$$

A current in the magnitude of the parameter P-0-0092 is limited after the set time (P-0-0052 = 1 ms…65535 ms) to the value of the parameter P-0-0093. With I_{Appl} < P-0-0092, t_{Appl} is > P-0-0052.

14.1 Special features in the case of an AX520x two-channel device

In the case of the AX520x, the parameter S-0-0112 indicates the sum of the nominal currents for both channels. The value is device-related.

It is possible to enlarge the value of the nominal current (P-0-0093) for one channel to more than half of the value of the sum. As a result, this channel receives a larger portion of the overcurrent time area. The remainder of the nominal sum current is available to the second channel.

In the above calculation, P-0-0091 is replaced by the configured channel nominal current P-0-0093 or half of the nominal sum current:

Where I_{conf} = maximum from P-0-0093 and S-0-0112 / 2:

$$t_{Appl} = \frac{(P{-}0{-}0090 - I_{conf}) \cdot t_{max}}{I_{Appl} - I_{conf}}$$

Example: AX5203

How long can a current of 7 A be supplied with the settings for channel A selected here?

Number	Name	Value channel A	Value channel B
P-0-0052	Time limitation for peak current	0 A	0 A
P-0-0090	Channel peak current	10 A	10 A
P-0-0091	Channel rated current	6 A	6 A
P-0-0092	Configured channel peak current	7 A	7 A
P-0-0093	Configured channel current	3.5 A	2 A
P-0-0112	Amplifier rated current	6 A	6 A
t_{max}	Max. time for I_{peak}	7 s	7 s

I_{conf} = max (3.5 A; 6 A / 2) = 3.5 A

$$t_{Appl} = \frac{(10\,A - 3{,}5\,A) \cdot 7\,s}{7\,A - 3{,}5\,A} = 13\,s$$

After 13 s the current of 7 A is limited to 3.5 A (P-0-0093).

For channel B, the following applies: I_{conf} = S-0-0112 – P-0-0093 (Ch A)

In the example. I_{conf} = 6 A – 3.5 A = 2.5 A

$$t_{Appl} = \frac{(10\,A - 2,5\,A) \cdot 7\,s}{7\,A - 2,5\,A} = 11.66\,s$$

After 11.66 s the current of 7 A is limited to 2 A (P-0-0093).

14.1.1   Taking AX5206 as an example

The rated current for channel A is increased to 6.6 A and the peak current set to 11 A.

Reference values for the example calculation (channel A):

IDN	Description	Value
S-0-0112	Amplifier rated current	12.0 A (fixed)
P-0-0052	Time limitation for peak current	0
P-0-0090	Channel peak current	13.0 A (fixed)
P-0-0091	Channel rated current	6.0 A (fixed)
P-0-0092 (channel A)	Configured channel peak current	11.0 A
P-0-0093 (channel A)	Configured channel current	6.6 A (> P-0-0091, therefore select this value)
t_{max}	Max. time for I_{peak}	7.0 s (fixed)

Calculation for channel A

Total overcurrent time area of the device:

$$I \cdot t_{max} = (P\text{-}0\text{-}0090 - P\text{-}0\text{-}0093) \cdot 7s = (13A - 6{,}6A) \cdot 7s = 44{,}8s$$

Maximum possible time ($P\text{-}0\text{-}0052_{max}$):

$$P\text{-}0\text{-}0052_{max} = \frac{I \cdot t_{max}}{P\text{-}0\text{-}0092 - P\text{-}0\text{-}0093} = \frac{44{,}8s}{11A - 6{,}6A} = 10{,}18s$$

The set maximum current of 11 A can be provided for 10.18 sec.
After that the current is limited to P-0-0093 (6.6 A).
The maximum settable time in P-0-0052 is thus 10.18 s.

Calculation for channel B

There is a limitation in P-0-0093 for channel B in this example:

P-0-0093$_{max}$ = S-0-0112 – P-0-0093 (Ch. A) = 5.4 A

Reference values for the example calculation (channel B):

IDN	Description	Value
P-0-0052	Time limitation for peak current	0
P-0-0092	Configured channel peak current	11 A
P-0-0093$_{max}$	Configured channel current	5.4 A

Maximum possible time ($P\text{-}0\text{-}0052_{max}$):

$$P\text{-}0\text{-}0052_{max} = \frac{(P\text{-}0\text{-}0090 - P\text{-}0\text{-}0093_{max}) \cdot 7s}{P\text{-}0\text{-}0092 - P\text{-}0\text{-}0093_{max}} = \frac{(13A - 5{,}4A) \cdot 7s}{11A - 5{,}4A} = 9{,}50s$$

The set maximum current of 11 A can be provided for 9.50 sec.
After that the current is limited to P-0-0093 (5.4 A).
The maximum settable time in P-0-0052 is thus 9.50 s.

● **Although a smaller value is set for P-0-0093, P-0-0093$_{max}$ is used in the calculation.**

ⓘ

15 Configuration and control of the motor brake

> **i** ● **Reference values of the motor brake:**
>
> S-0-0134; S-0-0163; S-0-0206; S-0-0207; S-0-0273; P-0-0059; P-0-0060; P-0-0072; P-0-0096; P-0-0097

If your servomotor is equipped with a motor brake, it is controlled via the AX5000 servo drive. For Beckhoff servomotors of the AM8000 series, the data for the motor brake are taken from the electronic type plate (or offline from the motor data files *.xeds). The motor data generator can be used to create motor data files for third-party motors. In situations with special application requirements, the motor brake can be opened and closed using the „*MotorCtrlWord*" or via the TC3 Drive Manager for testing purposes.
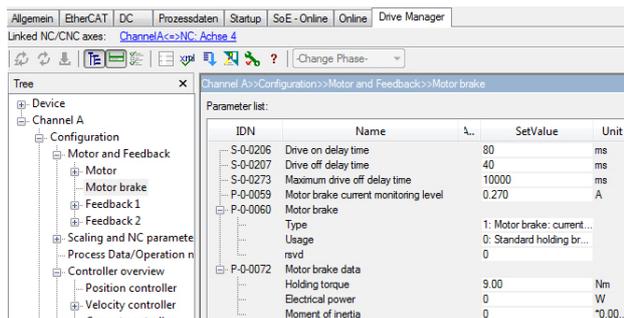
In the TC3 Drive Manager the IDNs for the motor brake are consolidated in a group under „*Configuration → Motor and Feedback → Motor brake*".

The selection options for IDN P-0-0060 (*motor brake*) are described in chapter Configuration [▶ 77]. Further information on the parameters S-0-0206 and S-0-0207, and on manual control of the motor brake can be found in chapter Control [▶ 79].

The holding torque of the motor brake is mapped in parameter P-0-0072 (*motor brake data*). The *moment of inertia* is added to that of the servomotor.

15.1 Configuration

Configuration of the motor brake in the TC3 Drive Manager takes place via parameter P-0-0060. The setting options of this IDN are described below.

Type
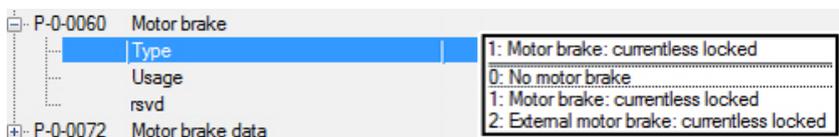
Default value: 0 No motor brake

Here you can choose between the following settings:

- **0: No motor brake**
  The servomotor has no holding brake.

- **1: Motor brake: currentless locked**
  The servomotor has a holding brake. If no current flows through the holding brake, the brake is closed and the rotor is prevented from moving.

- **2: External motor brake: currentless locked** (from firmware v2.10)
  A servomotor with electronic type plate is used without motor brake. The AX5000 is intended to control an external motor brake via the brake output.
  For this combination the setting „*2: External motor brake: currentless locked*" must be selected, otherwise a parameter error (F4A5) is issued.
  This error message describes a software conflict between the setting in P-0-0060 and the entry in the electronic type plate of the servomotor.

Usage

Default value: 0 Standard holding brake

Here you can choose between the following settings:

- **0: Standard holding brake**
  The default settings of the holding brake are used, based on which the holding brake only engages at standstill.

- **1: Holding brake: Emergency brake**
  When an error message occurs at the AX5000 servo drive, the holding brake engages (independent of standstill monitoring S-0-0124). Therefore the holding brake also acts on rotating axes. This can lead to increased wear and premature failure!

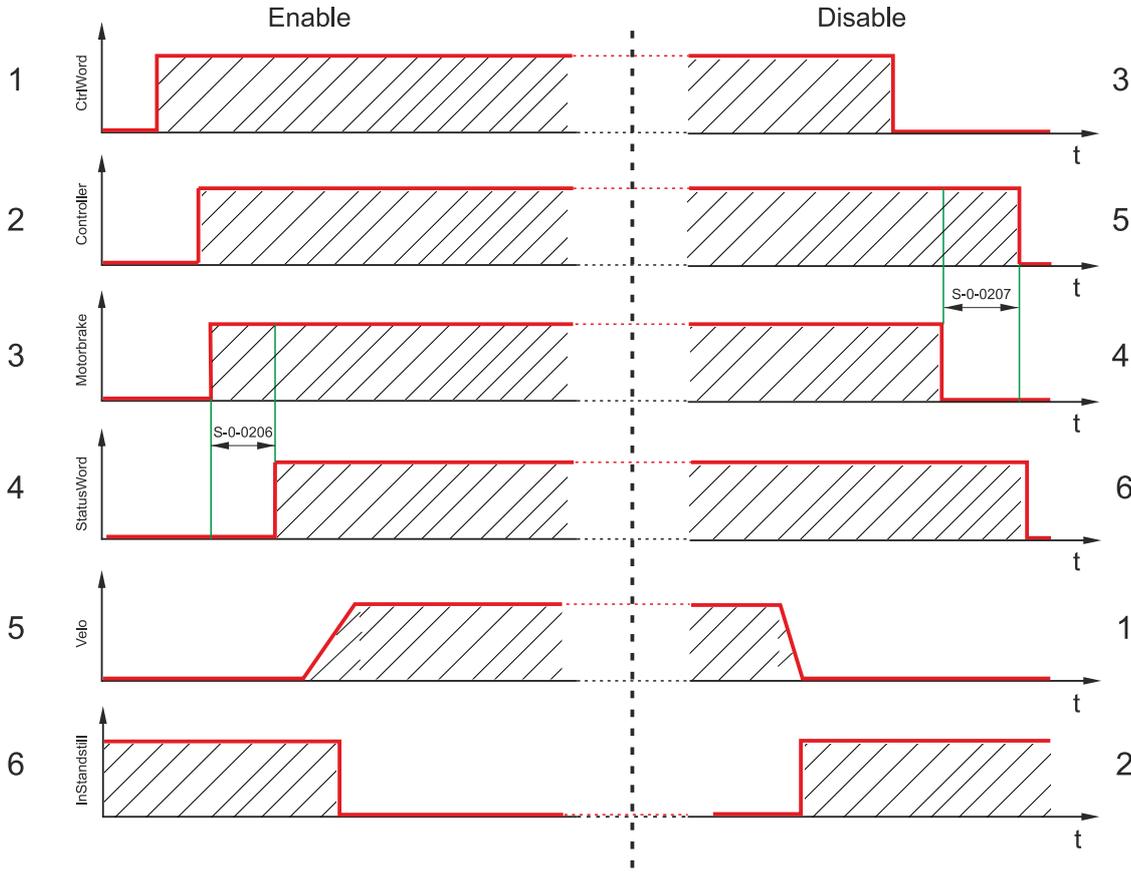| ⚠ CAUTION |
|---|
| **Risk of injury through falling or moving axes!** |
| As a rule, holding brakes in Beckhoff servomotors are **not** designed for service braking of the axes! |
| **Service braking causes increased wear of the holding brake!** |
| The service life would be reduced significantly. Increased wear leads to premature failure of the components. |
| High risk of injury through axes that failed to stop! Particularly applications with vertical axes can have a high risk potential. |
| Check the different machine states and the brake control in different scenarios. If necessary, install an additional (safe) service brake. |

15.2 Control

The motor brake is generally controlled automatically via the AX5000 servo drive. For manual control, select the service function „*Manual brake control*" in the TC3 Drive Manager. This function is described later in this chapter.

Flow diagram for the motor brake control

The following diagram shows the temporal and functional relationship between the enable signal and opening and closing of the motor brake.

| Pos	Enable process description	Pos	Disable process description
1	The controller (NC) issues an enable request for the holding brake to the AX5000 servo drive.	1	The target speed and the actual velocity approach standstill.
2	The control loop of the AX5000 is activated (v_{target} = 0).	2	The servo drive detects the standstill of the axis with the aid of the standstill window (S-0-0124 and the time (P-0-0354).
3	The brake output at the servo drive is now triggered.	3	The controller (NC) disables the axis. The AX5000 servo drive continues to control with it v_{target} = 0. The axis now no longer follows the setpoints of the controller (NC). Bit 3 in the status word is set to 0.
4	When the "*Drive on delay time*" (S-0-0206) has elapsed, the servo drive follows the setpoints of the controller. This sets bit 3 in the status word (NC).	4	The brake output for the motor brake is now disabled.
5	The controller (NC) now specifies a travel profile for the servo drive.	5	When the "Drive off delay time" (S-0-0207) has elapsed, the controller in the AX5000 is disabled.
6	The standstill flag changes its status from 1 to 0, since the axis is now in motion.	6	The drive control is now fully disabled.

NOTICE

Weight counterbalance!

If the axis drops on enable, the weight counterbalance should be activated with S-0-0163. Enter the current value required by the drive for holding the axis. For a stationary axis this can be read in parameter S-0-0084.

Manual control of the motor brake for testing purposes

In order to use the service function of the TC3 Drive Manager for the motor brake, select it in the TC3 Drive Manager under „*Service functions → Manual brake control*".

Default setting
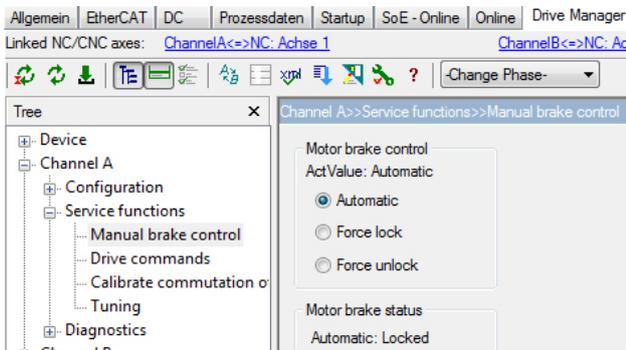
The default setting of the motor brake is „*Automatic*". The enabled mode is displayed under „*ActValue*" (current value). If it differs from your selection, the text is shown in red.

The current status of the motor brake is shown under „*Motor brake status*". It can be „*Locked*" or „*Unlocked*".

The status changes when a new start-up list is downloaded.

„Force unlock" option
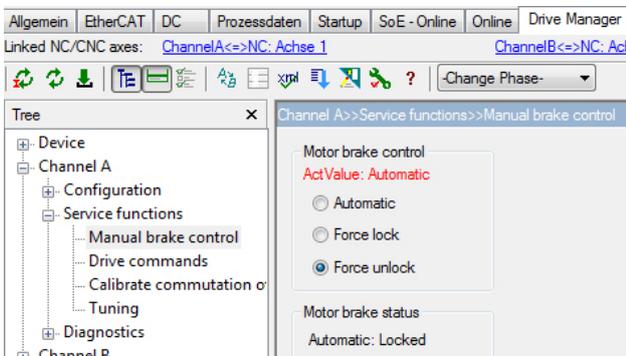
The motor brake is released via the command „*Force unlock*".

Release the holding brake as follows:

- Activate *Force unlock*

- Press the *Download* button .

The change is activated via the „*Download*" button. It contains your new settings.

You have successfully released your motor brake.

Controlling the motor brake for special application requirements

The parameters P-0-0096 (motor control word) and P-0-0097 (motor status word) are available for situations where the motor brake has to be controlled from within the application. The following table shows the command sequence for unlocking and locking the brake from the PLC.

Release the brake		Lock the brake	
Control-Word (P-0-0096)	Status-Word (P-0-0097)	Control-Word (P-0-0096)	Status-Word (P-0-0097)
	0x0000		0x0000
0x0002		0x0001	
	0x0003		0x0000

The PLC block: FB_SoEAX5000SetMotorCtrlWord is available for simplified control of the motor brake.

16 Configuration of a second feedback on the AX5000 servo drive

In some applications, it is useful to use a second encoder mounted directly on the load in addition to the motor feedback. The motor feedback is always necessary for commutation and speed control. The second encoder can be used for position control.

16.1 Possible encoders for the second feedback

All feedbacks that the AX5000 can evaluate, except resolver and MES, can also be configured as second feedback. Typically, a linear encoder is used, for example, to be independent of inaccuracies of a linear spindle.

If an AM8000 motor with OCT feedback is used, the encoder input of the AX5000, X11/ X21, remains free and can be used for an incremental encoder with sine/cosine signals or for an encoder with incremental and absolute (digital) signals.

For the use of a purely digital encoder with EnDat 2.2 or BISS-C interface, the AX572x option card is required.

16.2 Initial commissioning

Initially, commission the servo axis with the motor feedback only, ignoring the second encoder. Set the scaling factor for the NC axis and also adjust the parameters of the speed controller to the application. For information, refer to the AX5000 system manual and the AX5000 tuning guide.

16.3 Configuration of the second encoder

Please refer to the AX5000 system manual on how to connect the encoder.

