BECKHOFF New Automation Technology

Documentation | EN

EP7047-1032

Stepper motor box with incremental encoder and vector control

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1 Foreword

1.1 Notes on the documentation

Intended audience

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning these components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

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

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 prior announcement.

No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

Trademarks

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Patent Pending

The EtherCAT Technology is covered, including but not limited to the following patent applications and patents: EP1590927, EP1789857, EP1456722, EP2137893, DE102015105702 with corresponding applications or registrations in various other countries.

EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

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1.2 Safety instructions

Safety regulations

Please note the following safety instructions and explanations!
Product-specific safety instructions can be found on following pages or in the areas mounting, wiring, commissioning etc.

Exclusion of liability

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

Personnel qualification

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

Description of instructions

In this documentation the following instructions are used.
These instructions must be read carefully and followed without fail!

⚠ DANGER

Serious risk of injury!

Failure to follow this safety instruction directly endangers the life and health of persons.

⚠ WARNING

Risk of injury!

Failure to follow this safety instruction endangers the life and health of persons.

⚠ CAUTION

Personal injuries!

Failure to follow this safety instruction can lead to injuries to persons.

NOTE

Damage to environment/equipment or data loss

Failure to follow this instruction can lead to environmental damage, equipment damage or data loss.

Tip or pointer

This symbol indicates information that contributes to better understanding.

1.3 Documentation Issue Status

Version	Comment
1.0	• First release

Firmware and hardware versions

This documentation refers to the firmware and hardware version that was applicable at the time the documentation was written.

The module features are continuously improved and developed further. Modules having earlier production statuses cannot have the same properties as modules with the latest status. However, existing properties are retained and are not changed, so that older modules can always be replaced with new ones.

Documentation	Firmware	Hardware
1.0	06	00

The firmware and hardware version (delivery state) can be found in the batch number (D-number) printed on the side of the EtherCAT Box.

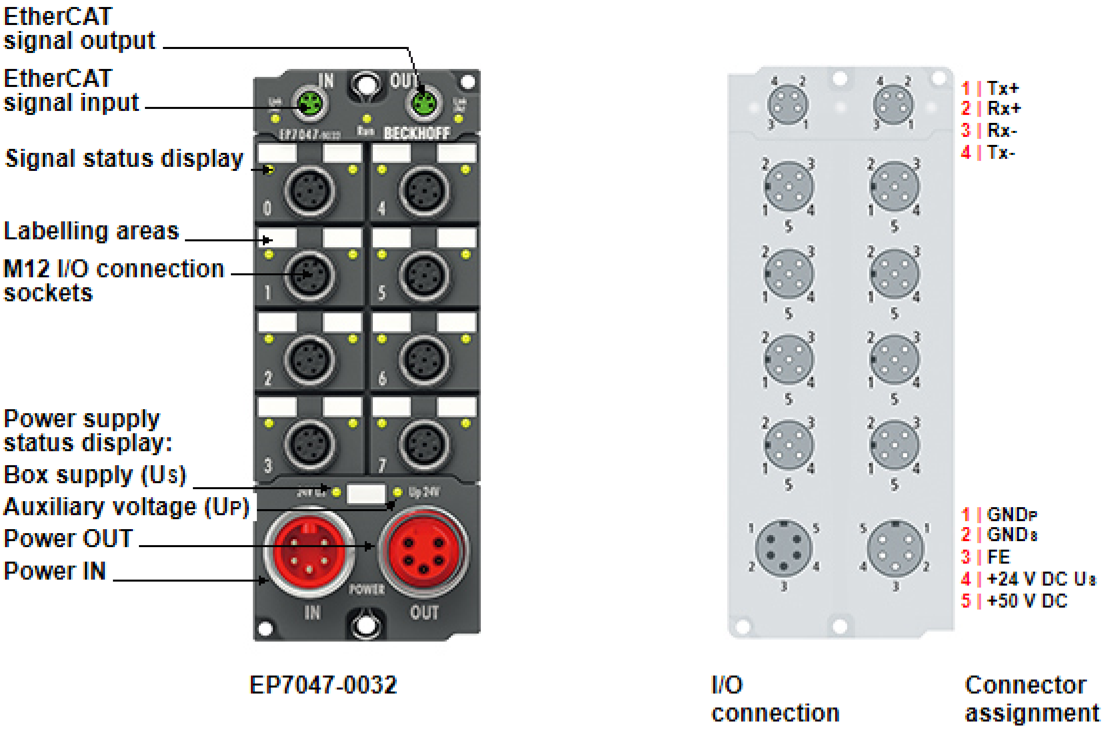
Syntax of the batch number (D-number)

D: WW YY FF HH	Example with D no. 29 10 02 01:
WW - week of production (calendar week) YY - year of production FF - firmware version HH - hardware version	29 - week of production 29 10 - year of production 2010 02 - firmware version 02 01 - hardware version 01

Further information on this topic: Version identification of EtherCAT devices [▶ 101].

2 Product overview

2.1 Introduction



Stepper motor box with incremental encoder and field-oriented control, 48 V DC, 5 A

The EP7047-0032 EtherCAT Box is designed for the medium performance range of stepper motors. The PWM output stages cover a wide range of voltages and currents. They are housed in the EtherCAT Box, together with two inputs for limit switches. The EP7047-0032 can be adapted to the motor and the application with just a few parameters. The torsionally stiff integrated encoder (1024 inc/rev) makes the AS2000 stepper motor ideal for closed-loop control of the EP7047-0032. Either a 5 V or a 24 V single-ended version can be used as an encoder.

Quick links

Technical data [▶ 9]
Process image [▶ 11]
Connections [▶ 29]
Commissioning and configuration [▶ 40]

2.2 Technical data

All values are typical values over the entire temperature range, unless stated otherwise.

EtherCAT	
Connection	2 x M8 socket, 4-pin, green
Electrical isolation	500 V

Supply voltages	
Connection	Input: 7/8" plug, 5-pin Downstream connection: 7/8" socket, 5-pin
U_S nominal voltage	24 V_{DC} (-15 % / +20 %)
U_S sum current [1)]	max. 16 A at 40 °C
Current consumption from U_S	120 mA + current consumption of connected devices: • encoder • motor brake • limit switches
U_P nominal voltage	8…48 V_{DC}
U_P sum current [1)]	max. 16 A at 40 °C
Current consumption from U_P	= current consumption of the stepper motor

Stepper motor	
Motor type	2-phase stepper motor, unipolar or bipolar
Connection	1 x M12 socket, 5-pin
Current per phase	max. 5 A (overload-proof and short-circuit proof)
Maximum step frequency	Adjustable: 1000 / 2000 / 4000 / 8000 / 16000 full steps per second
Microstepping	up to 64x [2)]
Current controller frequency	approx. 30 kHz
Resolution	approx. 5000 positions per revolution in typical applications

Encoder input	
Number	1
encoder type	Incremental encoders
Connection	1x M12 socket, 5-pin
Encoder supply	Alternatively: • 5 V_{DC}, max 0.5 A, short-circuit proof • 24 $V_{DC,}$ max. 0.5 A, *not* short-circuit proof
signals	A, B, C; single-ended (C = reference pulse / zero pulse)
Signal voltage "0"	-3…2 V
Signal voltage "1"	3.7…28 V
Pulse frequency	max. 400,000 increments per second (4-fold evaluation)

[1)] This value corresponds to the current carrying capacity of the connections for the supply voltages.

[2)] automatic switching, speed-dependent.

Digital inputs for limit switches	
Number	2
Nominal voltage high level	24 V_{DC}

Digital output for the motor brake	
Nominal voltage	24 V_{DC} from the control voltage U_S
Output current	max. 0,5 A

Environmental conditions	
Ambient temperature during operation	-25…+60 °C
Ambient temperature during storage	-40…+85 °C
Vibration / shock resistance	conforms to EN 60068-2-6 / EN 60068-2-27
EMC immunity / emission	conforms to EN 61000-6-2 / EN 61000-6-4
Protection class	IP65, IP66, IP67 conforms to EN 60529

Housing data	
Dimensions W x H x D	60 mm x 150 mm x 26,5 mm (without connectors)
Weight	approx. 440 g
Material	PA6 (polyamide)
Installation position	variable

Approvals	
Approvals	CE, UL in preparation

2.3 Scope of supply

Make sure that the following components are included in the scope of delivery:

- 1x EP7047-1032 EtherCAT Box
- 1x Protective cap for supply voltage output, 7/8”, black (pre-fitted)
- 2x protective cap for EtherCAT socket, M8, green (pre-assembled)
- 10x labels, blank (1 strip of 10)

Pre-assembled protective caps do not ensure IP67 protection

Protective caps are pre-assembled at the factory to protect connectors during transport. They may not be tight enough to ensure IP67 protection.

Ensure that the protective caps are correctly seated to ensure IP67 protection.