In the Tc Drive Manager, select the "Feedback 2" page and "Select a Motorfeedback" to select the encoder from the list of supported feedbacks. In the following example, a linear encoder from Heidenhain with EnDat interface and sine-cosine signals is selected:
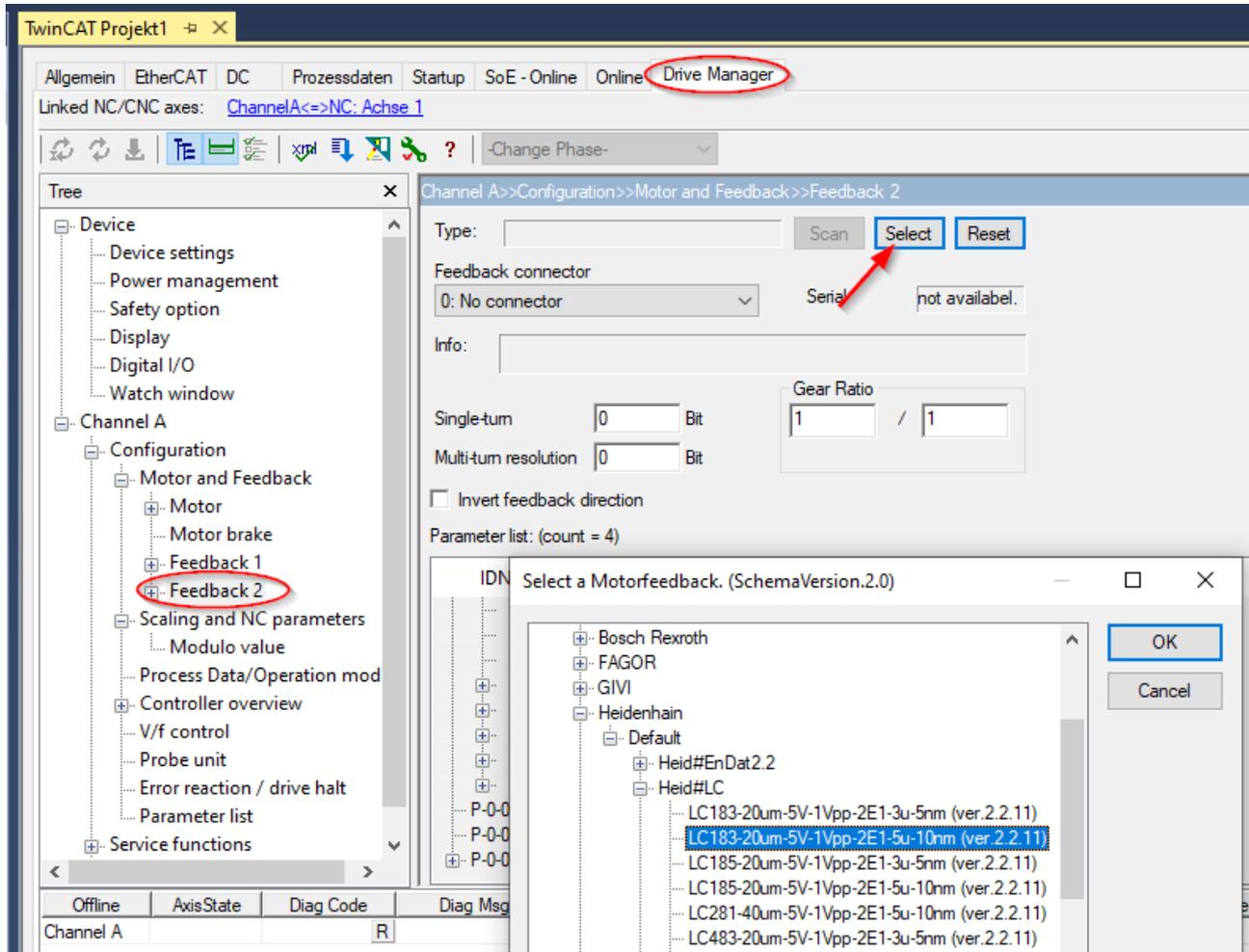
Confirm the message with "OK". The mentioned settings are described below.
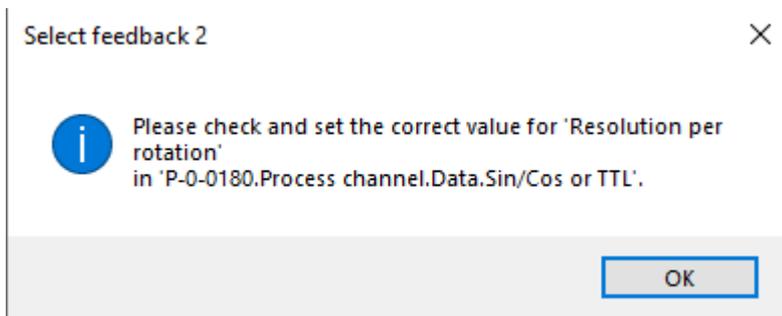
If the correct connector is not set automatically, select it from the list:
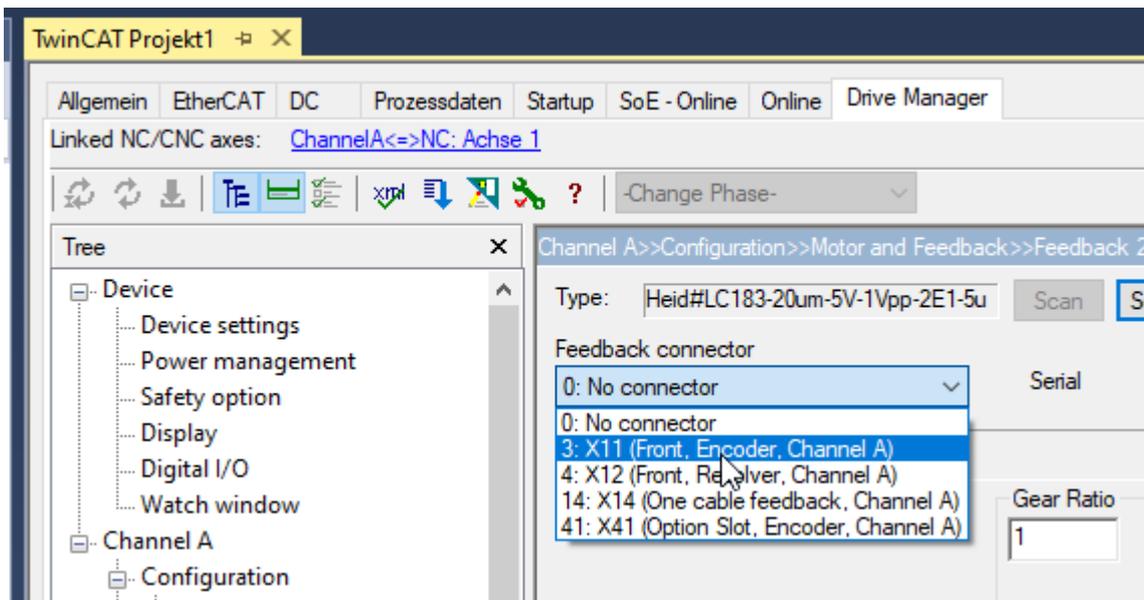
Open the parameter P-0-0180 to get to the entry Process channel/Data/Sin / Cos/:
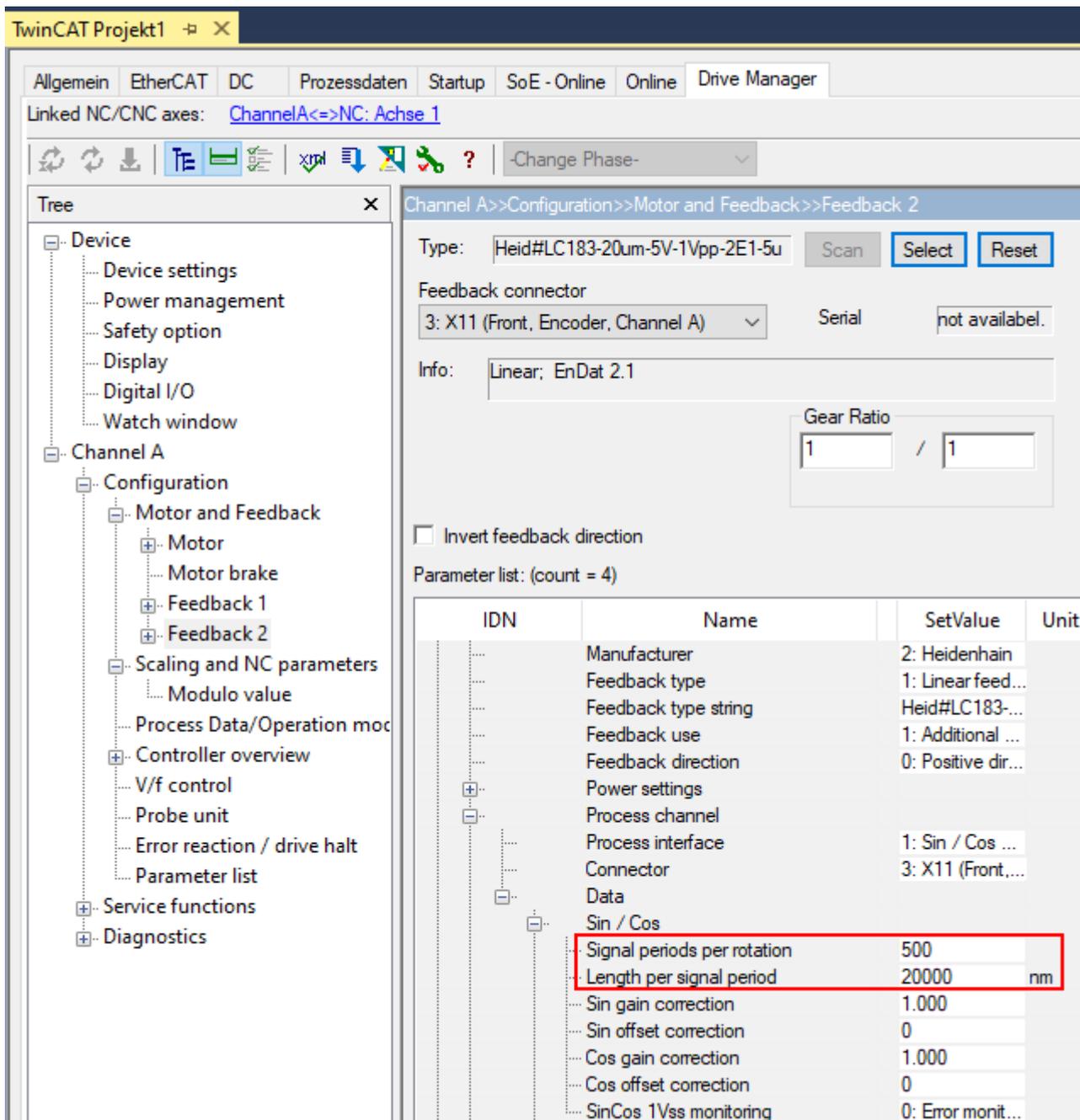
"Length per signal period" is set automatically from the database.

You must select "Signal periods per rotation" so that the product of the two gives the travel distance of the load during one motor rotation.

Example: The motor drives a ball screw with 10 mm pitch.

=> The load moves 10 mm per motor rotation.

Length per signal period = 20000 nm is automatically set from the database.

Signal periods per rotation = 10 mm / 20000 nm = 500

Note: Both parameters must have correct values for both rotary and linear feedback.

Add parameter P-0-0053 to the process image and ensure that the operating mode remains "11_ pos ctrl. feedback 1, lag less".
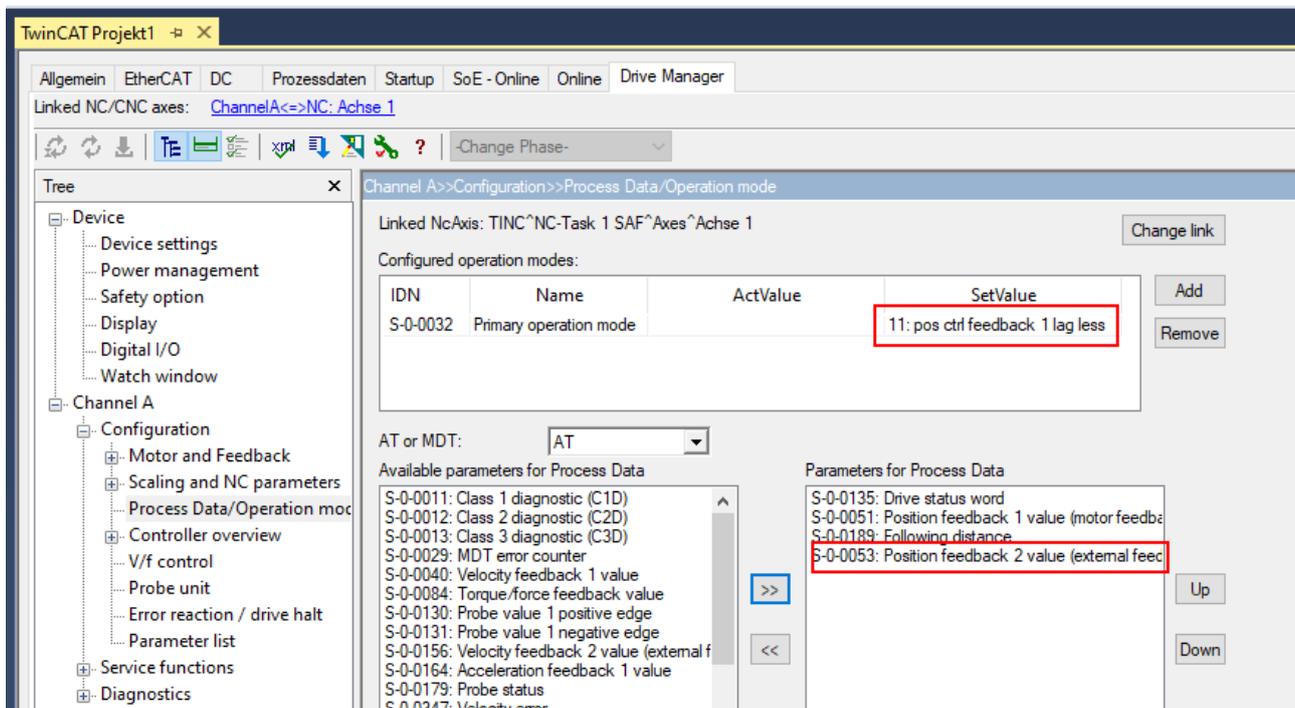
Execute "Activate configuration" for the changes to take effect.

16.4 Checking the second feedback

The aim of the check is to compare differences of both position signals and to make sure that both measure the same distance and count in the same direction.

For this purpose it is necessary either to move the axis with feedback 1 or to move it manually. To easily compare the values, they can be inserted into the Watch Window:

The absolute values of both feedbacks are different. Compare only differences: note the values and move the axis by a defined distance. Read the new values and determine the differences for both feedbacks.

Both counted in the same direction? If not, the counting direction for feedback 2 can be inverted:
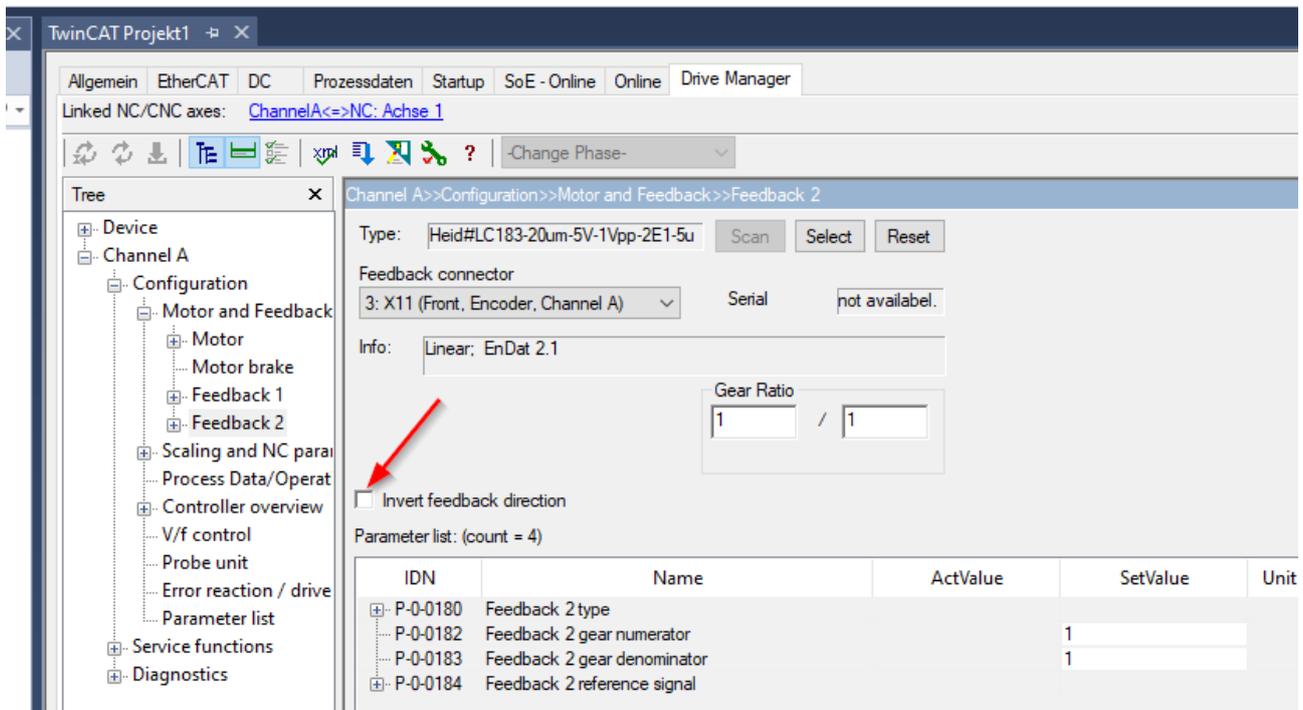
Please note: if the encoder has a digital and an analog channel, as in the example, you have to ensure that both channels count in the same direction. If this is not the case, the position of the encoder will change after the restart.

If both feedbacks have counted in the same direction but the number of counted increments differs, please check the settings in P-0-0180 (Signal periods per rotation, Length per Signal period).

16.5 Activate the second feedback

If both feedbacks count for a certain distance in the same direction and the same number of increments, you can switch the operation mode of the AX5000 so that it uses the second feedback for positioning:
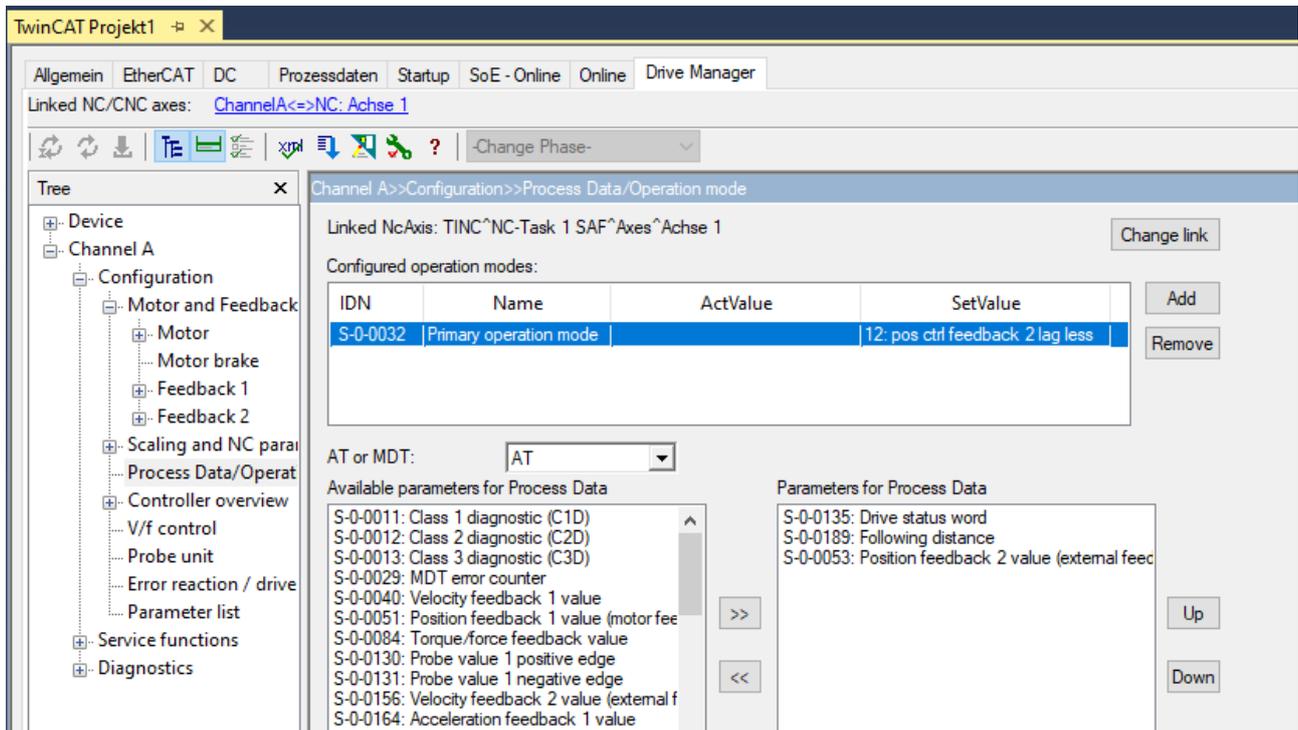
Tc Drive Manager will automatically link "Position feedback 2 value" with the position of the NC axis.

Note: Tc Drive Manager removes "Position feedback 1 value" from the process data. If you need the value further, add the parameter again.

16.6 Setting the "Feedback Gear Ratio"

A second example shows the setting of the feedback gear.

Application: The load is moved by a toothed belt whose pulley has a circumference of 125 mm. The motor drives the pulley via a gear with i=3.

Feed constant for the first feedback:

125 mm / 3 revs. = 41.6666 mm/rev.
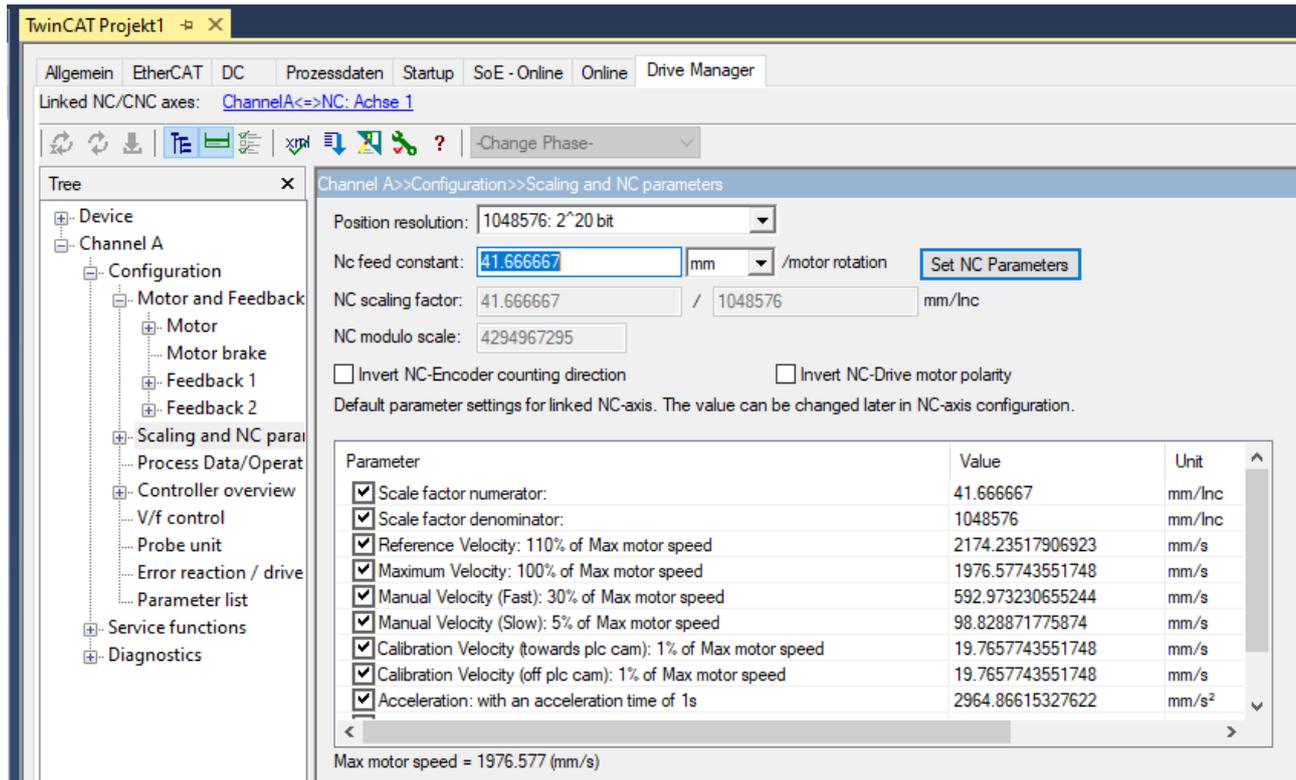
The linear encoder from the above example is used again as the second feedback.

"Signal periods per rotation" must be set accordingly:

125 mm / 20000 nm = 6250 (1)

To get the same number of increments per motor revolution, the feedback "Gear Ratio" is set to 1 / 3: (2).
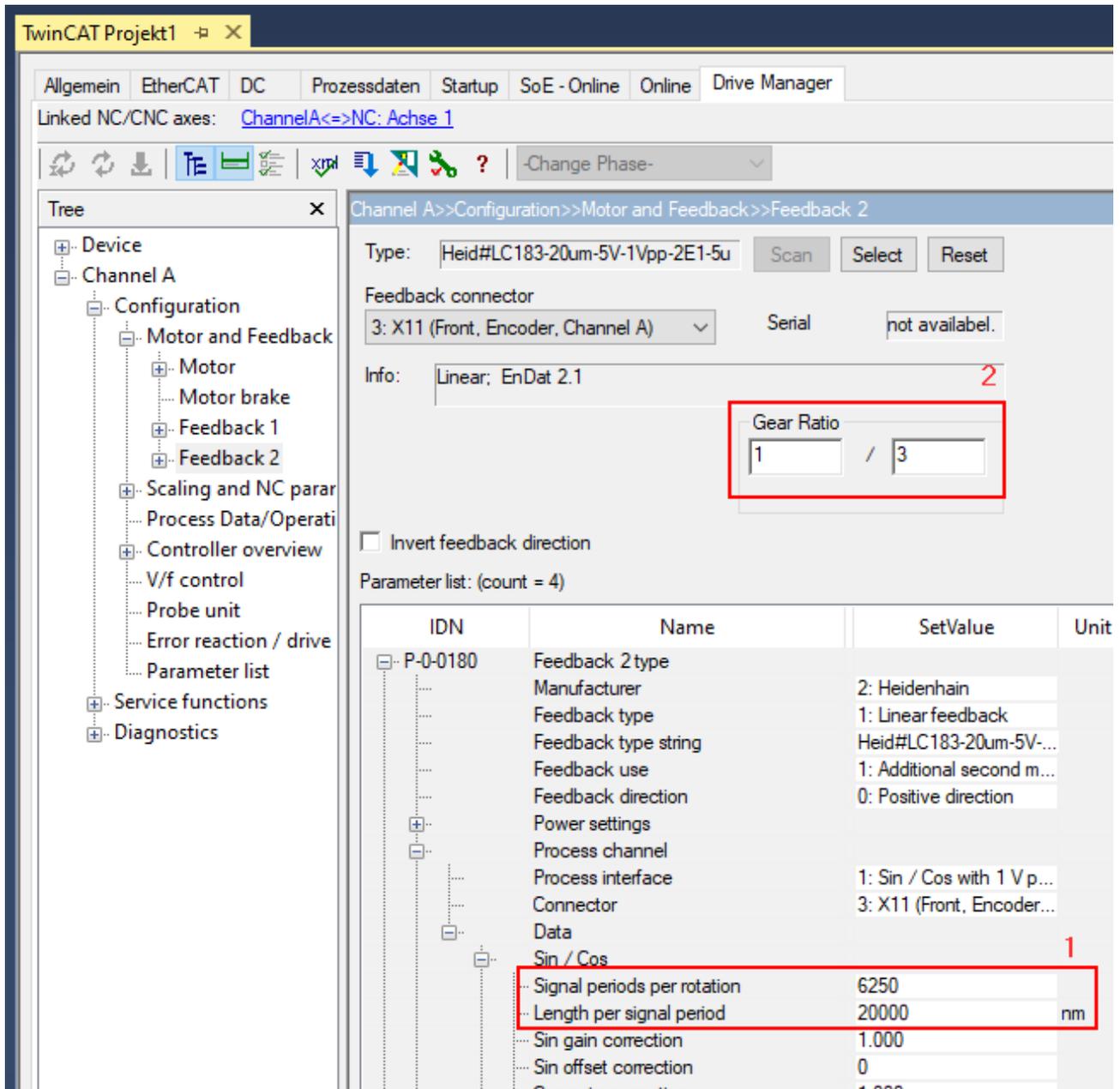
With these settings, continue with Test and Enable as described above (Checking the second encoder, Enabling the second encoder).