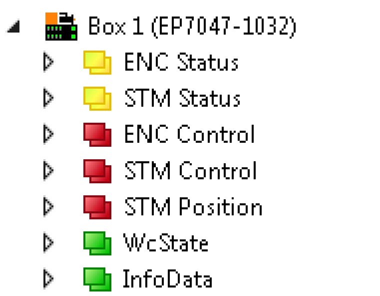
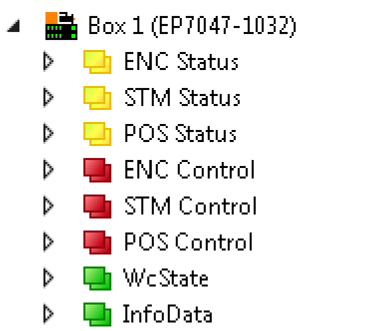
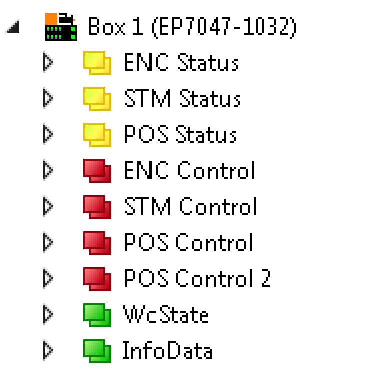
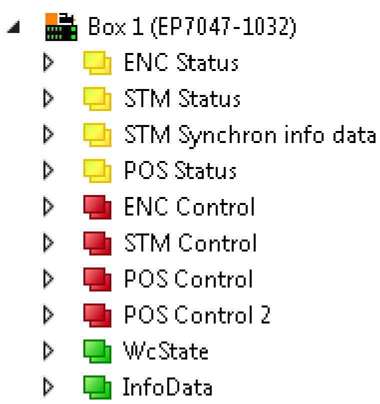
2.4 Process image

The scope of the process image is adjustable.

EP7047-1032 has several predefined variants of the process image: "Predefined PDO Assignments". Select the "Predefined PDO Assignment" according to the operating mode [▶ 45].

The factory default setting is "Velocity control compact" [▶ 12].

2.4.1 "Predefined PDO Assignments"

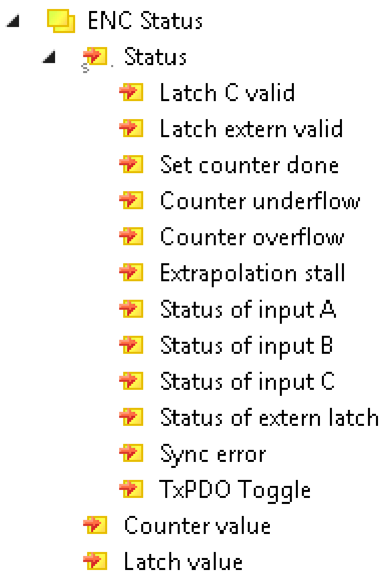
Name	Process image	Process data objects
Position control		ENC Status [▶ 13] STM Status [▶ 15] ENC Control [▶ 16] STM Control [▶ 17] STM Position [▶ 17]
Positioning interface		ENC Status [▶ 13] STM Status [▶ 15] POS Status [▶ 14] ENC Control [▶ 16] STM Control [▶ 17] POS Control [▶ 16]
Positioning interface (Auto start)		ENC Status [▶ 13] STM Status [▶ 15] POS Status [▶ 14] ENC Control [▶ 16] STM Control [▶ 17] POS Control [▶ 16] POS Control 2 [▶ 16]
Positioning interface (Auto start) with info data		ENC Status [▶ 13] STM Status [▶ 15] STM Synchron info data [▶ 15] POS Status [▶ 14] ENC Control [▶ 16] STM Control [▶ 17] POS Control [▶ 16] POS Control 2 [▶ 16]

Name	Process image	Process data objects
Positioning interface compact	Box 1 (EP7047-1032) ENC Status STM Status POS Status compact ENC Control STM Control POS Control compact WcState InfoData	ENC Status [▶ 13] STM Status [▶ 15] POS Status compact [▶ 14] ENC Control [▶ 16] STM Control [▶ 17] POS Control compact [▶ 16]
Velocity control	Box 1 (EP7047-1032) ENC Status STM Status ENC Control STM Control STM Velocity WcState InfoData	ENC Status [▶ 13] STM Status [▶ 15] ENC Control [▶ 16] STM Control [▶ 17] STM Velocity [▶ 17]
Velocity control compact (*Factory setting*)	Box 1 (EP7047-1032) ENC Status compact STM Status ENC Control compact STM Control STM Velocity WcState InfoData	ENC Status compact [▶ 13] STM Status [▶ 15] ENC Control compact [▶ 16] STM Control [▶ 17] STM Velocity [▶ 17]
Velocity control compact with info data	Box 1 (EP7047-1032) ENC Status compact STM Status STM Synchron info data ENC Control compact STM Control STM Velocity WcState InfoData	ENC Status compact [▶ 13] STM Status [▶ 15] STM Synchron info data [▶ 15] ENC Control compact [▶ 16] STM Control [▶ 17] STM Velocity [▶ 17]

2.4.2 Process data objects

2.4.2.1 "ENC status"

"ENC Status" contains the status variables of the encoder input. "ENC" is the abbreviation for "Encoder".