17 Modulo

In a rotary multi-turn-feedback system the axis position may be difficult to once the maximum multiturn rage has been reached (overflow) and the machine is switched off and restarted. This problem can be avoided via the controller, although the solution is rather complex and requires a UPS that enables important data to be saved after a power failure. The modulo function of the AX5000 replaces complex programming of the controller with a simple parameterization in the AX5000.

> **Basis of the position control in the servo drive**
>
> Without activation of the modulo function, the servo drive always outputs the absolute position of the encoder, including the problem of overflow. If the modulo function is activated the servo drive always outputs the position of the application, without overrun problems. This application position is generally output for all position data. The servo drive also expects the setpoint values from the controller in modulo format.

> **Modulo reference values**
>
> S-0-0047; S-0-0048; S-0-0051; S-0-0053; S-0-0076; S-0-0091; S-0-0103; S-0-0131; S-0-0189; P-0-0010; P-0-0159; P-0-0270; P-0-0277; P-0-0279; P-0-0554

Functionality up to firmware v2.06

The modulo function was implemented in v2.06 and is usable with the exception of operation with a prime number gear unit.

Functionality from firmware v2.10

From this version, operation with a primary number gear unit is also possible.

Typical modulo application:
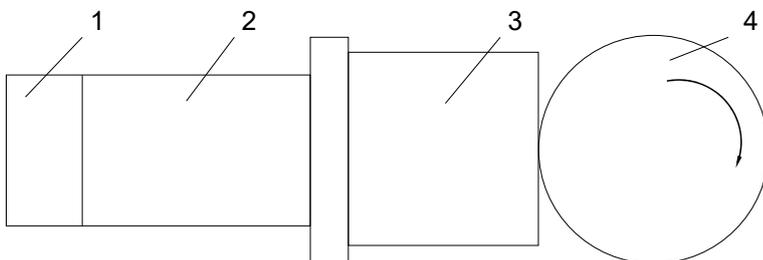
1	Multi-turn feedback system
2	Motor
3	Transmission (gear unit)
4	Application requires absolute position (e.g. turntable)

17.1 Operation without modulo (application with 1:5 gear unit)

In the example below, a multi-turn absolute value feedback is used that has 4096 revolutions and a transmission ratio of 1:5. If the maximum encoder position at 4096 revolutions is exceeded, the encoder begins to count from zero again. It is therefore no longer possible to tell from the feedback position that 4096 revolutions have already taken place. Since a gear unit with a transmission ratio of 1:5 is used in this example and since 4096 is not divisible by 5 without a remainder, the problem described below results. In practice this means that, up to 4096 revolutions, the correct application position can be calculated from the feedback position without further information. After the overwriting of the feedback overrun, this is no longer possible without knowing the overrun that has taken place. This behavior is explained below: The first switch-off point is at 12.5 motor revolutions or 2 application revolutions + 180°. The feedback provides the value correctly after switching on again. The second switch-off point is at 4103 (4096+7) motor revolutions or 820 application revolutions + 216°. Due to the overrun at 4096 revolutions, the feedback system has not taken into account the revolution in the range (a) and displays 7 motor revolutions, but only 1 application revolution + 144°; one motor revolution (72°) is missing. This problems occurs every 4096 motor revolutions and keeps growing by one motor revolution. In order to be able to determine the correct application position,

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the overruns or the resulting position offset must be stored on the application side. This requirement necessitates the use of the UPS mentioned at the start, so that this can be guaranteed even in the case of a power failure.
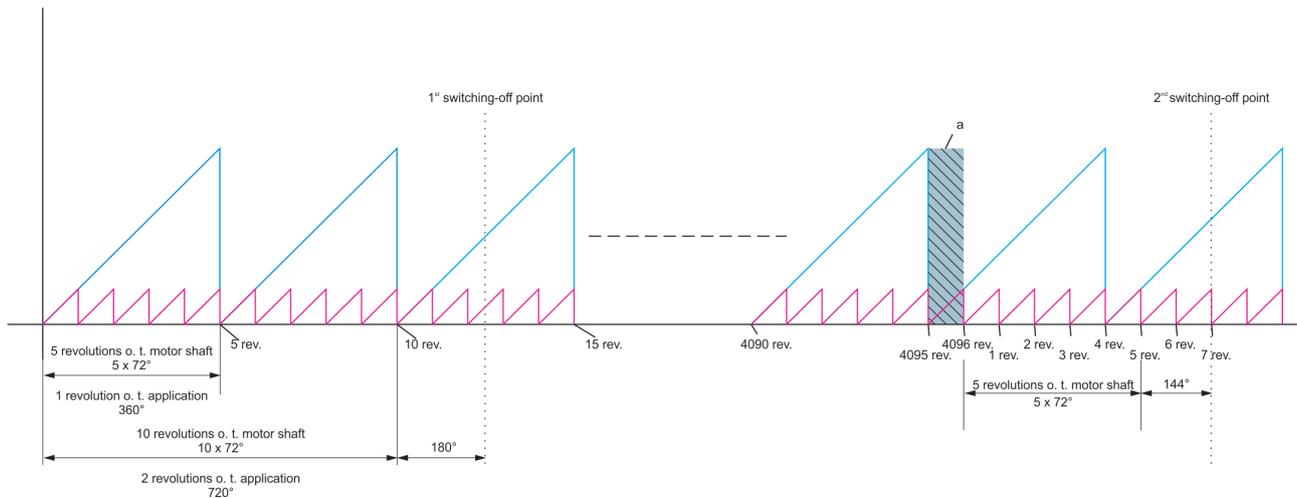
> **ⓘ** **Selecting the gear unit!**
>
> If a gear unit with a transmission ratio of 2^x is selected, the zero points of the motor revolution and the overrun of the absolute value encoder coincide. The above behavior does not occur.

17.2 Operation with modulo

In the case of operation with a modulo, the following properties are brought to bear:

1. The range of the multi-turn encoder is subdivided into four large ranges
   - ⇨ Range of the multi-turn encoder = 4096 revolutions
   - ⇨ One quarter range = 1024 revolutions

2. Saving procedure
   - ⇨ On each transition from one quarter range to another, the modulo data set is modified and saved in the servo drive (real position and CRC)
   - ⇨ The servo drive always has two modulo data sets saved. These data sets are used in alternation.
   - ⇨ A modulo data set is also saved if the EtherCAT state changes from SaveOP to PreOP.

3. Power-on procedure
   - ⇨ Both modulo data sets are read if the EtherCAT transition changes from Boot to Init. The last valid data set is used to reconstruct the modulo position.

4. Power supply error (uncontrolled voltage drop of the 24 V supply)
   - ⇨ Under certain circumstances it may no longer be possible to save a data set because the 24 V supply has been interrupted. Because two data sets exist at all times, however, one of them is valid and can be used to reconstruct the modulo position at the next power-on.

5. Maximum speed during operation with modulo
   - ⇨ Since the saving of the modulo data sets in an internal persistent memory in the AX5000 cannot take place at an infinitely fast speed, the motor speed is limited. An example of the calculation of the maximum possible speed can be found in the section <u>Maximum possible speed [▶ 94]</u>.

17.3 Parameterisation

17.3.1 Activating the modulo function

Valid parameterization of the modulo function necessitates the setting of IDNs in the AX5000 as well as corresponding parameterization of the NC or CNC. It is recommended to commission the modulo function with the help of the TcDriveManager, since this also sets the NC or CNC parameterization correctly. The procedure when using the TcDriveManager is described below.

The following IDNs are used for the parameterization of the modulo function:

S-0-0076 - "Position data scaling type"

The modulo function is activated with the bit "Processing format" in IDN S-0-0076 "Position data scaling type".

S-0-0076	Position data scaling type		
	Scaling method	2: rotational scaling	2: rotational scaling
	Scaling type	1: parameter scaling	1: parameter scaling
	Units for linear/rotational scaling	0: metres [m] / degrees	0: metres [m] / degrees
	reserved	0	0
	Data reference	0: at the motor shaft	0: at the motor shaft
	Processing format	1: modulo format	1: modulo format
	reserved		

S-0-0103 - "Modulo Value"

The maximum calculated value for an application period is entered in IDN S-0-0103 "Modulo Value". The unit is "inc", and 2^x inc (where x = [20 to 30], see S-0-0079) correspond to one motor revolution. For the conversion please take into account the gear ratio of any gear unit installed after the motor. Accordingly, the maximum modulo position is S-0-0103 - 1 inc. Please note that S-0-0103 must be > S-0-0079.

S-0-0103	Modulo Value	26214400	26214400	inc

In this example a multi-turn absolute value feedback system with 4096 turns and a gear unit with a gear ratio of 1:5 is used. 5 motor revolutions correspond to 1 application revolution. In this case the maximum modulo position is $5 \times 2^{20} - 1$ inc, for S-0-0103 = 5×2^{20}.
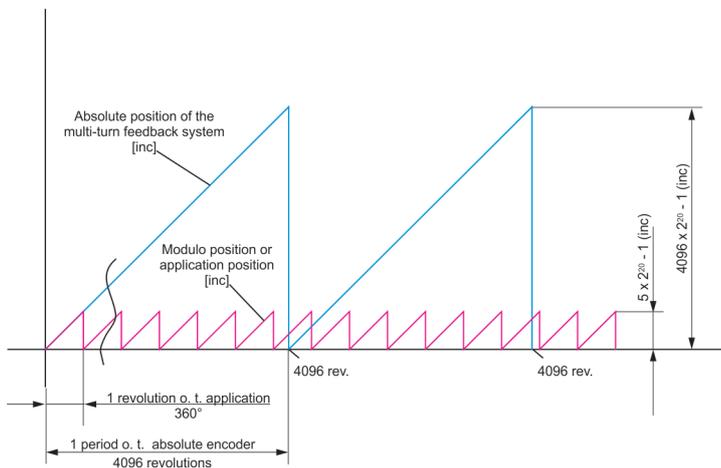
P-0-0276 – „Modulo calculation control"

⊟ P-0-0276	Modulo calculation control		
⊟	Feedback 1		
	Data storage	0: Modulo data storage enabled	0: Modulo data storage enabl...
⊟	Feedback 2		
	Data storage	0: Modulo data storage enabled	0: Modulo data storage enabl...

This IDN can be used to select whether the offset required for the modulo calculation is to be stored cyclically in the drive, and in a fail-safe manner.

„0: Modulo data storage enabled":
This setting requires a multi-turn encoder, otherwise the necessary memory operations cannot be performed fast enough. Thanks to the fail-safe storage of data, the modulo position can be reconstructed unambiguously after the drive was switched off and back on again, provided the encoder position was not changed by more than ¼ **of the absolute range** during the off state.

„1: Modulo data storage disabled":
With this setting, no data are stored in the drive. It enables activation of the modulo calculation even for feedback systems that only provide a single-turn position. However, after the drive is switched off and on again, the modulo position cannot be reconstructed unambiguously, so that homing of the axis is necessary.

The further procedure is described in the section

17.3.2   Influenced IDNs

IDN	Name	ActValue	SetValue	Unit

S-0-0047 – "Pos command value"
The setpoint position is transmitted by the controller to the AX5000 as the modulo position and calculated back into an absolute position in the range $0---2^{32}-1$ inc. in the AX5000.

S-0-0048 "Additive pos command value"
The additional setpoint position is transmitted by the controller to the AX5000 as the modulo position.

S-0-0051 "Pos feedback value 1 (motor feedback)"
The current actual position is calculated by the AX5000 from the position of the feedback system and the current modulo data and is output as the actual modulo position (first feedback system).

S-0-0053 "Pos feedback value 2 (external feedback)"
The current actual position is calculated by the AX5000 from the position of the feedback system and the current modulo data and is output as the actual modulo position (second feedback system).

⊟ S-0-0076	Position data scaling type		
	Scaling method	2: rotational scaling	2: rotational scaling
	Scaling type	1: parameter scaling	1: parameter scaling
	Units for linear/rotational scaling	0: metres [m] / degrees	0: metres [m] / degrees
	reserved	0	0
	Data reference	0: at the motor shaft	0: at the motor shaft
	Processing format	1: modulo format	1: modulo format
⊞	reserved		

S-0-0076 "Position data scaling type"
This is set by the TCDriveManager on activating the modulo function. "Processing format" = 1 enables the modulo function.

S-0-0091 "Bipolar velocity limit value"
Maximum possible speed (see below).

S-0-0103 "Modulo Value"
Defines the modulo range. Is defined in the TCDriveManager.

S-0-0130 "Probe value 1 positive edge"
Position value from the probe unit; this is converted in the same way as the actual value.

S-0-0131 "Probe value 1 negative edge"
Position value from the probe unit; this is converted in the same way as the actual value.

S-0-0189 "Following distance"
The position lag is not reduced to the modulo period.

P-0-0010	Feature flags		
	Enable adjusted velocity controller gain scaling	1: enabled	1: enabled
	Enable adapted axis state machine	1: enabled	1: enabled
	View enlarged error history	1: enabled	1: enabled
	Enable excessive position deviation monitoring	1: enabled	1: enabled
	View extended software versions list (P-0-0320)	1: enabled	1: enabled
	Enable extended power management	1: enabled	1: enabled
	Consider the 'Additive position command value' ...	1: enabled	1: enabled
	Enable extended Umain check	1: enabled	1: enabled
	Enable switching frequency reduction to 4 kHz	1: enabled	1: enabled
	Enable phase clamping	1: enabled	1: enabled
	Explicit modulo init data saving required	1: Yes	1: Yes
	Probe unit: Hardware delay compensation	1: enabled	1: enabled
	Feedback value sampling point: Adjusted to Sy...	1: Yes	1: Yes

P-0-0010 "Feature flags", bit 10, "Explicit modulo init data saving required"
This bit is set from interface rev. 0202. The modulo calculation must be explicitly initialized if this bit is set; see Resetting the modulo error [▶ 98].

P-0-0159 "Raw position feedback value 1"
Feedback position without accounting for a position offset.

P-0-0270	Saved modulo data	
	Modulo init data	
	Feedback 1	EKM36-0KF0A018A
	Serial number feedback 1	337964839527
	Feedback 2	
	Serial number feedback 2	0
	Modulo value	26214400
	Data read from file	
	Current data	

P-0-270 "Saved modulo data"
Representation of the saved modulo data for use for diagnostic purposes by AX5000 support.

P-0-0277	Schedule modulo init data saving (PreOp->Safe...	
	Schedule modulo init data saving	0: No

P-0-0277 "Schedule modulo init data saving (PreOp -> SafeOp)"
If bit 0 is set to 1, the modulo Init data (serial number of the encoder, modulo value) will be saved in the AX5000 on the next PreOp -> SafeOp transition.

P-0-0279 "Modulo Value Remainder"
This IDN must be parameterized if a prime number gear unit is used. This IDN can be used to enter the residual (error) of the modulo period parameterized in S-0-0103, relative to the actual modulo period. The parameterized value may be positive or negative. It should always be the smallest absolute value (see also section "Prime number gears [▶ 95]")

P-0-0554 "Effective pos command value"
The IDN outputs the internally available set position value. No modulo calculation takes place for this parameter. (See also S-0-0047 and S-0-0048)

17.3.3 Maximum possible speed

Activation of the modulo function may result in a relevant reduction of the maximum speed.

Maximum speed:

$$v_{max} = \frac{1}{4} \cdot \frac{S\text{-}0\text{-}0103}{S\text{-}0\text{-}0001}$$

The above equation results in a limitation of the maximum value of IDN S-0-0091 "Bipolar velocity limit value"

17.4 Configuration

To configure the modulo function, proceed as follows:
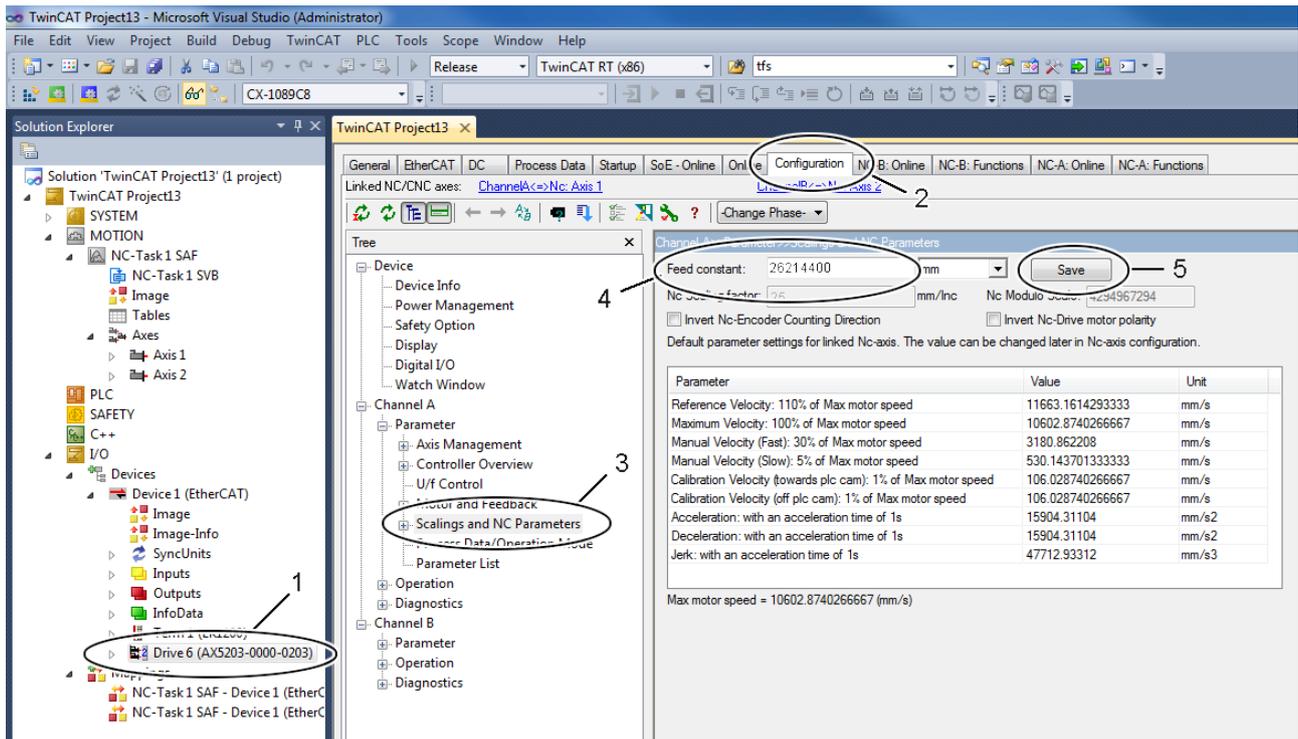
- Select the device "AX5203" (1).
- Open the TCDriveManager (2).
- Select the item "Scalings and NC Parameters" (3) for channel A.
- Define the feed constant (4).
- Complete the input with "Save" (5).
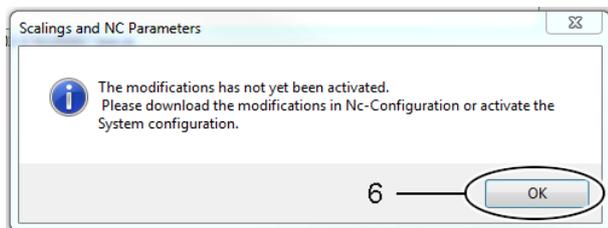
- Confirm the message with "OK" (6).
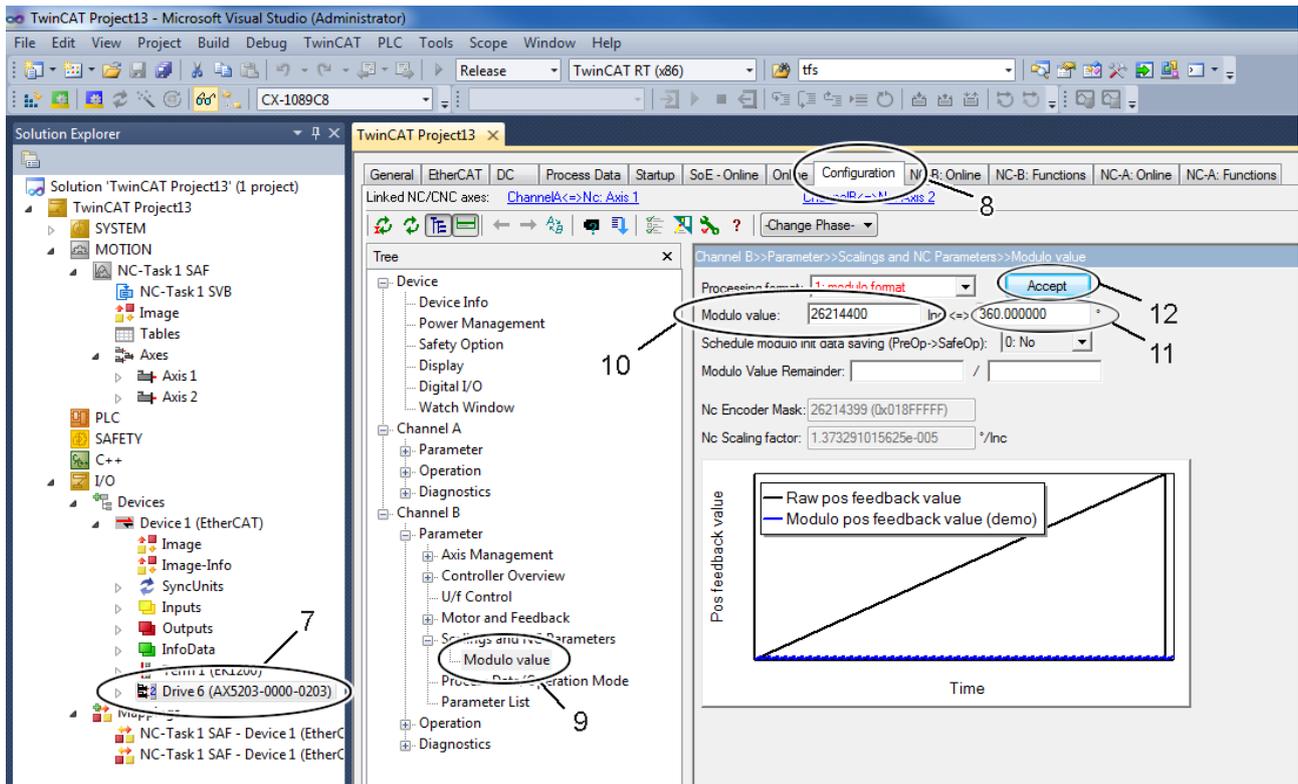
- Select the device "AX5203" (7).
- Open the TCDriveManager (8).
- Select the item "Modulo value" (9).
- Define the modulo range in the preset unit (11).
  The TcDriveManager subsequently calculates the modulo value in the unit increments (10).
  Complete the input with "Accept" (12).
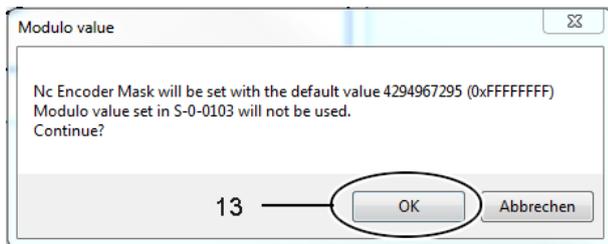
- Confirm the message with "OK" (12).

- Repeat the procedure for the second channel ("Channel B").
- Activate the configuration.

- If no modulo data have been saved in the servo drive yet, error code F350 ("No saved data could be loaded") appears on initialization; see also section Exchange [▶ 97].

- The reset functionality is described in section Resetting the modulo error [▶ 98].

17.4.1   Prime number gears

Prime number gears always have an odd number of teeth and are often used in practice to minimize wear of the individual teeth. If one gearwheel of a pair has a prime number as the number of teeth, the number of meshings of the same pair of teeth is minimized. This gear type is parameterized with IDN P-0-0279 "Modulo Value Remainder".

Application example

Turntable with a gear reduction ratio of 63/17.
On the motor side, 360 ° (1 revolution) correspond to 2^{20} increments.

The resulting modulo period at the gear output (turntable) is:

2^{20} inc x 63/17 = 3885899.2941176470588235294117647 inc

= 3885899 + 5/17 inc

or = 3885900 – 12/17 inc

The modulo period of the AX5000 (S-0-0103) can only be parameterized with an integer value. Thus, if 3885899 inc is used as modulo period, the resulting error is 5/17 inc per modulo period on the turntable side and 5/17 x 63/17 = 1.08997 inc on the motor side. Because this error accumulates with each modulo revolution, the error becomes significant after n modulo revolutions in the same direction.

Extended parameterization

To avoid the accumulating error illustrated in the above application example, IDN P-0-0279 "Modulo Value Remainder" was implemented in the AX5000.

IDN	Name	ActValue	SetValue	Unit	MinValue	MaxValue
⊟ P-0-0279	Modulo Value Remainder					
	Numerator	5	5		-1024	1024
	Denominator	17	17			1024

This IDN can be used to enter the residual (error) of the modulo period parameterized in S-0-0103, relative to the actual modulo period. The parameterized value may be positive or negative. It is best to always use the smallest absolute value. In the above example, this would be 5/17 with S-0-0103 = 3885899. The same result is obtained with the value
-12/17 with S-0-0103 = 3885900. However, this option results in a greater position jump at the correction point, since |-12/17| > |5/17|.

The drive corrects the modulo calculation as if the actual modulo period were to correspond to the value parameterized in
S-0-0103. Consequently, when calculating the NC scaling, the value in S-0-0103 must be used. The resulting scaling factor is
360°/ S-0-0103 = 360°/3885899 inc.

17.4.2   Exchange

The modulo position is no longer correct if the motor or servo drive is exchanged. To prevent mechanical damage in the case of an uncontrolled restart, the servo drive starts with an initialization error, which leads to the EtherCAT status being set to Err-PreOp.

The servo drive and the NC axes are thus not ready for operation and the drive cannot be activated. To prevent inadvertent acknowledgement by the application program, this error cannot be acknowledged with the reset command S-0-0099. Instead, the procedure described in the section Resetting the modulo error [▶ 98] must be followed.

The table below shows various exchange cases and the corresponding behavior with the firmware v2.06:

Modulo / exchange scenario	P-0-0275	Modulo parameter, saved in the servo drive
• Motor exchanged; • New motor from the stores; • Encoder memory is empty	EtherCAT State	Err PreOP
	DriveStatus	Error: F351 – Initialization data invalid
• Motor exchanged; • Old motor; • Motor already has a position offset saved in the encoder memory	EtherCAT State	Err PreOP
	DriveStatus	Error: F351 – Initialization data invalid
• Servo drive exchanged; • New servo drive from the stores; • Servo drive memory empty	EtherCAT State	Err PreOP
	DriveStatus	Error: F350 – no saved data could be loaded
• Servo drive exchanged; • Old servo drive; • Servo drive already has modulo data saved in the servo drive memory	EtherCAT State	Err PreOP
	DriveStatus	Error: F351 – Initialization data invalid

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17.4.3 Resetting the modulo error

The following figure shows channel B with modulo error F351.

	AxisState	Diag Code		Diag Msg	Umain OK	DcLink OK	Ampl-.Te...	Actual op...	v <= v_0	Positive c...	Negative ...	Periph. Vo...
PreOp												
Channel A	Drive Ready	0x0000D012	R	Axis state machine...	●	●	29.7	11: pos ctrl f...	●	●	●	23.142
Channel B	Axis Error	0x0000F351	R	Modulo Calculatio...	●	●	31.0	11: pos ctrl f...	●	●	●	23.125

The modulo error F350 / F51 can be reset using the System Manager / TCDriveManager or the PLC.

Reset with the System Manager

- Select the device "AX5203" (1).
- Open the TCDrivemanager (2).
- Cancel the EtherCAT error with "Change Phase – Clear Error" (3).
- Select item "Modulo value" (4).
- Set "Schedule modulo init data saving (PreOp->SaveOp" (5) to "Yes".
- Set the EtherCAT status to "Op" (3).

17.4.4 Clearing the modulo data

It is possible to clear the modulo data and reset the servo drive to the factory settings.
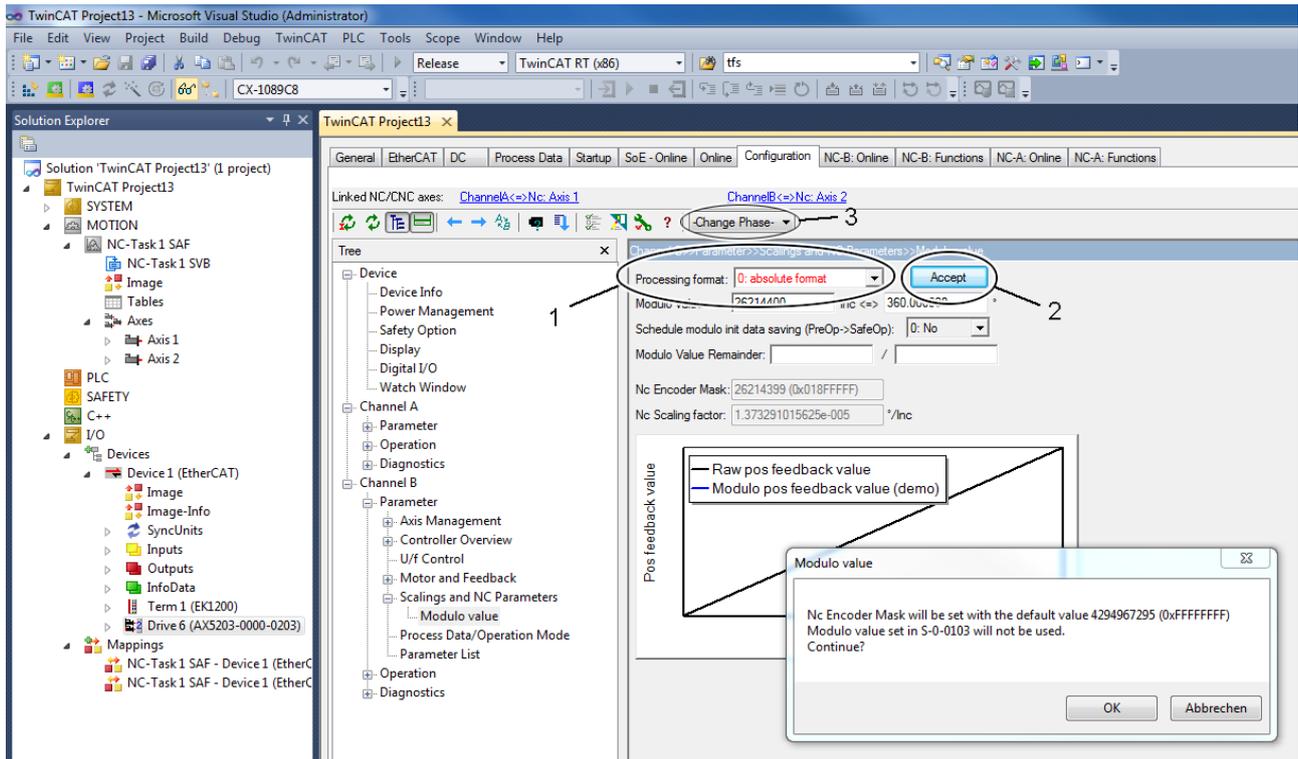
- Disable the modulo function (1).
- Complete the input with "Accept" (2).

- Activate the configuration.
- Switch to the EtherCAT phase "Bootstrap" (3).
- Switch to EtherCAT phase „OP" (3).

The affected IDNs are changed automatically. The modulo data are shown as an example.

Saved modulo data			Reset modulo data		
P-0-0270	Saved modulo data		P-0-0270	Saved modulo data	
	Modulo init data			Modulo init data	
	Feedback 1	EKM36-0KF0A018A		Feedback 1	
	Serial number feedback 1	337964839527		Serial number feedback 1	0
	Feedback 2			Feedback 2	
	Serial number feedback 2	0		Serial number feedback 2	0
	Modulo value	26214400		Modulo value	0
	Data read from file			Data read from file	
	Data[0][0]			Data[0][0]	
	Feedback number	0		Feedback number	0
	Data set	0		Data set	0
	Data			Data	
	Feedback position	0x00000000		Feedback position	0x00000000
	Modulo position	0x00000000		Modulo position	0x00000000
	Crc	0x1000000000000		Crc	0x00000000
	Data[0][1]			Data[0][1]	
	Data[1][0]			Data[1][0]	
	Data[1][1]			Data[1][1]	
	Current data			Current data	

18 Motor types and operation modes

In this chapter the relationships between physical motor types, feedback systems and the necessary operation mode will be explained.

Functionality from firmware v2.12

The firmware V2.12 enables the operation of voice coil motors with feedback system and (a)synchronous servomotors with and without feedback (sensorless regulation).

Structure of the parameter P-0-0050 (Motor construction type)

P-0-0050	Motor construction type		16
	Functional principle	0: synchronous	1
	Construction	0: rotary	1
	Functional principle replacement	1: VoiceCoil	2
	rsvd	0	12

The functional principle of the motor (asynchronous/synchronous) and the type of construction (rotary/linear) are defined in this parameter.

Structure of the parameter P-0-0451 (Current controller settings)

P-0-0451	Current controller settings		16	0
	Enable Smith Predictor	0	1	0
	Control mode	0: Field-oriented current control with feedback	3	1
	Optimized I-part limitation	0: Field-oriented current control with feedback	1	4
	Enable acceleration control	1: Current control without feedback	1	5
	Enable stall protection	2: U/f control	1	6
	Enable slip compensation	3: U/f control with independent feedback	1	7
	Customized1	4: Field-oriented current control without feedback	1	8
	Customized2	5: Current control with feedback	0	9
	Current limitation according to motor characteristics	0	1	10
	Velocity limitation according to motor characteristics	0	1	11
	Motor characteristics with consideration of neg mai...	0	1	12
	Direct addition of S-0-0081	0: No	1	13
	Linear interpolation of S-0-0081	0: No	1	14
	Enable internal Id command	0	1	15

In *Control mode* the operation mode is selected in relation to the predetermined motor type (P-0-0050). Please refer to the table below for the relationships.

Relationships between motor type and operation mode

Case	Motor type	Settings in P-0-0050	Settings in P-0-0451
1	Rot. synchronous servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback
2	Linear synchronous servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 1: linear **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback
3[1]	Rot. synchronous servomotor without feedback	**Functional principle** = 0: synchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 4: Field-oriented current control without feedback
4	Rot. asynchronous servomotor with feedback	**Functional principle** = 1: asynchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback
5[2]	Rot. asynchronous servomotor without feedback	**Functional principle** = 1: asynchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 2: U/f control **or** **Control mode** = 3: U/f control with independent feedback
6[3]	Rot. voice coil servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 0: rotary **Functional principle replacement** = 1: VoiceCoil	**Control mode** = 5: Current control with feedback
7[3]	Linear voice coil servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 1: linear **Functional principle replacement** = 1: VoiceCoil	**Control mode** = 5: Current control with feedback

1): Mandatory setting in parameter P-0-0464 = *Mode*: *1: EMF-based observer*.
2): With an asynchronous servomotor and the operation mode *V/f control with independent feedback* (setting in P-0-0451), an independent encoder can also be read. An encoder error does not affect the operation of

the motor.

3): As soon as you select a voice coil motor in parameter P-0-0050 the range in *Functional principle (synchronous / asynchronous)* will be overwritten.

Functionality from firmware v2.06 to firmware v2.10

The firmware versions v2.06 - v2.10 allow the operation of synchronous servomotors with feedback and asynchronous servomotors without feedback.

Structure of the parameter P-0-0050 (Motor construction type)

The functional principle of the motor (asynchronous/ synchronous) and the type of construction (rotary/linear) are defined in this parameter.

Structure of the parameter P-0-0451 (Current controller settings)

In *Control mode* the operation mode is selected in relation to the predetermined motor type (P-0-0050)

.

Please refer to the table below for the relationships.

Relationships between motor type and operation mode

Case	Motor type	Settings in P-0-0050	Settings in P-0-0451
1	Rot. synchronous servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback
2	Linear synchronous servomotor with feedback	**Functional principle** = 0: synchronous **Construction** = 1: linear **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback
3	Rot. asynchronous servomotor without feedback	**Functional principle** = 1: asynchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 2: U/f control **or** **Control mode** = 3: U/f control with independent feedback
4	Rot. asynchronous servomotor without feedback	**Functional principle** = 0: synchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 4: Field-oriented current control without feedback
5	Rot. asynchronous servomotor with feedback	**Functional principle** = 1: asynchronous **Construction** = 0: rotary **Functional principle replacement** = 0 (Default)	**Control mode** = 0: Field-oriented current control with feedback

19 Parameter set switchover

ℹ️ **Reference values for the parameter set switchover:**

S-0-0216; S-0-0217; S-0-0219; S-0-0254; P-0-0360; P-0-0361

The parameters of the AX5000 servo drive contain reference values or commands.

A distinction is made between:

- S-IDNs (e.g. S-0-0206): Standard Sercos parameters, which are automatically provided in the start-up list of the servo drive. The value ranges and functions cannot be changed / configured.
- P-IDNs (e.g. P-0-0001): Custom IDNs, which are set by the NC (CNC) program. The value ranges and functions can be configured in the TC Drive Manager.

The standard parameters are not relevant for the parameter set switchover. In an application, switching takes place within a very short time. The AX5000 servo drive are configured with an internal version. This enables faster switching than with the EtherCAT master.

Parameter sets

The Sercos specification stipulates that all parameters can exist n times. In this way parameter sets are formed. The AX5000 may contain up to eight different parameter sets. The parameter sets are identified via the type key of the IDNs.

Configuration

A parameter set can be configured by entering the corresponding parameters in IDN S-0-0219 (list of parameter sets). Only the IDNs entered here are available for a parameter set switchover. The other IDNs retain the value stored in parameter set "0".

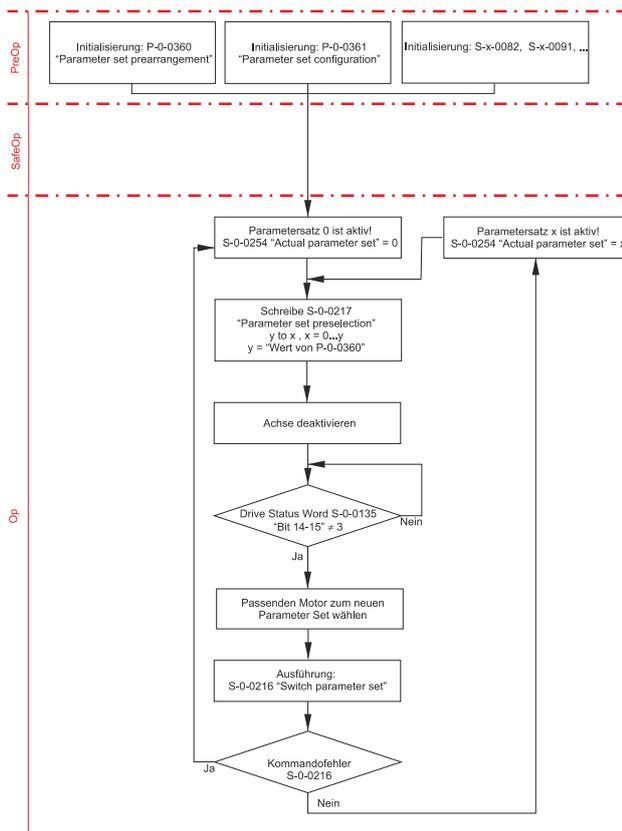**Selection**

A parameter set is selected via IDN S-0-217 "Parameter set preselection". Numbers 0-7 are entered in this IDN as required.

Type key

Infographic	Identifying letter and definition	
IDN-x-y-zzzz	x	S = standard Sercos parameters P = product-specific parameters
	y	Corresponding parameter set (0 – 7)
	z	Serial number

19.1 Switching to a parameter set

Parameter sets are switched via IDN S-0-0216 "Switch parameter set (pc)". During the switchover the parameter listed in IDN S-0-0219 are switched to the parameter set with the number defined in IDN S-0-0217 (0-7).

19.2 Parameter description

IDN S-0-0216 (Switch parameter set)

Command for executing the parameter set switchover

IDN S-0-0217 (Parameter set preselection)

The parameter number for the switchover is entered in this IDN. If, for example, 2 is entered here and then the command S-0-0216 is executed, the parameter of parameter set S/P-2-xxxx are activated.

IDN S-0-0219 (IDN-list of parameter set)

This table contains all IDNs for which parameter sets 0 to 7 are available.

IDN S-0-0254 (Actual parameter set)

This IDN indicates the currently active parameter set.

IDN P-0-0360 (Parameter set prearrangement)

This IDN is used to specify how many parameter sets are prepared for switchover in the AX5000. If this IDN is parameterized to 3 it is possible to switch between parameter sets 0 to 3.

IDN P-0-0361 (Parameter set configuration)

This list is intended for the IDNs to be switched, which should also be listed in S-0-0219. The parameters of the IDNs entered here are prepared for parameter set switchover and switched accordingly.

20 Probe unit (functionality)

A probe unit is a hardware-oriented functional group that can store the actual axis position for a parameterizable 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-controlled position detection via the user program „MC_TouchProbe". An additional application is logging of 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 parameterized before it can be used. The following configuration refers to an AX5000 servo drive (SoE). More generally, it can also be used for parameterization of a SERCOS drive.

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

20.1 Parameterization
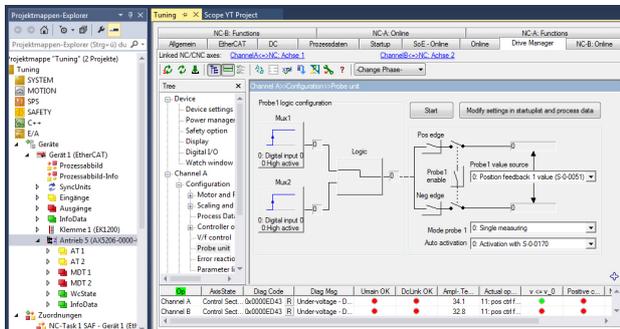
The probe unit is parameterized via a configuration dialog of the AX5000 servo drive. In multi-channel devices a probe unit is available for each channel.
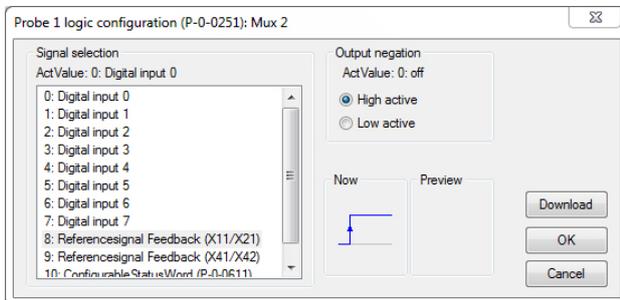
Proceed as follows to parameterize the probe unit:

- Select a signal source (in our sample „Mux2" on the left) for triggering the probe unit.
- Assign a digital input of the AX5000 servo drive (0-7) to the signal source.

Homing:
Select the configuration „Mux2" for homing with evaluation of the encoder zero track. „Reference signal feedback" is only available in this signal source.

The following window (left) appears for a configuration with „*Reference signal feedback*".

- Confirm with OK

The "Feedback 1" menu appears.