Status

- **Latch C valid**: A signal edge has been detected at encoder signal "C". As a result, the "Counter value" was written to the variable "Latch value" at the time of the signal edge.[1)]
- **Latch extern valid:** A signal edge was detected at the latch input X06 [▸ 36]. As a result, the counter value was written to the variable "Latch value" at the time of the signal edge.[1)]
- **Set counter done:** The value from "Set counter value" was written to the variable "Counter value" after setting of "Set counter" (ENC Control [▸ 16]).
- **Counter underflow:** The counter value "Counter value" has fallen below the value 0.
- **Counter overflow:** The counter value "Counter value" has exceeded the maximum value.
- **Extrapolation stall:** The extrapolated part of the counter is invalid ("Micro increments").
- **Status of input A:** Current signal level of encoder signal "A" (X03 / X04 [▸ 34])
- **Status of input B**: Current signal level of encoder signal "B" (X03 / X04 [▸ 34])
- **Status of input C**: Current signal level of encoder signal "C" (X03 / X04 [▸ 34])
- **Status of extern latch**: Current signal level at the latch input (X06 [▸ 36])
- **Sync error**: Distributed Clocks synchronization error in the previous cycle.
- **TxPDO Toggle**: This bit is inverted each time an input data update occurs.

Counter value: The current counter value.

Latch value: Counter value stored at the time of the last signal edge at latch input X06 or encoder signal "C".[1)]

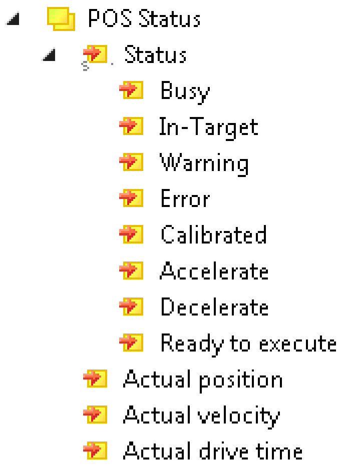
[1)] The latch function is deactivated in the factory setting. You may activate and configure the latch function in process data object "ENC Control" [▸ 16] or "ENC Control compact" [▸ 16].

2.4.2.2 "ENC Status compact"

This process data object is identical with "ENC status" [▸ 13], see there.

2.4.2.3 "POS Status"

"POS Status" contains the status variables of the Positioning Interface [▶ 60].



Status

- **Busy**: A motion command is active.
- **In-Target**: The target position of the motion command has been reached.
- **Warning**: Warning message.
- **Error**: Error message.
- **Calibrated**: The motor is calibrated.
- **Accelerate**: The motor accelerates.
- **Decelerate**: The motor brakes.
- **Ready to execute**: Ready for a motion command.

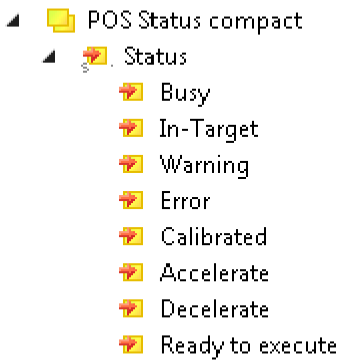
Actual position: current set position

Actual velocity: current set velocity

Actual drive time: the elapsed time of the motion command.

2.4.2.4 "POS Status compact"

"POS Status compact" contains the status variables of the Positioning Interface [▶ 60].

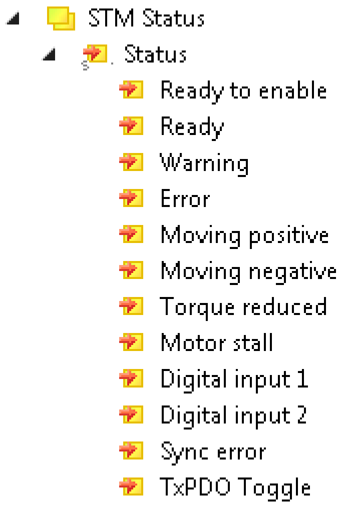


Status

This variable is identical to the "Status" variable in the process data object "POS Status [▶ 14]". See there.

2.4.2.5 "STM Status"

„STM Status" contains the status bits of the stepper motor output stage. "STM" is the abbreviation for "Stepper Motor".



Ready to enable: The output stage can be enabled. See output variable "Enable" in the process data object STM Control [▶ 17].

Ready: The output stage is enabled.

Warning: Warning message.

Error: Error message. The output stage was switched off due to an error. You can acknowledge the error message with the output variable "Reset" in the process data object STM Control [▶ 17]

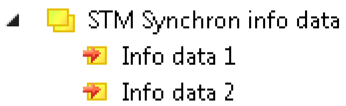
Moving positive: The speed is greater than 0.

Moving negative: The speed is less than 0.

Motor stall: A loss of step has occurred.

2.4.2.6 "STM Synchronous info data"

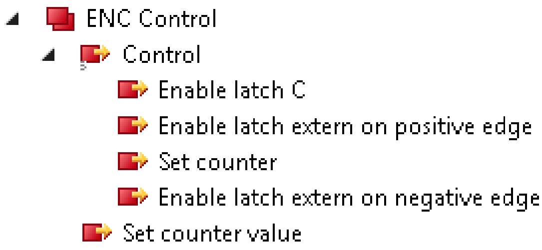
"STM" is the abbreviation for "Stepper Motor".



Info data *n*: Additional information from the box.
You can select what information these variables should contain:

- Parameter $8012:11_{hex}$ Select info data 1 [▶ 94]
- Parameter $8012:19_{hex}$ Select info data 2 [▶ 94]

2.4.2.7 "ENC Control"



Enable latch C: Activate edge trigger for encoder input "C".

Enable latch extern on positive edge: Activate edge trigger for positive signal edges at latch input X06 [▶ 36].

Set counter: Accept the value of the variable "Set counter value" as the current counter value.

Enable latch extern on negative edge: Activate edge trigger for negative signal edges at latch input X06 [▶ 36].

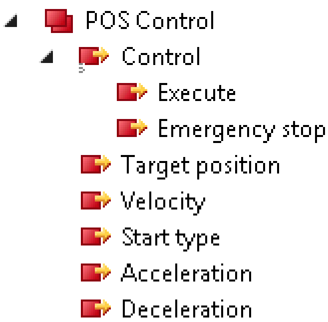
Set counter value: Default value for "Set counter".

2.4.2.8 "ENC Control compact"

This process data object is identical with "ENC Control" [▶ 16].

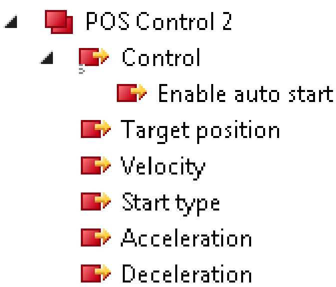
2.4.2.9 "POS Control"

This process data object contains variables for controlling the Positioning Interface [▶ 60].



2.4.2.10 "POS Control 2"

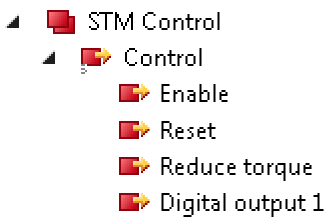
This process data object contains variables for controlling the Positioning Interface [▶ 60].



2.4.2.11 "POS Control compact"

This process data object contains variables for controlling the Positioning Interface [▶ 60].

2.4.2.12 "STM Control"



Enable: Enable output stage.

Reset: Acknowledge error message, reset error status. See input variable "Error" in the process data object STM Status [▶ 15]

2.4.2.13 "STM Position"

Position: Position setpoint.
Specify the position setpoint in increments.

Conversion from degrees (°) to increments: See below.

Conversion of position setpoints

The formula for converting a position setpoint from degrees (°) to increments depends on whether you are using an encoder.

- If you are not using an encoder (feedback type [▶ 94] = "Internal counter"), use this formula:

$$Position = \frac{\theta_{set} \times 64}{\varphi}$$

Position: Setpoint [increments]

Θ_{set}: Setpoint [°]

φ: Step angle of the motor [°]
(for AS10xx stepper motors: φ = 1.8 °)

- If you are using an encoder (feedback type [▶ 94] = "Encoder"), use this formula:

$$Position = \frac{\theta_{set} \times PPR}{90}$$

Position: Setpoint [increments]

Θ_{set}: Setpoint [°]

PPR: Resolution of the encoder [increments/revolution]
(for AS10xx stepper motors: inc = 1024)

2.4.2.14 "STM Velocity"

Velocity: Speed setpoint in % of the parameter "Speed range" [▶ 44].
32767_{dec} corresponds to 100%, -32767_{dec} corresponds to -100%.