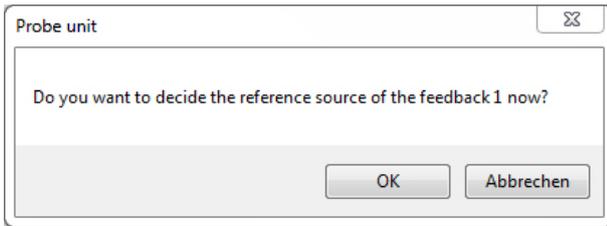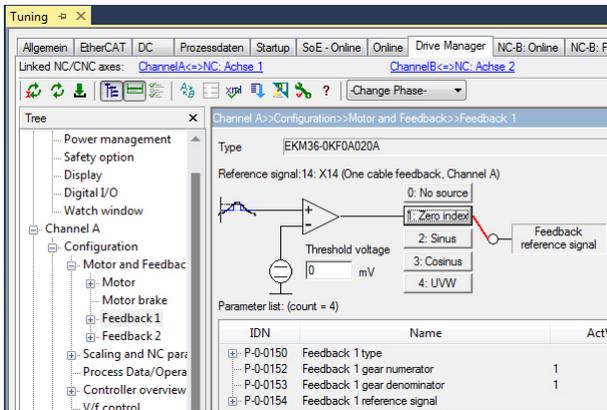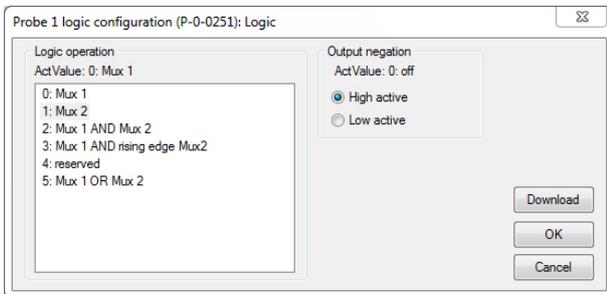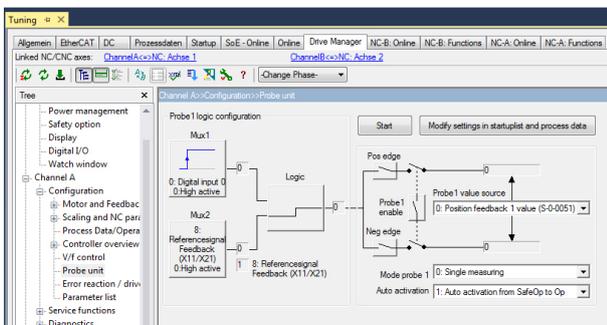- Select the source of the "*Feedback reference signal*" (usually „*Zero index*").

Further settings are required in the "*Probe unit*" window (left).

- Press the „*Logic*" button.

The trigger signal can be linked to a further signal source (Mux 2). The simplest case consists of a signal source and the combination logic ("*logic operation*").

- Specify which signal edge (positive or negative) should be evaluated in the signal sequence (Pos Edge or Neg Edge).
- The decision for a particular signal edge is made during parameterization of the AX5000 servo drive. It is not possible to select it later in the control program (NC / CNC).
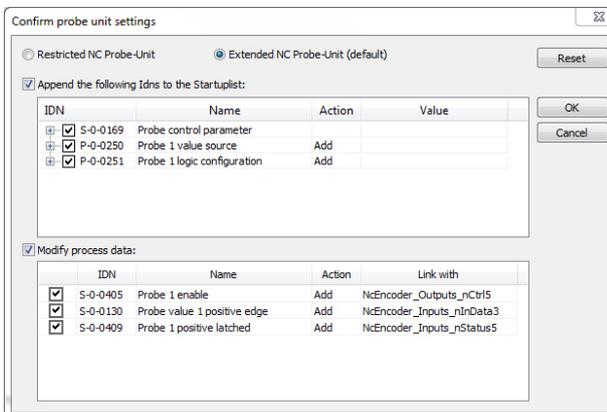
In the last step the "*Mode*" and the activation type are specified.

Mode probe 1: 0 Single measuring:
After each measurement event the new process must be activated through a
0-1 enable switch (default).
Mode probe 1: 1 Continuous measuring:
The measurement is repeated as long as enable remains 1.
Auto activation: 0:Activation with S-0-0170:
The probe unit is activated with command S-0-0170 from the user program (default).
Auto activation 1: Auto activation from SafeOp to Op:
The probe unit is enabled automatically when the AX5000 switches from SafeOp state to Op.

Once all options have been selected, press "Modify settings in startup list and process data". An overview appears, which lists the parameters and process data to be modified. Confirm with OK. If the AX5000 is properly linked to an NC axis, the settings required for this axis are implemented automatically.

21 Position offset

> ℹ **Terminology**
>
> In this documentation, the term offset tends to be used to describe the function of the position offset.

An offset can be configured if an absolute encoder is used in the AX5000. The value can be stored in the motor encoder, in the AX5000 or in the startup list. The offset is taken into account when the AX5000 starts up. It is added to the absolute encoder position. The result is reported to the higher-level controller as an actual value.

In contrast to the offset stored in the TwinCAT NC, the offset stored in the AX5000 or in the encoder can also be modified and stored from the PLC (see procedure described below).

Parameters involved

The meaning of the parameters in relation to the offset is explained in the following sections.

> ℹ **Reference values of the position offset**
>
> S-0-0051; P-0-0159, P-0-0271; P-0-0272; P-0-0273; P-0-0274; P-0-0275; P-0-0278

Requirements

The AX5000 requires firmware v2.06 build 8 or higher. For positioning, an absolute encoder must be connected to the AX5000. The offset can also be used with a single-turn encoder or a resolver, which use an absolute counting method within a revolution.

Procedure

A PLC function block is available in the library **TC2_MC2_Drive** under TwinCAT 3 for saving or modifying the offset from a user program:

The description of this PLC function block can be found in the Beckhoff Online Infosys, for example.

The offset is stored in increments. The TC Drive Manager should therefore be used for entering or modifying the offset without a PLC program. It deals with the conversion between user units and increments. The following page becomes active, if the AX5000 is linked with an NC axis:
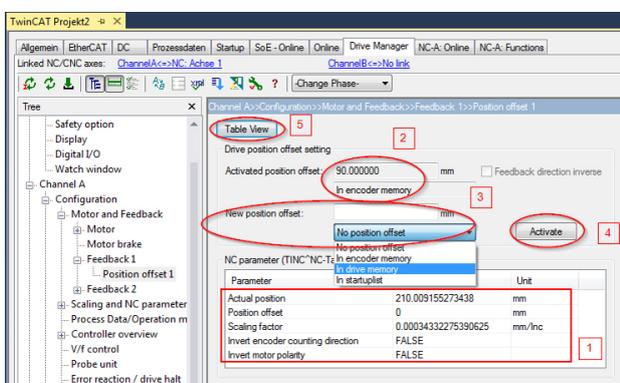
It shows settings from the NC (1) and whether an offset is already active (2). To save a new offset, enter the value in user units and select the storage location (3). Use the "*Activate*" button (4) to store and enable the offset. The "*Activate*" function can only be executed if the axis is not in controlling mode.
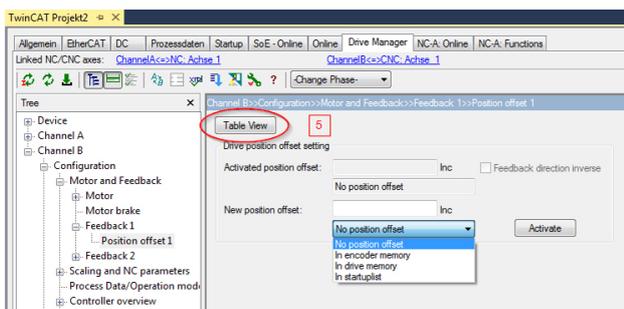
If the AX5000 is linked to a CNC axis, the TC Drive Manager does not "know" the feed constant. The window shows fewer data, and the offset must be entered in increments.

The "*Table View*" button (5) can be used to switch the view in both cases (NC or CNC) (see figure below).
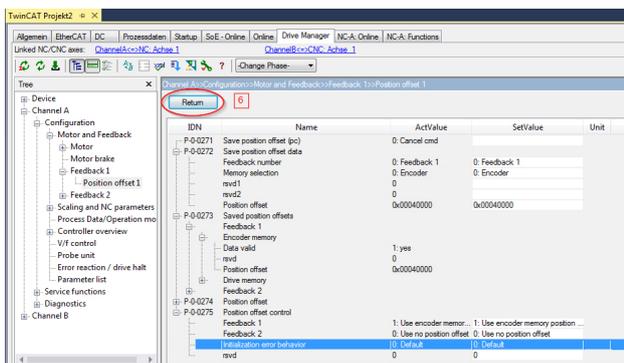
The parameters involved and their current values are displayed here. Use the "*Return*" button (6) to return to the original view (top figure).

Behavior when components are replaced

If a faulty motor or servo drive (AX5000) is replaced, the axis should be prevented from starting with an incorrect offset, which could result in damage. The following scenarios are conceivable, depending on where the offset is stored and which component is replaced:

| Offset stored in encoder (P-0-0275 "Use encoder memory position offset")	
Replaced	**Result**
Motor: No offset is stored in the encoder for the new motor	**EtherCAT Status:** Err PreOp **Drive Status:** Error F341 No position offset available
Motor: An (incorrect) offset is already stored for the new motor.	**EtherCAT Status:** Op **Drive Status:** Ready D012
Servo drive AX5000 (with or without stored offset)	**EtherCAT Status:** Op **Drive Status:** Ready D012

Offset stored in AX5000 (P-0-0275 "Use drive memory position offset")	
Replaced	**Result**
Motor: No offset is stored in the encoder for the new motor	**EtherCAT Status:** Err PreOp **Drive Status:** Error F340 Position offset invalid, wrong serial number
Motor: An (incorrect) offset is already stored for the new motor.	**EtherCAT Status:** Err PreOp **Drive Status:** Error F340 Position offset invalid, wrong serial number
Servo drive AX5000: New device without stored offset	**EtherCAT Status:** Err PreOp **Drive Status:** Error F341 no position offset available
Servo drive AX5000 (with or without stored offset)	**EtherCAT Status:** Err PreOp **Drive Status:** Error F340 Position offset invalid, wrong serial number

Delete position offset
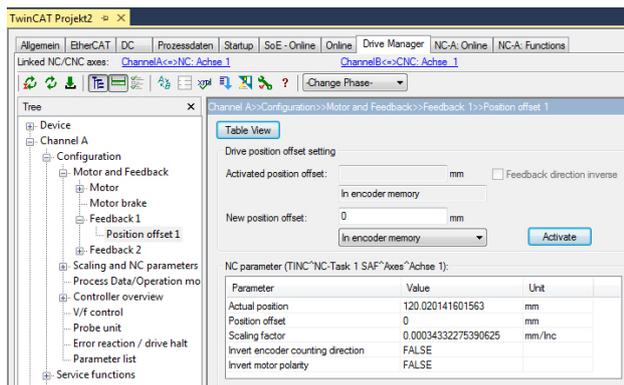
To delete a stored offset, enter the value 0 and select the memory location to be deleted (encoder or servo drive):

Click "*Activate*" and confirm the error message that appears (see figure below) with OK:
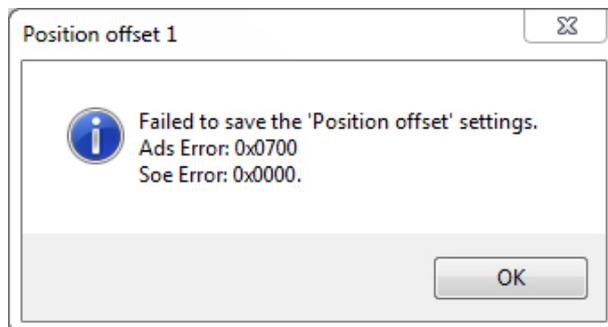
Then select "*No position offset*" (1) and click "*Activate*" (2) again. The display (3) then switches to "*No position offset*".
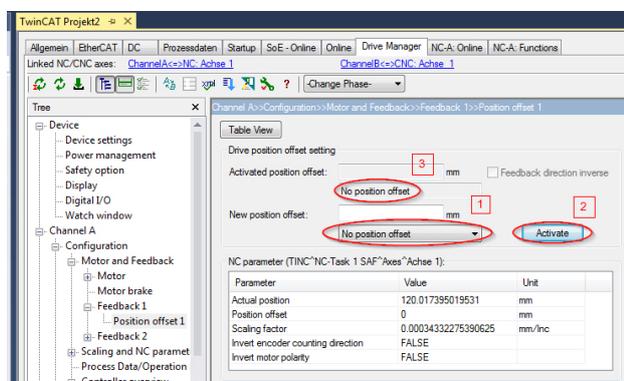
21.1   Parameter description

IDN P-0-0159 (Raw Position Feedback Value 1)
Position of feedback 1 without consideration of offset.

IDN P-0-0271 (Save Position Offset)
Command for saving the position offset.

IDN P-0-0272 (Save Position Offset Data)
Specific data saved with the P-0-0271 command.

IDN P-0-0273 (Saved Position Offsets)
Displays already saved position offsets.

IDN P-0-0274 (Position Offset)
Position offsets for the startup list.

IDN P-0-0275 (Position Offset Control)
Selection of the position offset to be used (from encoder, AX5000 or startup list).

IDN P-0-0278 (Ignore P-0-0275 'Position Offset Control')
Command to acknowledge the position offset error.

IDN S-0-0051 (Position Feedback Value 1)
Position of feedback 1 after consideration of offset

Units of the parameters: Increments

22 Power Management

ⓘ **Power management reference values:**

P-0-0201; P-0-0202; P-0-0203; P-0-0214

The AX5000 is normally operated with a 3-phase AC voltage. This is rectified in the device with the aid of a bridge rectifier and charges the DC link. Furthermore, there is an option to input a DC voltage.

Parameterization:

- Mains voltage with P-0-0201
- Tolerances with P-0-0202 and P-0-0203
- DC link connection with P-0-0214

The further basic parameterization then takes place according to the following criteria:

- Voltage on X01:
  AC 3-phase or single -phase or DC input.
  All monitors are activated (default parameterization).
  The phase monitoring must be deactivated in the case of "AC single-phase" or "DC".

- DC voltage on X02:
  In P-0-0204, activate the commands "DisableUmainMonitoring" and "DisableUmainLossMonitoring".
  There is NO LONGER ANY DEVICE PROTECTION via X01! Further information in the section DC input.

22.1 Mains voltage monitoring

The servo drive monitors the connected mains voltage for minimum and maximum values. 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.

ⓘ **phase monitoring**

Phase monitoring must be disabled for single-phase mains supply, to facilitate commissioning of the servo drive.
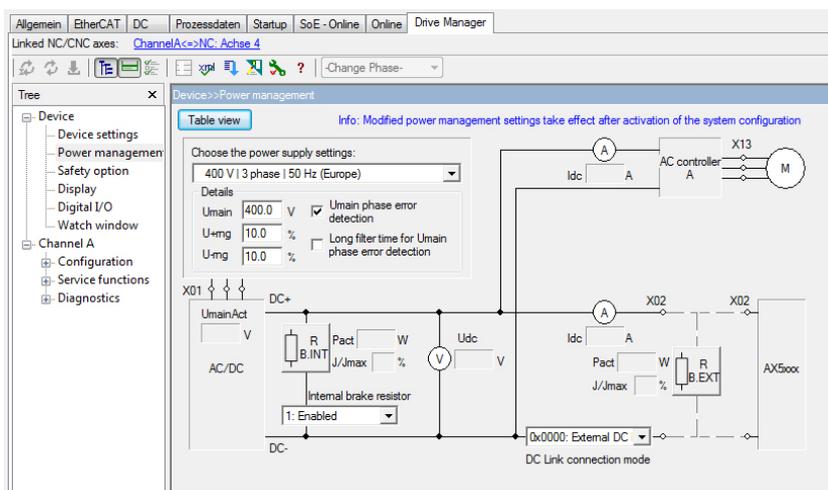
22.2 DC supply

For special applications it may be useful to input a DC voltage. Several things need to be observed for the connection and the parameter settings, which are described below.

The DC voltage can be connected:

- via the AC input (X01) or
- directly into the DC link (X02).

Voltage parameterization

P-0-0201	Nominal mains voltage	24.0
P-0-0202	Mains voltage positive tolerance range	20.0
P-0-0203	Mains voltage negative tolerance range	20.0

The desired DC voltage is set with P-0-0201 "Nominal mains voltage". The controller automatically recognizes the DC voltage form during the initialization (from firmware v2.10).

In the case of small DC voltages, the parameters P-0-0202 and P-0-0203 "Mains voltage tolerance" should be 24 V or 48 V (at least 20%, better 30%). Due to the tolerances when measuring the voltages, an error would otherwise frequently be caused.

If the exchange of energy between several AX5000 devices is desired, the following parameterization must be used:

DC-Link connection mode (P-0-0214):
"0x0003: AX5x01-AX5x25 [X02] Static external DC Link connection"

DC input via the wide-range voltage input – X01

In the case of input via X01, note that (as with the single-phase connection) only two of the six rectifier diodes conduct the current. The same limitations apply as to the power or output current (see startup manual). The voltage can be connected at L1 and 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

DC input via the DC link input – X02

The charging circuit for the DC link is inactive. The user must ensure that the starting current does not become too high when the voltage is switched on.

For the calculation, for example, of a resistor that limits the starting current, the DC link of the AX5000 is to be regarded as a short-circuit at the moment of switching on.

Be sure to observe the correct polarity of the connection (DC+, DC-)!

Terminal point	Connection	
DC +	DC link +	External brake resistor and DC link connection
DC -	DC link -	

The table below shows values that may not be exceeded:

Device	Max. starting current
AX5x01 – AX5112	10A
AX5118 – AX5140	20A

The settings in the Power Management Control Word (P-0-0204) marked below are important in the case of input via X02 (from firmware V2.10):

Important! With the parameterization "Disable Umain loss monitoring", the device protection with regard to mains voltage interruptions at X01 is switched off. Therefore, only switch the monitors off in case of DC input at X02.

22.3 Diagnostics for external brake resistors

i **Reference values for the external brake resistor:**

P-0-0207; P-0-0208; P-0-0209; P-0-0210; P-0-0218; P-0-0219; P-0-0220; P-0-0221

This chapter provides basic information on dimensioning and configuration of external brake resistors. The parameters described in this chapter can be recorded with the TwinCAT Scope View for diagnostic purposes.

If an internal brake resistor is used, the configuration takes place via the IDNs:

- P-0-0209 (Internal brake resistor actual continuous power) in watts and
- P-0-0218 (Internal brake resistor actual peak energy) in %

If an external brake resistor is used, the configuration takes place via the IDNs:

- P-0-0210 (External brake resistor actual continuous power) in watts and
- P-0-0219 (External brake resistor actual peak energy) in %

"Actual continuous power" is an arithmetically averaged value of the actual power. Even after several typical machine cycles the value of P-0-0210 (P-0-0209 internally) must always remain below the value of the continuous power of the brake resistor.

A cycle time of 100 s is assumed for calculating the brake resistor power. Monitoring should therefore take place over this time as a minimum. The permissible value for the continuous power can be found in P-0-0207 (internal brake resistor) or P-0-0208 (external brake resistor):

"Actual peak energy" indicates the greatest measured braking energy, much like a drag indicator does. The situation with the maximum required peak braking power, e.g. emergency stop, is supposed to be determined and tested. In the process, the value of P-0-0218 (internal) or P-0-0219 (external) should stay considerably below 100%.

For more exact observations it is possible to record the parameters with the software oscilloscope. If for example the velocity or the position is recorded, a better allocation of the current braking power to the machine cycle is possible. To this end the parameters must be inserted into the process image beforehand:
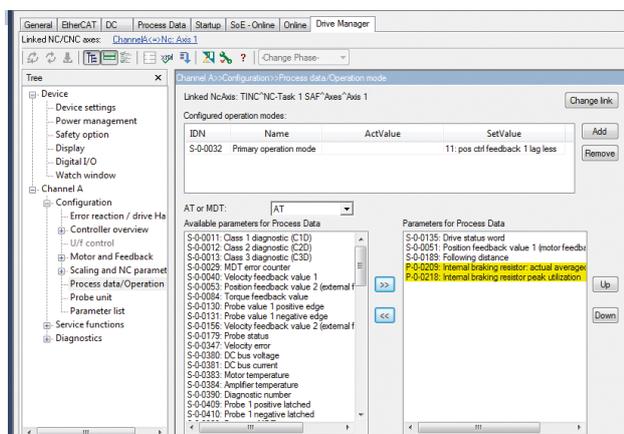
i **Further information on external brake resistors can be found at:**

Information on mechanical and electrical installation, dimensions and technical data can be found in the system manual for the AX5000 servo drive under: „Accessories – External brake resistor – AX2090-BW5x-xxxx".

For further analysis peak values are recorded in the parameters P-0-0220 (internal brake resistor) or P-0-0221 (external) with respect to the duty cycle.

Duty cycle (DC) = switch-on time / cycle time (machine cycle) x 100%

Beckhoff specifies an overload factor for the brake resistors, depending on the duty cycle (see diagram below):
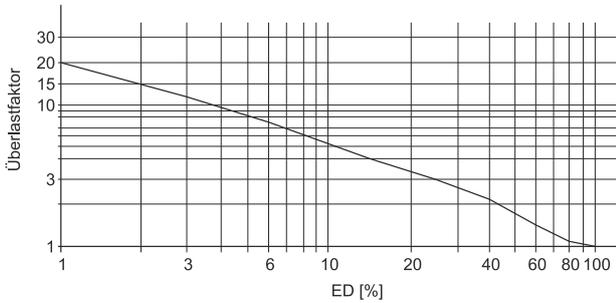
AX2090-BW51-3000 and AX2090-BW51-6000
AX2090-BW52-3000 and AX2090-BW52-6000
AX2090-BW53-3000 and AX2090-BW53-6000
AX2090-BW54-3000 and AX2090-BW54-6000

AX2090-BW50-xxxx and AX2090-BW51-1000

Overload factor depending on duty circle

Overload factor depending on duty circle
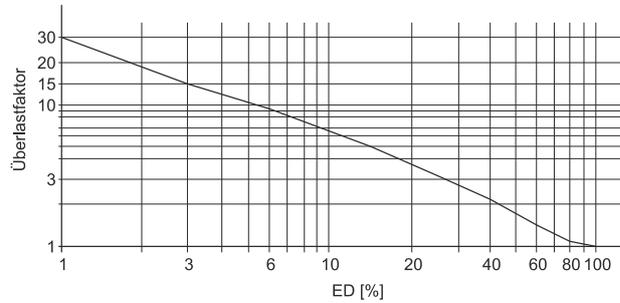
Multiplied by the power rating, the permissible short-term power results from the overload factor dependent on the duty cycle:

Short-term power = Power rating x Overload factor (ÜF)

For the AX5000 energy values were calculated for the supported brake resistors from the power rating, duty cycle and overload factor and saved as parameters. They can be found for the internal brake resistor in P-0-0207 and after selecting an external brake resistor P-0-0208.