Conversion of speed setpoints

$$Velocity = 196602 \times \frac{n_{set}}{\varphi \times f_{max}}$$

Velocity: Setpoint [increments/s]

n_{set}: Setpoint [rpm]

φ: Step angle of the motor [°]
(for AS10xx stepper motors: φ = 1.8 °)

f_{max}: "Speed range" [▶ 44] [full steps/s]

The speed setpoint can be positive or negative, depending on the desired direction of rotation of the motor.

2.5 Technology

EP7047-1032 provides two basic modes of operation.

- In standard mode [▸ 23] all unipolar and bipolar stepper motors that comply with the specifications of EP7047-1032 can be controlled. Two currents with sine/cosine curve are provided. The current is clocked with 64 kHz and resolved with up to 64-fold microstepping to achieve a smooth current.
- Extended mode [▸ 25] is based on field-oriented control. This mode can only be used for stepper motors from Beckhoff. The current is not only provided, but controlled in a comprehensive manner. Typical stepper motor problems such as pronounced resonance are therefore finally a thing of the past. Furthermore, the current is adjusted depending on the load, thereby enabling considerable energy savings and lower thermal loads at the stepper motor.

Realisation of more demanding positioning tasks

More demanding positioning tasks can be realised via the TwinCAT automation software from Beckhoff. Like other axes, EP7047-1032 is integrated via the TwinCAT System Manager and can be used like standard servo axes. Special stepper motor features, such as speed reduction in the event of large following errors, are automatically taken into account via the *stepper motor axis* option. The effort for changing from a servomotor to a stepper motor - and back - is no greater than changing from one fieldbus to another one under TwinCAT.

The output stages of EP7047-1032 have an overload protection in the form of an overtemperature warning and switch-off. Together with short circuit detection, diagnostic data are accessible in the process image of the controller. In addition, this status is displayed by LEDs, along with other information. The output stage is switched on via an Enable-Bit. The motor current can be set and reduced via a parameter value.

Optimum adaptation to the motor and the implementation of energy-saving features require minimum programming effort. Since all data are set in the form of parameters in the CoE register, it is easily possible to replace an EtherCAT device or store certain parameters for transfer to the next project. It is therefore no longer necessary to transfer certain potentiometer settings or to document DIP switch settings.

2.5.1 Stepper motor

Stepper motors are electric motors and are comparable with synchronous motors. The rotor is designed as a permanent magnet, while the stator consists of a coil package. The frequency of the stator rotary field is always in a fixed ratio relative to the rotor speed. In contrast to synchronous motors, stepper motors have a large number of pole pairs. In a minimum control configuration, the stepper motor is moved from pole to pole, or from step to step.

Stepper motors have been around for many years. They are robust, easy to control, and provide high torque. In many applications, the step counting facility saves expensive feedback systems. Even with the increasingly widespread use of synchronous servomotors, stepper motors are by no means "getting long in the tooth". They are considered to represent mature technology and continue to be developed further in order to reduce costs and physical size, increase torque and improve reliability. For a standard stepper motor with 200 full steps, the best possible positioning accuracy is approx. 1.8°.

Today, the most widely used type in industry is the hybrid stepper motor type. In this type of motor the rotor consists of a toothed iron core with one or a few permanent magnets in the rotor core. The rotor is designed such that the polarity of successive teeth is inverse. This enables the production of motors with a high number of steps, which is essential for positioning accuracy, combined with a relatively high torque. The electrical behaviour of such a hybrid stepper motor is comparable with a multipole synchronous servomotor. However, thanks to the synchronous toothing of stator and rotor, hybrid stepper motors offer a significantly higher cogging torque.

Hybrid stepper motors with two or more phases are available on the market. Since EP7047-1032 is designed for two-phase motors, the description focuses on the two-phase type, with the phases referred as A and B in this documentation.

Stepper motor parameters

- **Mechanical system**

Irrespective of the drive and the stepper motor itself, the configuration of the mechanism attached to the motor shaft has significant influence on the achievable control quality.

Natural resonances, load resonances, gear backlash (loose) and static friction have negative affect on the controllability of the drive system. This often requires "softer" controller parameterisation, which in turn leads to a higher position lag in the system. Sliding friction can result in reduced efficiency (due to increased energy demand), but on the other hand it can have a positive effect on the control stability, due to its dampening effect.

As a general rule, the "stiffer" the mechanics of a drive system, the easier it is to control, which is beneficial for achieving a small position lag in the drive system.

- **Speed**

Stepper motors have low maximum speed, which is usually specified as a maximum step frequency.

- **Number of phases**

Motors with 2 to 5 phases are common. EP7047-1032 supports 2-phase motors. 4-phase motors are basically 2-phase motors with separate winding ends. They can be connected directly to EP7047-1032.

- **Torque**

Refers to the maximum motor torque at different speeds. This parameter is usually represented by a characteristic curve. Stepper motors have comparatively high torque in the lower speed range. In many applications, this enables them to be used directly without gearing. Compared with other motors, stepper motors can quite easily provide a holding moment of the same order of magnitude as the torque.

• **Cogging torque**

In many cases the stepper motors design results in high cogging torque, which can lead to relatively strong natural resonance in a motor- and load-dependent speed range. In relation to the cogging torque, increased inertia often leads to a less strong resonance and smoother operation.

• **Mass moment of inertia**

In standard mode, the key parameter of the mechanical system is the mass moment of inertia J_Σ. It is essentially composed of the mass moment of inertia of the stepper motor rotor J_M and the mass moment of inertia of the connected load J_L. The friction moment J_{fric} and the moment of inertia of the encoder J_{Enc} can be neglected in a first approximation.

$J_\Sigma \approx J_M + J_L$

The ratio between the load torque and the motor torque is defined by the constant k_J.

$k_J \approx J_L / J_M$

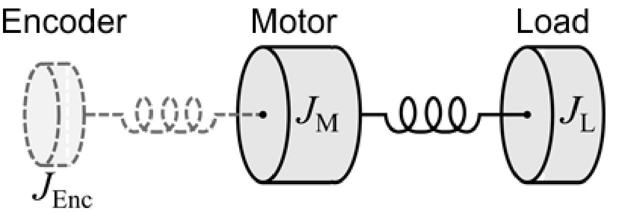


Fig. 1: *Simplified representation of the mass moments of inertia*

As a first approximation, the coupling of the individual masses over the rotor shaft can be modelled as two-mass oscillator. The resonance frequency between the motor and the encoder lies in a relatively high frequency range, which is usually not relevant for stepper motor drives and is suppressed within the drive by low-pass filtering. The resonance frequency between the motor and the load is frequently in the range between 20 and 500 Hz. It is therefore often in the operating range of the drive control. Design measures to reduce the influence of the load resonance include a small load ratio k_J and a rigid coupling of the motor shaft to the connected load.

• **Resonance**

At certain speeds, stepper motors run less smoothly. This phenomenon is particularly pronounced when the motor runs without coupled load, in which case it may even stop (in standard mode). This is caused by resonance. A distinction can roughly be made between

- resonances in the lower frequency range up to approx. 250Hz; and
- resonances in the medium to upper frequency range.

Resonances in the medium to upper frequency range essentially result from electrical parameters such as inductance of the motor winding and supply line capacity. They can be controlled relatively easily through high pulsing of the control system.

Resonances in the lower range essentially result from the mechanical motor parameters. Apart from their impact on smooth running, such resonances can lead to significant loss of torque, or even loss of step of the motor, and are therefore particularly undesirable.
In principle, the stepper motor represents an oscillatory system (comparable to a mass/spring system), consisting of the moving rotor with a moment of inertia and a magnetic field that creates a restoring force that acts on the rotor. Moving and releasing the rotor creates a damped oscillation. If the control frequency corresponds to the resonance frequency, the oscillation is amplified, so that in the worst case the rotor will no longer follow the steps, but oscillate between two positions.
EP7047-1032 prevents this effect thanks to the field-oriented control (Extended Operation Modes) for all Beckhoff stepper motors.

•Torque constant

In the Extended Operation Modes the torque constant k_T is used as an additional parameter for the mechanical controlled system. It indicates the ratio between the torque-forming motor current and the active torque at the shaft. However, since the field-oriented operating mode is not common for stepper motors, the torque constant is usually not listed in the motor data sheet.

Electrical system

• Nominal voltage, supply voltage and winding resistance

Under steady-state conditions, the rated current at the rated voltage depends on the winding resistance. This voltage should not be confused with the supply voltage of the power output stage. EP7047-1032 applies a controlled current to the motor winding. If the supply voltage falls below the nominal voltage, the power output stage can no longer apply the full current, resulting in a loss of torque. It is desirable to aim for systems with small winding resistance and high supply voltage in order to limit warming and achieve high torque at high speeds.