Sample: AX2090BW50-1600 with 47 ohm and 1600W power rating

Overload factor for 1% duty cycle: 30

1% duty cycle for 100s cycle time corresponds to 1s

1s x 1600W x 30 = 48000J

Correspondingly the other saved values result:

Duty cycle [%]	40	20	10	1	0.1
Overload factor	2.2	3.9	7	30	144.375
Peak E. [J]	140800	124800	112000	48000	23100

When the brake resistor becomes active, the software program calculates the current energy values, related to the duty cycle and presents the maximum values in P-0-0220 or P-0-0221. Both parameters are reset when the device is restarted (=0). The values entered in operation are preserved until the next restart or until they are overwritten by the user. They can be compared with the permissible values in P-0-0207 (internal brake resistor) or P-0-0208 (external). As a result it may be possible to influence the braking power in critical regions by modifying the cycle.

The greatest percentage value is entered in P-0-0218 or P-0-0219 (in %) (see above).

22.4 DC link charging and monitoring

The new state machines for "Umain" and "DC link charging" ensure high availability and at the same time improved protection of the servo drive.
Basis is the fast measurement of the mains (X01) and DC link voltage.

All servo drives in a common DC link group should be operated with a firmware v2.06 or ≥ v2.10.

The charging of the DC link is faster and the axis is thus ready for operation sooner.

The voltage tolerance of the mains voltage for error messages has become larger:

- By default the overvoltage limit is 120% of the mains voltage
- and the undervoltage limit 70% of the mains voltage.

If larger values are desired, they can be entered with P-0-202 (overvoltage, values > 20%) and P-0-0203 (undervoltage, values > 30%).

The warnings for mains overvoltage or undervoltage are always triggered at the limits defined by P-0-0202 (overvoltage) and P-0-0203 (undervoltage).
This means in the case of P-0-202 >20% and voltage values > nominal voltage (P-0-0201) + P-0-0202 [in %] that the error is triggered simultaneously with the warning.

In the case of undervoltage, error and warning are triggered simultaneously if P-0-0203 > 30% and the present voltage is < P-0-0201 – P-0-0203 [in %].

Mains interruptions do not cause an error message as long as the DC link voltage approximately corresponds to the last measured mains voltage. In the case of low energy requirement of the axes it is quite possible to bridge mains interruptions lasting up to one second.

The requirement "axis should move until no more voltage is there"
(P-0-0204 "DisableDcLinkVoltageMonitoring") results in no error message being generated in relation to the DC link voltage. At a lower voltage, however, not all speeds can be reached. The application must therefore monitor the DC link voltage.

23 Cogging torque compensation

● Available from firmware v2.13

ℹ The cogging torque compensation function is available from firmware v2.13.

This documentation applies to the AX5000 servo drive. The chapters contain information on how to parameterize cogging torque compensation via the corresponding IDNs.

You can then check the status of the function and interpret error messages. Finally, information is provided about different IDNs that are important for the function.

23.1 Function

In synchronous servomotors with permanent magnets, torque fluctuations occur due to design-related asymmetries, which have a particular effect at low speeds. The servomotor becomes unstable as a result. The cogging torque compensation improves the synchronization characteristics of the servomotor considerably by applying compensation torques.

By default, the function is always switched on, provided that the servomotor is equipped with the corresponding compensation parameters. Below a speed of 500 rpm, the speed fluctuation is reduced significantly.

23.2 Requirement

The compensation parameters must be available in the electronic identification plate of the encoder memory of the servomotors.

23.3 Parameter description

The following information explains which S-parameters and P-parameters are involved in the function. The commissioning scenarios serve as examples. The configuration is always dependent on the application and environmental and operational conditions.

Parameter	Name	Description
P-0-0630	Cogging compensation control	Switching on and off the function. Selection of the source of the compensation parameters.
P-0-0631	Cogging compensation status	Shows the current status of the function
P-0-0632	Cogging compensation parameter	Compensation parameters
P-0-0633	Cogging compensation feedforward torque	Current applied compensation torque

23.3.1   P-0-0630

	Value	Selection	Information
Control	0	Use encoder memory cogging comp para if available	Default value The compensation parameters are taken from the encoder memory if they are available
	1	Use encoder memory cogging comp para	The compensation parameters are taken from the encoder memory. An error message of the servo drive is issued if the compensation parameters are not available.
	2	Use drive memory cogging para	The compensation parameters are taken from the servo drive memory
	3	Use startup list cogging comp para	The compensation parameters are part of the startup list of the servo drive
	4	Cogging comp off	Deactivating the function

24 Thermal motor model

i ● **Reference values for the thermal motor model:**

S-0-0012; S-0-0111, S-0-0135; S-0-0196, P-0-0052; P-0-0061; P-0-0062, P-0-0066 and P-0-0063.

The thermal motor model calculates the current thermal utilization (P-0-0063 in %) of the motor. This utilization display serves to determine the application-specific utilization reserves. Furthermore, the thermal motor model offers motor protection by means of the dynamic detection of overloads. The motor data for Beckhoff servo motors from the series AM8000 originate from the electronic name plate (offline from the motor data files *.xeds). The motor data generator can be used to create motor data files for third-party motors.

If a temperature sensor (e.g. KTY83-110, KTY84-130, PT1000) is installed in the motor that allows a temperature evaluation over the entire operating temperature range (see motor technical data), the motor is initialized in accordance with the current temperature.

The operating temperature cannot be measured if PTC thermistors are used that exhibit a fast increase in the resistance value in the region of the nominal response temperature (motor cut-off temperature). In this case the motor is initialized in accordance with the max. permissible ambient temperature (40 °C). It should be noted here that after switching off the 24 V system supply a waiting time (5 times the motor time constant P-0-0062, time constant 1) is required before switching on again. This ensures the thermal motor protection with the motor model. The value of the load display is incorrect if the waiting time is not adhered to.

24.1 Functionality from firmware v2.10

A more precise thermal motor model is used from firmware v2.10. This second order model calculates the winding temperature with the help of the winding time constant (P-0-0062, time constant 2). Furthermore, a speed-dependent calculation of the iron losses is carried out. This ensures a considerably improved utilization of the motors.

i ● **Calculation of the copper and iron losses!**

For the calculation of the copper and iron losses must be the IDNs S-0-0111, S-0-0196 and P-0-0066 filled with reliable and engine-specific data!

24.2 Functionality up to firmware v2.06

Up to and including firmware v2.06, the copper losses are used in connection with the thermal time constants of the stator and the housing (P-0-0062, time constant 1) for a utilization display.

Motor windings with a small thermal mass are protected by means of a time limitation of the peak current (P-0-0052, default: 3 s).

The model is initialized independently of the temperature sensor on the basis of the max. permissible ambient temperature (40 °C).

i ● **Calculation of the copper losses!**

For the calculation of the copper losses must be the IDNs S-0-0111 and P-0-0066 filled with reliable and engine-specific data!

24.3   Parameter description

IDN P-0-0062 (Thermal motor model)

IDN	Name	ActValue	SetValue	Unit
⊟ P-0-0062	Thermal motor model			
	Time constant 1	780	780	s
	Time constant 2	70	70	s
	Partial fraction factor	25	25	%
	Warning limit	80	80	%
	Error limit	100	100	%
	Error reaction	1: Shut down on error ...	1: Shut down on error l...	
P-0-0063	Thermal motor utilization	0		%

Time constant 1

Represents the thermal time constant of the motor (stator and housing). It can typically be taken from the motor manual.

Time constant 2

Represents the thermal time constant of the winding. In the case of Beckhoff motors, the value of this time constant exists both in the electronic name plate and in the motor data sets.

Partial fraction factor

Divides the thermal resistance.

Warning limit

The threshold value for a warning output can be set here. The warning allows a motor overload to be detected at an early stage. The user can react, for example, with an (automated) load adjustment.

The reaching of the warning limit can be read from S-0-0012 – Class 2 diagnostic (C2D) bit 2. A pending C2D error is also displayed in S-0-0135 Drive Status Word bit 12.

Error limit

The threshold value for the error reaction can be set here.

Error reaction

If the set threshold value (error limit) is reached, one of the following error reactions can be chosen:

No.	Error response
0	The motor model is inactive (no calculation)
1	The error FD17 is generated and the associated error reaction is activated (see AX5000 diagnostic messages) (Shut down on error level)
2	Reduction of the current to the S1 characteristic of the motor (Reduction to the S1 characteristic)

IDN P-0-0063 (Thermal motor utilization)

The IDN contains the output value of the thermal motor model, which displays the utilization of the motor as a percentage.

25 Torque (Force) – Controller Structure

ℹ **Terminology**

Based on this documentation, the term that is usually used for the functional description of the torque and
force controller structure is torque controller structure. Force controller structure is used for linear motors.

ℹ **Parameters used for the torque (force) controller structure:**

S-0-0080; S-0-0081, S-0-0082, S-0-0083, S-0-0084, S-0-0092, P-0-0002; P-0-0074, P-0-0092, P-0-0094, P-0-0454, P-0-0459, P-0-0465, P-0-0505

25.1 Functionality from firmware v2.10

ℹ **Torque-Interface!**

If the torque interface is active, the torque setpoint (S-0-0080) must be mapped directly in the process data. The mapping then enables these process data to be linked externally (NC / CNC / PLC).

The torque control structure is realized through a current controller and a proportionality relationship between current and torque. The torque controller structure enables the torque requirement of the higher-level velocity controller to be met. The characteristic torque/current curve therefore maps the motor characteristics (saturation effect).
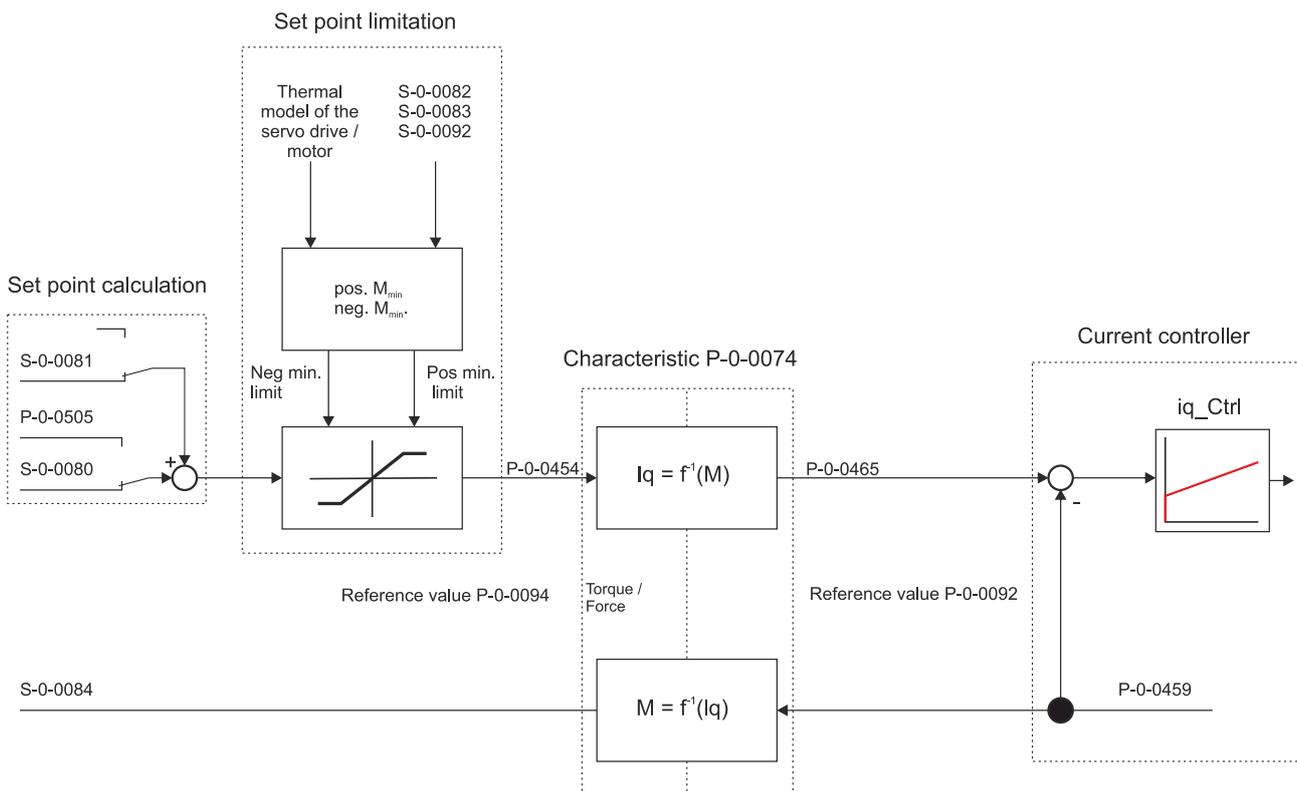
This results in the following relationships for representing the torque:

$$Act\_torque \ [Nm] \ = \ S\text{-}0\text{-}0084 \ [‰] \ \cdot \ \frac{P\text{-}0\text{-}0094}{1000} \left[\frac{Nm}{‰} \right]$$

25.1.1 Setpoint value calculation

Depending on the set operation mode (S-0-0032), the set value is either generated in the velocity controller (P-0-0505) or provided directly via the torque interface (S-0-0080). The pre-control value (S-0-0081) is then added.

25.1.2 Setpoint limiting

Setpoint limiting (see block diagram on page 1) affects the torque setpoint. Limiting is unipolar positive (S-0-0082), unipolar negative (S-0-0083) and bipolar (S-0-0092).

25.1.3 Motor torque characteristic

The required current setpoint is determined in relation to the torque setpoint, based on the motor torque characteristic. This current setpoint is then fed to the current controller. The actual torque for the actual current is also based on the motor torque characteristic. When the torque controller is used with Beckhoff motors, the data required for the motor torque characteristic are included in the electronic type plate or the motor data files (.xeds).

If the precise motor characteristics (saturation effects) are not available via the motor torque characteristic (blue curve), an approximation based on the diagram shown below is used.
This approximated function (based on linear interpolation) is formed from the IDNs:

- P-0-0070, P-0-0073, S-0-0111 and S-0-0109 for rotary motors and
- P-0-0126, P-0-0128, S-0-0111 and S-0-0109 for linear motors

(see red characteristic curve).
If only the standstill torque (P-0-0070) with corresponding standstill current (S-0-0111) is available, a conversion is performed via K_{T0} (green characteristic curve).
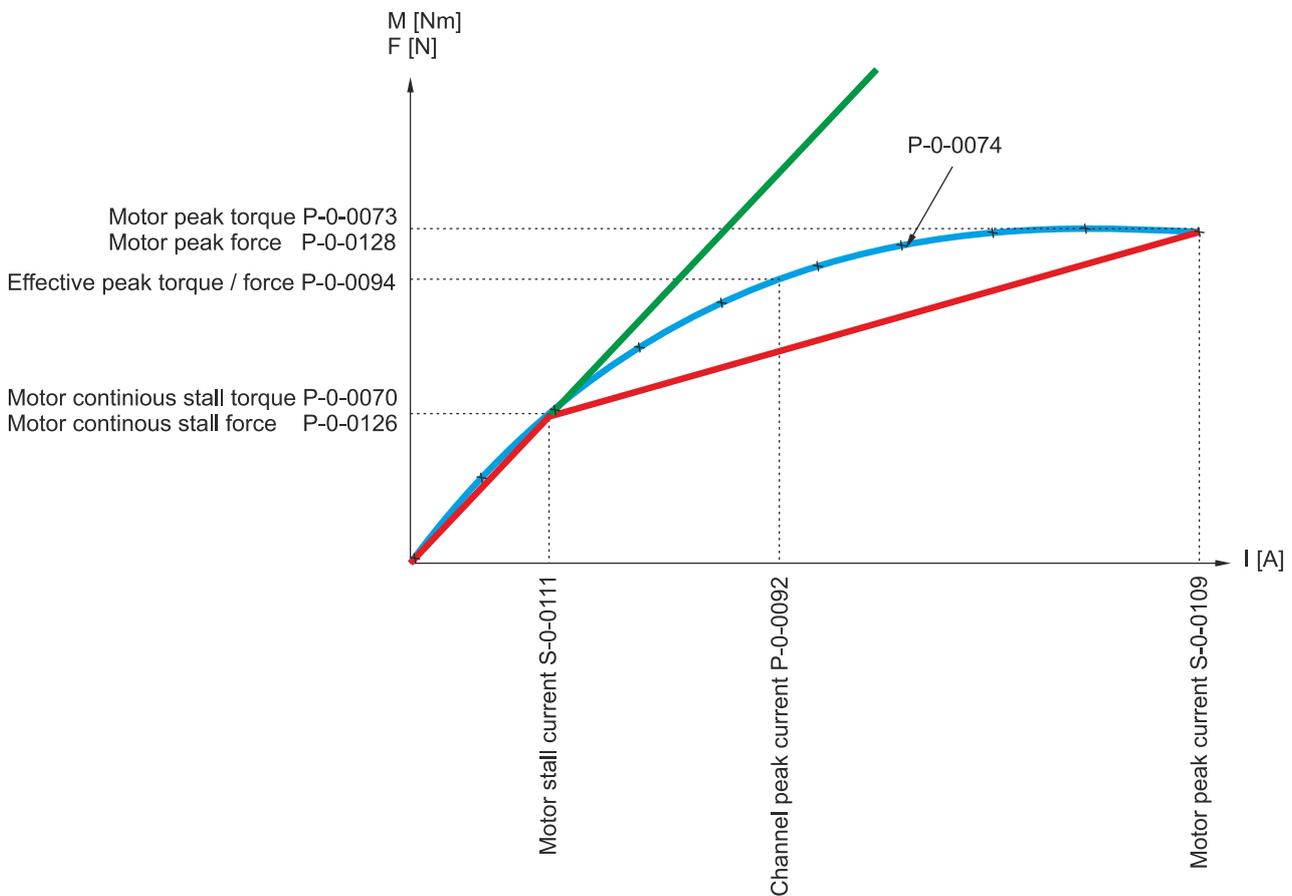
25.1.4 Current controller

The current controller represents the inner controller of the cascading control loop structure. Based on field-oriented control, an advanced PI controller provides the current components required for the requested operation mode S-0-0032. The q-current is proportional to the torque (for linear motors it is proportional to the force). The settings for the current controller parameters K_p and T_N are based on the motor winding data and the optimum bandwidth (compromise between dynamics and noise generation).

For Beckhoff motors the settings for the optimum bandwidth are taken from the electronic type plate (or offline from the motor data files *.xeds). For the most applications these settings can be left unchanged. The motor data generator can be used to create motor data files for third-party motors.

Corresponding pre-controls are applied to deal with systematic interference:

- Load and mains voltage-dependent fluctuations of the DC link voltage
- Induced motor voltage and
- Voltage over the winding inductance.

25.1.4.1 Generation of the output voltage

Generation of the output voltage for the AX5000 servo drive is based on a PWM clock frequency of 8 kHz. In order to reach an acceptable compromise between power loss and requirements for the insulation system of the motor, the AX5000 operates with a maximum rate of voltage rise (d_u / d_t) of 5 kV per µs.

● IDN P-0-0001 (Switching frequency of the IGBT module)

ℹ Further information on the clock frequency of the AX5000 servo drive can be found in the description of the IDN parameters (www.beckhoff.com) under:
P-0-0001 (Switching frequency of the IGBT module).

The voltage profile at the servo drive output described above results in certain requirements for:

- the cable configuration,
- the cable length and
- the insulation system of the motor.

If Beckhoff cables and motors are used, all requirements are met, based on the procedures described in chapter „Motors and cables for servo drives".

● EMC-compliant commissioning

ℹ Further information on EMC-compliant commissioning can be found in the AX5000 EMC leaflet, which is available on the Beckhoff website (www.beckhoff.com).

25.2 Functionality up to firmware v2.06

ⓘ **Description of the function blocks**

All firmware v2.06 function blocks that were not described specifically (lower diagram) are equivalent to the function blocks of the block diagram for firmware v2.10.

The current controller structure enables the current requirement of the speed controller to be met. This current is proportional to the torque. Conversion according to the individual motor characteristic (P-0-0074) enables the required current to be determined. It depends on the requested torque, which in firmware v2.06 is provided in the form of a current. This current is proportional to the torque.
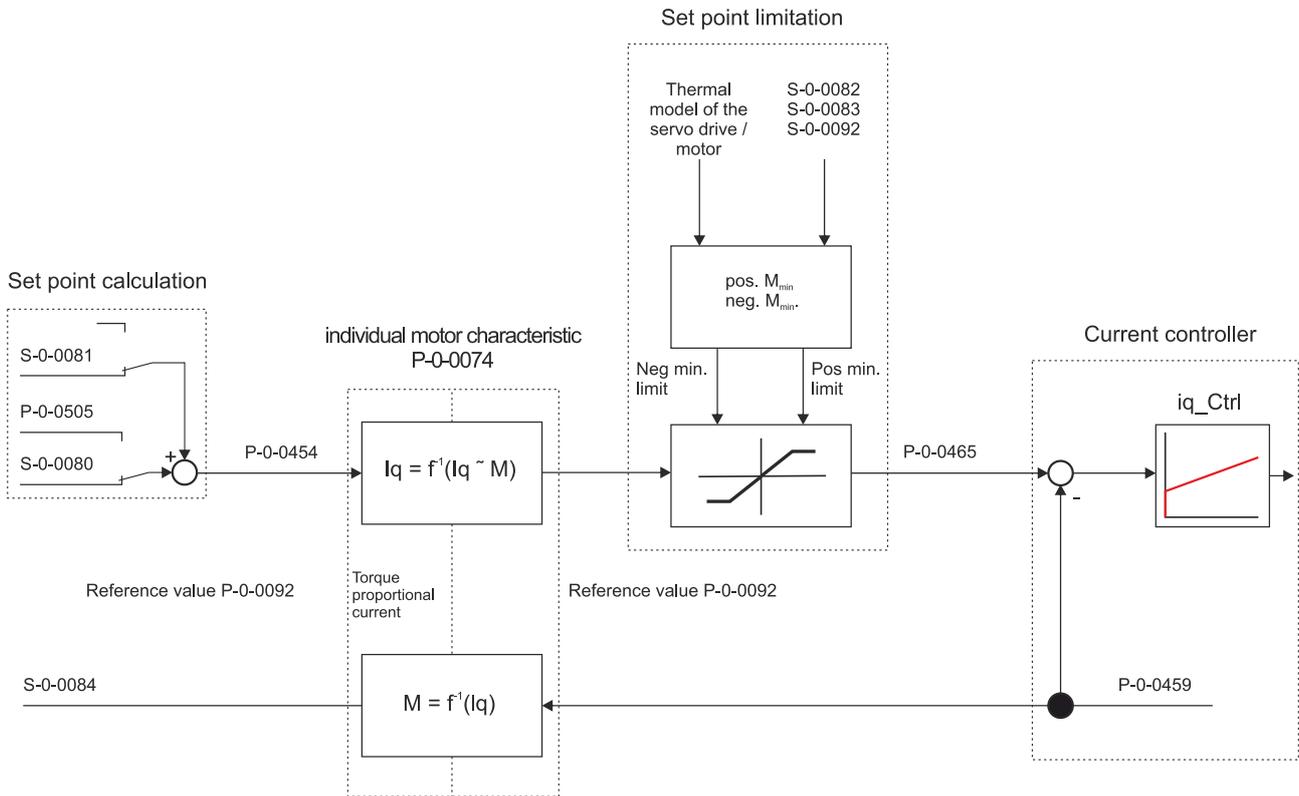
This results in the following relationship for representing the torque:

$$Act\_torque~[Nm]~=~S\text{-}0\text{-}0084~[\permil]~\cdot~\frac{P\text{-}0\text{-}0092}{1000}\left[\frac{A}{\permil}\right]~\cdot~K_{T0}~\left[\frac{Nm}{A}\right]$$

25.3 Parameter description

IDN P-0-0074 (Motor torque characteristic)

The parameter contains 10 ordered pairs of numbers. They describe the relationship between torque-forming current and torque, as a function of $M = f(I_q)$.

IDN P-0-0092 (Configured channel peak current)

Preset peak current of the channel. The peak current is usually preset to twice the rated motor current.

Unit: ampere (A)

IDN P-0-0094 (Configured channel peak torque)

Preset peak torque of the motor. The peak torque depends on the control parameter. The parameter is related to the motor characteristics and parameter P-0-0092 (from firmware v2.10).

Unit: newton meter (Nm)

IDN P-0-0454 (Effective torque command value)

Set torque value based on parameter P-0-0094. This parameter matches parameter P-0-0456 (actual motor current phase).

Unit: per thousand; one-tenth of a per cent (‰)

IDN P-0-0459 (Actual torque generating current)

Actual value of torque-forming current, based on parameter P-0-0092. This parameter matches the actual torque value S-0-0084. The parameters are related via the motor characteristics.

Unit: ampere in ‰

IDN P-0-0465 (Effective current command value)

Instantaneous set current value, based on parameter P-0-0092. This parameter matches the set torque value P-0-0454. The parameters are related via P-0-0454 and P-0-00465.

Unit: ampere in ‰

IDN P-0-0505 (Velocity controller output)

Output value of the torque controller, based on parameter P-0-0094. The parameter is only used during commissioning of the higher-level speed controller (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0081 (Additiv torque command value)

Pre-control value for acceleration pre-control. This value is added directly to parameter P-0-0505 and indicates a torque based on parameter P-0-0094. The parameter is only used during commissioning of the higher-level speed controller (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0082 (Positive torque limit value)

The parameter limits the set torque/force value of the controller. The upper positive limit is specified (unipolar pos.). If this limit is exceeded, the drive sets bit 3 of S-0-0013.

The reference value is P-0-0092 and P-0-0094 (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0083 (Negativ torque limit value)

The parameter limits the set torque/force value of the controller. The lower negative limit is specified (unipolar neg.). If the value falls below this, the drive sets bit 3 of S-0-0013.

The reference value is P-0-0092 and P-0-0094 (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0084 (Torque feedback value)

Actual value of torque current, based on parameter P-0-0094. The parameters are related via the motor characteristics. (from firmware v2.10)

Unit: ampere in ‰

IDN S-0-0092 (Bipolar torque limit value)

The parameter limits the set torque/force value of the controller. The lower negative (bipolar neg.) and upper positive (bipolar pos.) limit is specified. The lowest value of all set limits applies.

The reference value is P-0-0092 and P-0-0094 (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0109 (Motor peak current)

Peak current of the motor (according to data sheet)

Unit: ampere (A)

IDN S-0-0111 (Motor continuous stall current)

Standstill current of the motor (according to data sheet)

Unit: ampere (A)

26 Variable position interface

i

Reference values for the variable position interface:

S-0-0051; S-0-0053; S-0-0079

If the AX5000 is to transfer a single-turn position with a resolution of more than 20 bits to the controller, the variable position interface must be used.

The position of the axis is recorded in the AX5000 and handed over to the controller in S-0-0051 with a data length of 32 bits. Parameter S-0-0079 (Position Resolution) now specifies how many of these 32 bits are used for the single-turn range in S-0-0051* (Position feedback value 1). The remaining bits form the variable multi-turn range.

*This function also exists in S-0-0053 (Position feedback value 2).

26.1 Functionality from firmware v2.10

From AX5000 firmware v2.10 S-0-0079 is writeable and can be parameterized between 2^{20} bits and 2^{30} bits. The single-turn position length in S-0-0051 and S-0-0053 can thus be set from 20 to 30 bits. That results in the multi-turn position length with 12 − 2 bits. Note that both ranges always change. If the single-turn resolution is increased, the maximum multi-turn count value is reduced.

MT: 12 - 2Bit   +   ST: 20 - 30Bit   = 32Bit
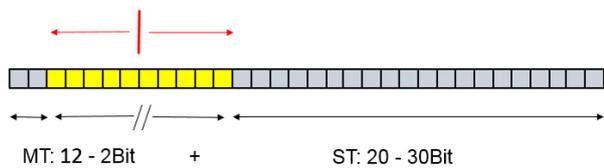
Captions

Yellow area	= variable range
Grey area	= permanently assigned range
MT	= Multi-turn range
ST	= Single-turn range

Commissioning
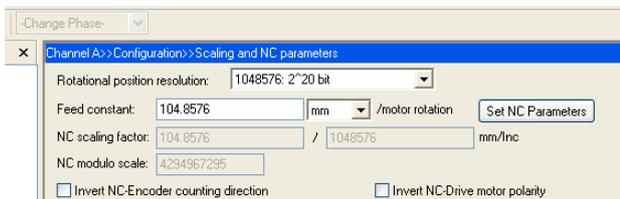
Parameter S-0-0079 (Position Resolution) can be adjusted via the TC Drive Manager. To do this, go to the corresponding (controller) channel → Configuration → Scaling and NC parameters.
This value (data length) can be manually set by the user in the TC Drive Manager.
The default value for parameter S-0-0079 is 1048576 (2^{20}) and corresponds to a 20-bit single-turn range.

If parameter S-0-0079 is changed via the TC Drive Manager, the changes necessary for NC take place automatically.
The following values are then changed in the NC axis under the object Enc (Encoder):

- Scaling Factor Denominator
- Encoder Sub Mask

If parameter S-0-0079 is changed manually and not via the TC Drive Manager, note that a decimal number is used there which corresponds to 2^n, where n = [20-30]. The PLC function block FUNCTION_BLOCK FB_SoEwrite is used for manual configuration of the parameter S-0-0079.

The following possible values thus result:

| max. single-turn resolution in bits	Number in S-0-0079
20	1048576
21	2097152
22	4194304
23	8388608
24	16777216
25	33554432
26	67108864
27	134217728
28	268435456
29	536870912
30	1073741824

26.1.1 Rotary feedback sample

A multi-turn feedback system with 23-bit single-turn and 12-bit multi-turn is used. If the position resolution is left at 20 bits, then 20 bits single-turn and 12 bits multi-turn are transmitted to the controller.

If the position resolution is changed to 23 bits, then 23 bits single-turn and 9 bits multi-turn are transmitted to the controller. The maximum multi-turn range is thus reduced to 9 multi-turn bits ($U_{max} = 2^9 = 512$).

26.1.2 Linear feedback sample

An absolute feedback system with a resolution of 5 nm is used together with a linear motor with a 24-mm pole pitch (see technical data for the linear motors). This results in 4.8 million increments per electrical revolution** (24 mm / 5 nm). In order to measure this, Position Resolution must be set to at least 23 bits (8.3 million increments). The maximum explicit travel range is thus reduced to 9 multi-turn bits ($S_{max} = 2^9$ x 24 mm = 12288 mm).
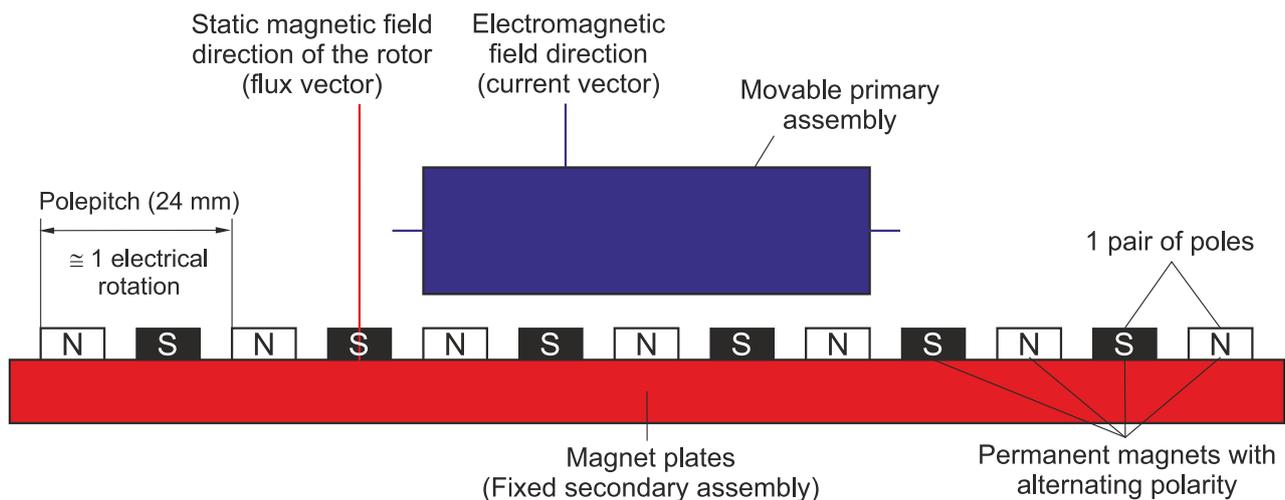
**An electrical revolution is defined in the case of a linear motor by the pole pair distance of the individual magnets. This electrical revolution is schematically illustrated in the picture above. For further information we recommend that you read the section "Commutation method".

27 Velocity - Controller Structure

ⓘ **Terminology**

The terminology used in this documentation primarily refers to rotary motors (e.g. actual velocity value).

ⓘ **Reference values for the velocity controller structure:**

S-0-0032; S-0-0036; S-0-0037; S-0-0040; S-0-0081; S-0-0084; S-0-0091; P-0-0003; P-0-0504; P-0-0505; P-0-0514 P-0-0519; P-0-0523; P-0-0524; P-0-0558

27.1 Functionality from firmware v2.10

ⓘ **Velocity-Interface!**

If the velocity interface is active, the velocity command value (S-0-0036) must be mapped directly in the process data. The mapping then enables these process data to be linked externally (NC / CNC / PLC).

The velocity controller structure is realized via velocity controllers and modules for determining the actual velocity value. The velocity controller structure enables compliance with the speed requirements of the higher-level position controller.
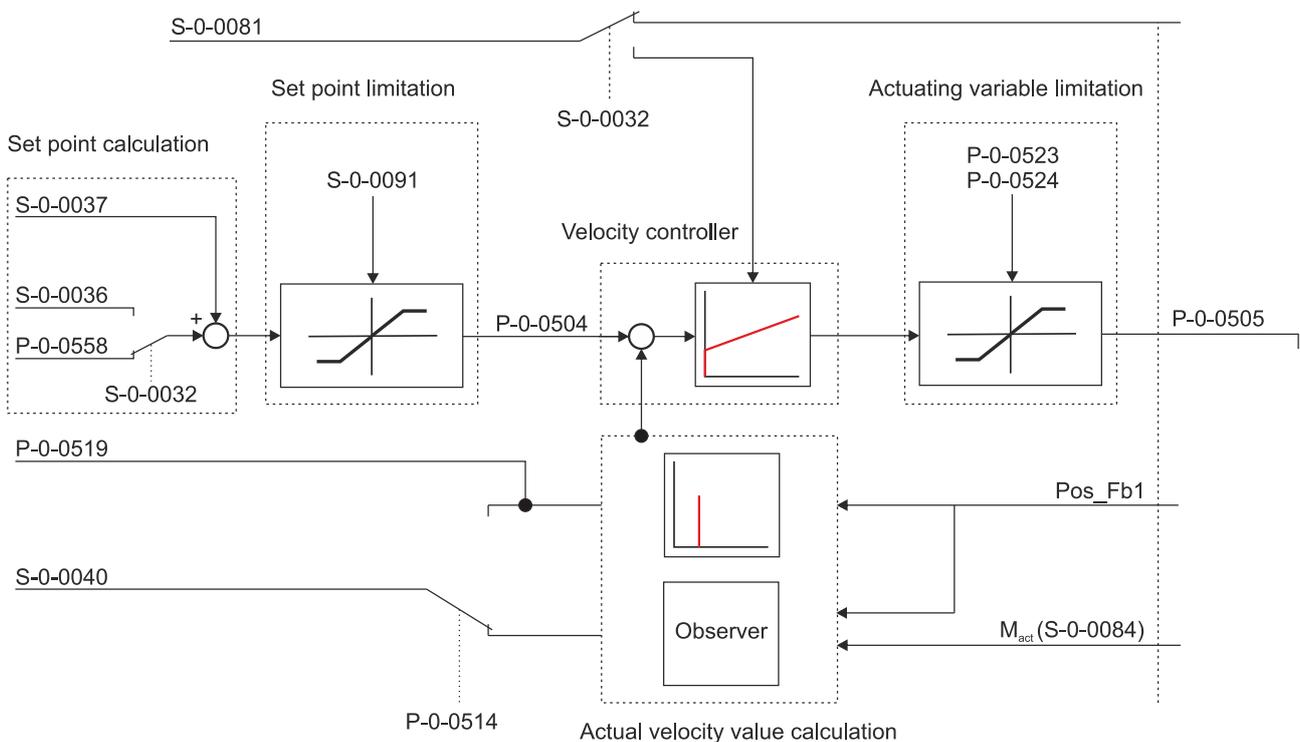
This results in the following relationship for the velocity values:

$$velocity\_feedback\_value~[rpm] ~=~ S\text{-}0\text{-}0040 \left[\frac{rev}{2^{30}ms}\right] \cdot \left(\frac{60 \cdot 1000}{2^{30}}\right)$$

Parameter P-0-0519 contains the result of the differentiation of the position signal. It has the same units as parameter S-0-0040. The origin of parameter S-0-0040 depends on the settings in parameter P-0-0514.

27.1.1 Setpoint value calculation

Depending on the set operation mode (S-0-0032) the control value (P-0-0558) for the position controller is provided as velocity command value or directly from the interface (S-0-0036). The pre-control value (S-0-0037) is then added.

27.1.2   Setpoint limiting

Setpoint limiting (see block diagram on page 1) affects the velocity command value. The limitations are bipolar (S-0-0091).

27.1.3   Velocity controller

i   The „Velocity controller" section is currently still in preparation and will be released as soon as possible.

27.1.4   Determining the actual velocity value (differentiation)

In the AX5000 a speed signal is calculated from the position signal of the motor feedback (through mathematical differentiation). This signal quickly responds to changes, but it contains noise and can surge in the presence of mechanical resonances. Mapping takes place in parameter P-0-0519.

27.1.5   Determining the actual velocity value (Velocity Observer)

i   **Reference values of the Velocity Observer:**

S-0-0040; S-0-0109; S-0-0111; P-0-0070; P-0-0071; P-0-0073; P-0-0074; P-0-0126; P-0-0127 P-0-0128

An Observer is a system for representing parameters that are difficult to measure, based on a model and known input and measured variables.

For frequencies above around 300 Hz the noise associated with the velocity signal calculated from the feedback becomes problematic. The Velocity Observer of the AX5000 is used to solve this problem. It estimates the acceleration from the measured current and from this the speed signal (through numerical integration). This speed signal is smoother and less susceptible to mechanical resonances.

When the Velocity Observer is used, up to the set bandwidth the velocity controller takes into account the speed signal calculated from the feedback, at higher frequencies it takes into account the speed signal estimated from the torque-forming current. The purpose of the Velocity Observer is to provide the velocity controller with a speed signal without resonance-induced oscillations over a wide frequency range. It acts similar to a low-pass filter, but without the disadvantage of a phase shift.

The result of the actual velocity value determination with the aid of the Velocity Observer is mapped in parameter S-0-0040.
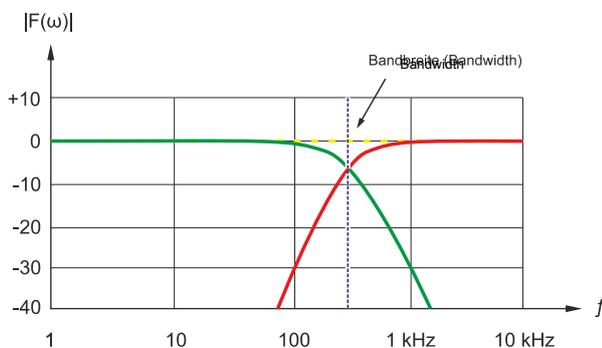
i   **Velocity Observer settings and internal filters!**

Further information about Velocity Observer settings and a detailed description of the procedure can be found below in this section.

Further information about the filter types mentioned above can be found in chapter: „Control quality – internal filters [▶ 66]" in the function manual for the AX5000 servo drive.

Functionality from firmware v2.10

From firmware v2.10, in addition to a third-order observer ("Basic mode"), a fifth-order observer ("Advanced mode") is available for special applications.

In Basic mode the position signal calculated from the velocity signal is attenuated with 20 dB / decade above the bandwidth. In Advanced mode attenuation takes place with 60 dB / decade.

Both versions, basic and advanced, operate with the cycle of the velocity controller (default setting 16 kHz).

glatter Amplitudengang ohne Phasenverschiebung
smooth amplitude response without phase shift

Hochpass gefilterte Geschwindigkeit aus mechatronischen Model
High-pass filtered velocity from mechatronic model

Tiefpass gefilterte Geschwindigkeit aus dem Feedback-Signal
Low-pass filtered velocity from the feedback signal

27.1.5.1 Prerequisites for the operation

Since the Velocity Observer estimates the axis acceleration from the current, it needs the value of the moment of inertia. This motor value is entered in parameter P-0-0071 or P-0-0127 (only for linear motors) when the motor is selected.

The value for the load must be added there:

P-0-0071	Mechanical motor data		
	Rotor moment of inertia	4.08	*0.0001 kgm^2
	Load moment of inertia	0.00	*0.0001 kgm^2

If the correct value is unknown, it should be estimated. Common values for the moment of inertia ratio between load and motor are in the range 3 - 10.

27.1.5.2 Adjustment procedure

For most applications it is beneficial to use the Velocity Observer in basic mode. The bandwidth should be left at the default value of 500 Hz. The diagram below illustrates the effect of activating the Velocity Observer with the default settings in the oscilloscope:

The recording originates from a linear axis with ball screw. The green line shows the actual velocity in mm/s. The Observer was activated at the black vertical line.

The Bode diagram shows that system peaking at approx. 380 Hz disappears after activation of the Velocity Observer, since the open-loop phase shift is lower with activated Velocity Observer from approx. 100 Hz. The result is a larger phase margin:
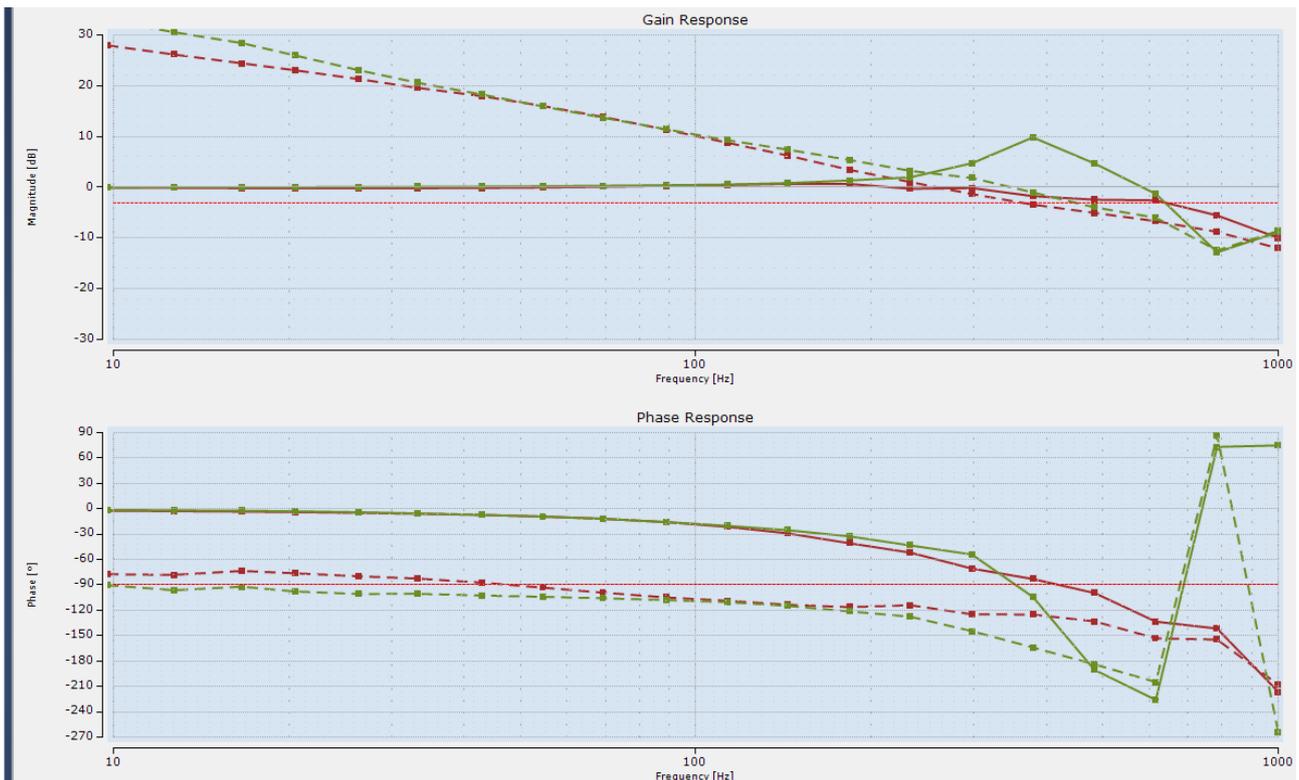
The green line was recorded with the Observer switched off, the red line with the Observer switched on. The dashed line shows the open-loop phase shift.

If interfering resonances occur in the lower frequency range, it may be useful to reduce the bandwidth of the Velocity Observer. For axes with very rigid coupling between motor and load it may be useful to increase the bandwidth.

Advanced Mode

Advanced mode is recommended for axes with high narrow-band resonance frequencies, for which a notch filter is considered. The bandwidth of the Velocity Observer should be lower than the resonance frequency by a factor 2 ... 3.
Compared with the notch filter, the Velocity Observer benefits from a greater tolerance, even though the resonance frequencies can vary somewhat over time, or depending on the position.

27.1.5.3 Practical example

Request:

The spindle of a machine tool has a resonance frequency at 800 Hz.
In advanced mode the bandwidth of the Velocity Observer is set to 300 Hz.

Aim of the setting:

The Velocity Observer should improve the bandwidth of the velocity controller. Once the velocity controller has been "calmed", e.g. by reducing the Velocity Observer bandwidth, one can try increasing the proportional gain, in order to achieve a better response of the velocity controller.

27.1.5.4 Description of IDN P-0-0514

P-0-0514	Velocity observer		
	Mode	0	
	Bandwidth	500	Hz
	Correction factor Iq to Acc	1.000	
	Damping	0.700	

Mode

Default value: 1 Basic Observer

Here you can choose between the following settings:

- 0: Off = Velocity Observer not active
- 1: = Basic Velocity Observer active in basic mode (3rd order)
- 2: = Advanced Velocity Observer active in advanced mode (5th order) (from firmware 2.10)

Bandwidth

Default value: 500 Hz

Here you can set the bandwidth of the Velocity Observer. The filter effect can be intensified by reducing the bandwidth. Increasing the bandwidth reduces the filter effect. At low bandwidth the speed signal is very smooth, although in this case any interference takes longer to compensate.

A higher bandwidth enables faster correction of faults. The associated higher bandwidth of the velocity controller causes a larger current ripple.

The basic rule:

The higher the resolution and quality of the motor feedback system used, the higher the bandwidth can be set.

Correction factor Iq to ACC

Default value: 1

If the moment of inertia for the motor and the load is set correctly in P-0-0071 or P-0-0127 (only for linear motors), the Observer can correctly calculate the axis acceleration from the measured current value:

$$\frac{d\omega}{dt} = \frac{M(i)}{JLast + JMotor} \times Correction\ factor$$

The Observer uses the table $M = M(i)$ stored in P-0-0074.

ℹ️ Torque/current characteristic curve P-0-0074

Further information about the torque/current characteristic curve P-0-0074 can be found in chapter: „Torque (force) controller structure [▶ 118]" of this function manual.

The equation indicates that the calculated acceleration value is too large if the value for J_{load} is too small and vice versa. Depending on the load and coupling type between motor and load, part of the load may become decoupled at frequencies above the Observer bandwidth and may then no longer be active. The "Correction factor" can be increased, in order to compensate this. The value for the full moment of inertia of the load is also required for the acceleration pre-control [▶ 24] and should therefore be entered as precisely as possible. If the acceleration pre-control [▶ 24] was enabled, the correct value for the moment of inertia can be determined. It is the value at which the pre-control works perfectly with the 100% setting. The optimum value for the "Correction factor Iq / Acc" can be determined using a Bode diagram for the velocity controller.

Damping

Default value: 0.7

The value can only be changed in basic mode. The default value of 0.7 should remain unchanged, if possible.

27.1.5.5   Velocity Observer parameter description

IDN P-0-0070 (Motor continiuous stall torque)

Standstill torque of the motor (according to data sheet)
Unit: newton meter (Nm)

IDN P-0-0071 (Mechanical Motor Data)

Rotor moment of inertia of the motor (from the electronic type plate) and motor-related moment of inertia of the load (to be entered by the user).
Unit: kgcm²

IDN P-0-0073 (Motor peak torque)

Peak torque of the motor (according to data sheet)
Unit: newton meter (Nm)

IDN P-0-0126 (Motor continiuous stall force)

Standstill force of the linear motor (according to data sheet)
Unit: Newton (N)

IDN P-0-0127 (Mechanical Linear Motor Data)

Weight of the coil unit of the linear motor (from the electronic type plate) and weight of the load (to be entered by the user).
Unit: Kilogram (kg)

IDN P-0-0128 (Motor peak force)

Peak force of the linear motor (according to data sheet)
Unit: Newton (N)

IDN S-0-0109 (Motor peak current)

Peak current of the motor (according to data sheet)
Unit: ampere (A)

IDN S-0-0111 (Motor continuous stall current)

Standstill current of the motor (according to data sheet)
**Unit:** ampere (A)

27.1.6   Control value limiter

The set value limitation affects the control value of the velocity controller. The limitations are unipolar positive (P-0-0523) and unipolar negative (P-0-0524). The limited control value can be read via P-0-0505.

27.2 Functionality up to firmware v2.06

● **Description of the function blocks**

ℹ All firmware v2.06 function blocks that were not described specifically (lower diagram) are identical to the function blocks of the block diagram for firmware v2.10.
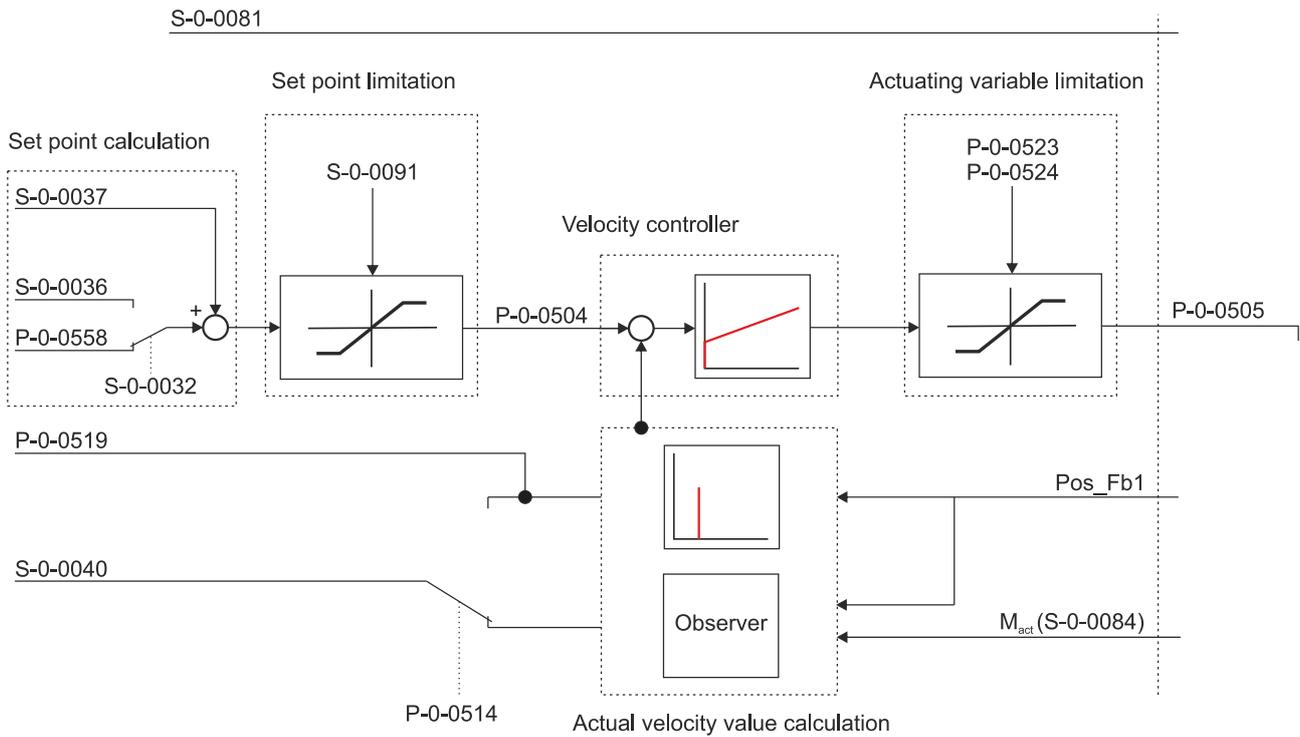
This results in the following relationship for the velocity:

$$velocity\_feedback\_value \ [rpm] \ = \ S\text{-}0\text{-}0040 \left[\frac{rev}{2^{30}ms} \right] \cdot \left(\frac{60 \cdot 1000}{2^{30}} \right)$$

Parameter P-0-0519 contains the result of the differentiation of the position signal. It has the same units as parameter S-0-0040. The origin of parameter S-0-0040 depends on the settings in parameter P-0-0514.

27.2.1   Determining the actual velocity value (Velocity Observer)
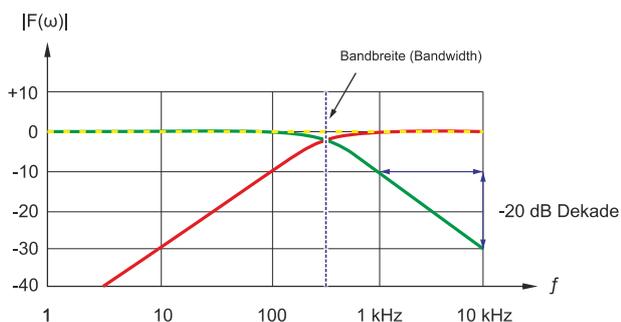
Functionality up to firmware v2.06

Up to firmware v2.06 there is a third-order Observer ("Basic mode").

Above the bandwidth the velocity signal calculated from the position signal is attenuated with 20 dB per decade.

The Observer operates with the cycle of the velocity controller (default setting 8 kHz).

27.3 Parameter description

IDN S-0-0036 (Velocity command value)

In the velocity controller, velocity command values are transferred cyclically from the controller to the servo drive via this parameter. The cycle time is specified in parameter S-0-0001.

Unit: $rev/(2^{30}ms)$

IDN S-0-0037 (Additive velocity command value)

The parameter contains the additive velocity command value. This is cyclically added to parameter S-0-0036 (velocity command value), if the controller provides the value.

Unit: $rev/(2^{30}ms)$

IDN S-0-0040 (Velocity feedback value 1)

The parameter contains the actual velocity value. It is determined from the signals of feedback system 1. If a Velocity Observer is active, the signal of feedback system 1 is transferred by the Velocity Observer.

Unit: $rev/(2^{30}ms)$

IDN S-0-0081 (Additiv torque command value)

Pre-control value for acceleration pre-control. This value is added directly to parameter P-0-0505 and indicates a torque based on parameter P-0-0094. The parameter is only used during commissioning of the higher-level velocity controller (from firmware v2.10).

Unit: per thousand; one-tenth of a per cent (‰)

IDN S-0-0091 (Bipolar velocity limit value)

This parameter limits the velocity command value of the drive. This parameter defines the upper (positive) and lower (negative) limit. The lowest value of all set limits applies.

Unit: $rev/(2^{30}ms)$

Further information on IDN P-0-0514 can be found under: .

28 Axis deceleration ramps

⚠ **DANGER**
Serious injuries caused by moving axes!
The deceleration ramps of the AX5000 servo drive are purely functional and **not** suitable for personal protection purposes!
A fault in the drive system may have the following effects:
- it may not be possible to enable the functional deceleration ramps;
- it may not be possible to bring the axes to a standstill.
In other words, the axes may **not** respond. This could cause serious injury.
Before commissioning ensure that all external personal protection measures were applied.

The AX5000 servo drive has functional deceleration ramps, which brake or coast down the connected motors in the event of fault.

Both ramps are configured via the parameters:

- S-0-0372 (Drive Halt Acceleration Bipolar) and
- S-0-0429 (Emergency Stop Deceleration)

.

When configuring the parameters, the braking energy balance of the whole system has to be taken into account. Mechanical and electrical limits affect the maximum deceleration.

Electrical limits result from:

- **the available current**
  The torque available for braking the axes depends on the maximum current limit. This determines the shortest possible deceleration time.
- **the absorption of regenerative energy (generated during braking)**
  The energy is first absorbed by the DC link. When this is saturated, energy is fed to the internal or external braking resistors. The capacity of the internal and/or external braking resistors indicates for how long the energy returned from the DC link can be converted to heat. This increases the deceleration time.

Testing the deceleration ramps

During operation the deceleration ramps are activated automatically in the event of an error reaction of the drive system. To assess these processes, it is necessary to trigger and test the functional ramps manually during commissioning.

Proceed as follows:

Parameter S-0-0372 (Drive Halt Acceleration Bipolar)

- Trigger the manual process via bit 14 "*Enable Drive*" in parameter S-0-0134 (master control word).

Parameter S-0-0429 (Emergency Stop Deceleration)

- Trigger the manual process via parameter P-0-0310 (error reaction verification)
  "*Force error reaction: Closed loop ramp*".

ⓘ **Further information on axis deceleration ramps.**

Settings and configuration instructions for the deceleration ramps can be found in this manual under digital inputs and outputs [▶ 35] → hardware enable [▶ 36] and limit switch monitoring [▶ 37].

29 Requirements for torque control

29.1 Function

To be able to use the TwinCat function block FB_TorqueControl, additional settings must be made on the servo drive. The following chapter explains these settings.

29.2 Requirement

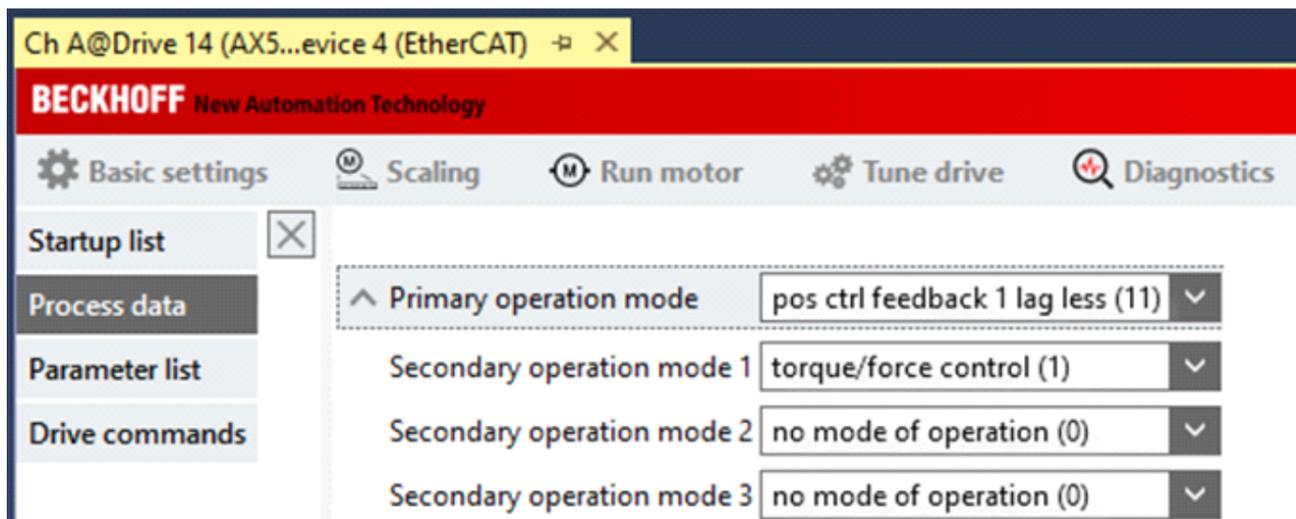> **ⓘ** **Important preparations for using torque control**
>
> The following preparations must be made before use:
> - Install firmware 2.14 or newer
> - Commissioning the servo drive
> - NC axis is scaled and can be moved

29.3 Configuration

29.3.1 Operation modes

In the "Basic settings" under the "Process Data" tab, the following options are to be selected:

| Operation mode	Selection
Primary operation mode	pos ctrl feedback 1 lag less (11)
Secondary operation mode 1	torque/force control (1)

29.3.2   Extend process data

Under the "Advanced" tab (1) in the "Process data" category, inputs and outputs must be added to the PDOs. To move the selection, the respective selection must be marked and moved with the right arrow (3). Refer to the following tables for the necessary settings:

29.3.2.1   Input
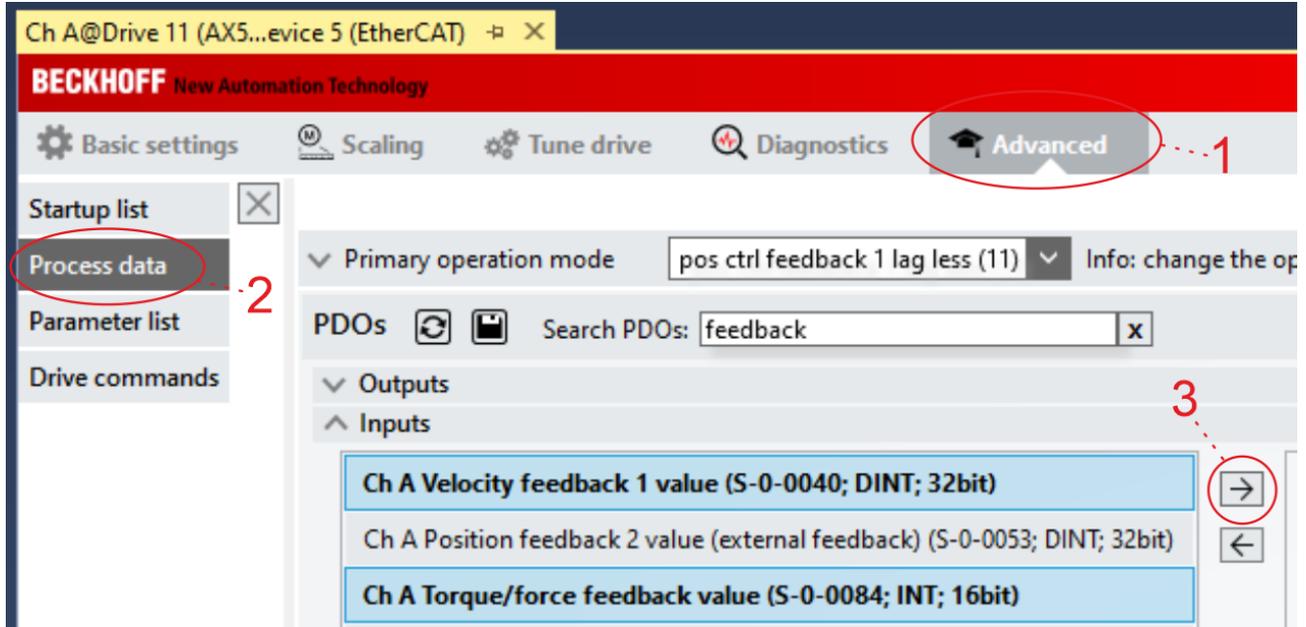
PDOs	Channel
Inputs	Ch A Velocity feedback 1 value (S-0-0040; DINT; 32bit)
	Ch A Torque/force feedback value (S-0-0084; INT; 16bit)

29.3.2.2   Output
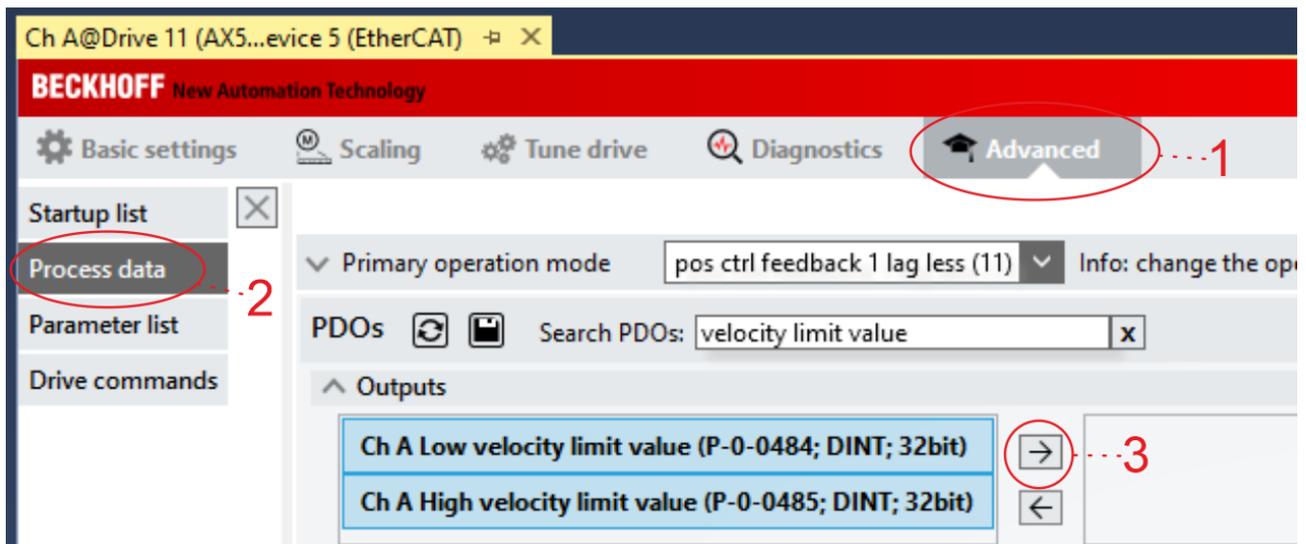
PDOs	Channel
Outputs	Ch A Low velocity limit value (P-0-0484; DINT; 32bit)
	Ch A High velocity limit value (P-0-0485; DINT; 32bit)

29.3.3 Re-Link Axis with NC

Switch to the NC axis and link again to the associated AX5000 channel.

The following links are added:

- Low velocity Limit value →"NCAxis" / Drive / Outputs / Out / nDataOut6
- High velocity Limit value →"NCAxis" / Drive / Outputs / Out / nDataOut5

29.3.4 Change parameters

To finish the setting process, you need to change the following parameter:

P486 → 1 Torque might be reduced to zero

29.4 Object description

IDN	Name	Description
P-0-0484	Ch A Low velocity limit value	This IDN shall provide the low velocity limit value in extended torque mode.
P-0-0485	Ch A High velocity limit value	This IDN shall provide the high velocity limit value in extended torque mode.
P-0-0486	Torque limitation option code	This IDN shall indicate the torque limitation modes of the extended torque mode.
S-0-0040	Ch A Low velocity feedback 1 value	The velocity feedback 1 value can be transferred from the drive to the control unit. The velocity feedback 1 value refers to the motor feedback. In case of using the observer the observed velocity is provided. Scaling see S-0-0036.
S-0-0084	Ch A Torque/force feedback value	The torque/force feedback is providing the actual torque/force to the control unit.

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