• Induced countervoltage

Like servomotors, hybrid stepper motors induce a voltage u_i [Vs/rad] in the stator winding of the motor, which is proportional to the speed. It is also referred to as Back Electromotive Force (BEMF). In conjunction with the DC link voltage (motor voltage), the induced countervoltage determines the physically achievable maximum speed of the motor.

The ratio of the magnitude of the induced countervoltage and the motor speed varies depending on the design and is described via the voltage constant k_e.

$u_i = k_e \cdot \omega_m$

The motor parameter k_e [mV/(rad/s)] is required for step loss recognition without encoder.

For stepper motors where the voltage constant is not specified in the data sheet, it can be relatively easily determined using a digital multimeter. To this end the motor to be measured must be operated (within the rated speed range) by an auxiliary motor via a coupling with constant speed. The motor phases of the motor to be measured must be open (not connected or shorted). The multimeter can then be used to determine the RMS value of the induced countervoltage, and therefore the voltage constant, at one of the two open motor phases (A or B).

• Step angle

The step angle indicates the angle travelled during each step. Typical values are 3.6°, 1.8° and 0.9°. This corresponds to 100, 200 and 400 steps per motor revolution. Together with the downstream transmission ratio, this value is a measure for the positioning accuracy. For technical reasons, the step angle cannot be reduced below a certain value. Positioning accuracy can only be improved further by mechanical means (transmission). An elegant solution for increasing the positioning accuracy is the microstepping function. It enables up to 64 intermediate steps. The smaller "artificial" step angle has a further positive effect: The drive can be operated at higher speed, yet with the same precision. The maximum speed is unchanged, despite the fact that the drive operates at the limit of mechanical resolution.

• Winding resistance, winding inductance

The winding inductance and winding resistance of the stepper motor stator determine the electrical motor time constant $T_e = L / R$, which is a key parameter for current controller configuration.

2.5.2 Selecting a stepper motor

Specifying the stepper motor

1. Determine the required positioning accuracy and hence the step resolution. The first task is to determine the maximum resolution that can be achieved. The resolution can be increased via mechanical gear reduction devices such as spindles, gearing or toothed racks. The 64-fold microstepping also has to be taken into account.
2. Determine mass m and moment of inertia (J) of all parts to be moved
3. Calculate the acceleration resulting from the temporal requirements of the moved mass.
4. Calculate the forces from mass, moment of inertia, and the respective accelerations.
5. Convert the forces and velocities to the rotor axis, taking account of efficiencies, moments of friction and mechanical parameters such as gear ratio. It is often best to start the calculation from the last component, usually the load. Each further element transfers a force and velocity and leads to further forces or torques due to friction. During positioning, the sum of all forces and torques acts on the motor shaft. The result is a velocity/torque curve that the motor has to provide.
6. Using the characteristic torque curve, select a motor that meets these minimum requirements. The moment of inertia of the motor has to be added to the complete drive. Verify your selection. In order to provide an adequate safety margin, the torque should be oversized by 20% to 30%. The optimisation is different if the acceleration is mainly required for the rotor inertia. In this case, the motor should be as small as possible.
7. Test the motor under actual application conditions: Monitor the housing temperatures during continuous operation. If the test results do not confirm the calculations, check the assumed parameters and boundary conditions. It is important to also check side effects such as resonance, mechanical play, settings for the maximum operation frequency and the ramp slope.
8. Different measures are available for optimising the performance of the drive: using lighter materials or hollow instead of solid body, reducing mechanical mass. The control system can also have significant influence on the behaviour of the drive. EP7047-1032 enables operation with different supply voltages. The characteristic torque curve can be extended by increasing the voltage. In this case, a current increase factor can supply a higher torque at the crucial moment, while a general reduction of the current can significantly reduce the motor temperature. For specific applications, it may be advisable to use a specially adapted motor winding.

2.5.3 Standard mode

Stepper motors were originally operated with very simple output stages, which were only able to switch the voltage of the motor phases separately (nowadays current control takes place via PWM with pulse-width modulation as standard). Initially the motor phases there were controlled individually in turn. A switching sequence in the positive direction of rotation corresponds to the switching sequence (+A, +B, -A, -B). Sequential switching results in rather irregular operation in this mode. In order to make the operation smoother, so-called microstepping was introduced later, in which the four set voltages were extended by intermediate values (e.g. from a stored sine table). These days, microstepping based on 64 steps is commonly used.

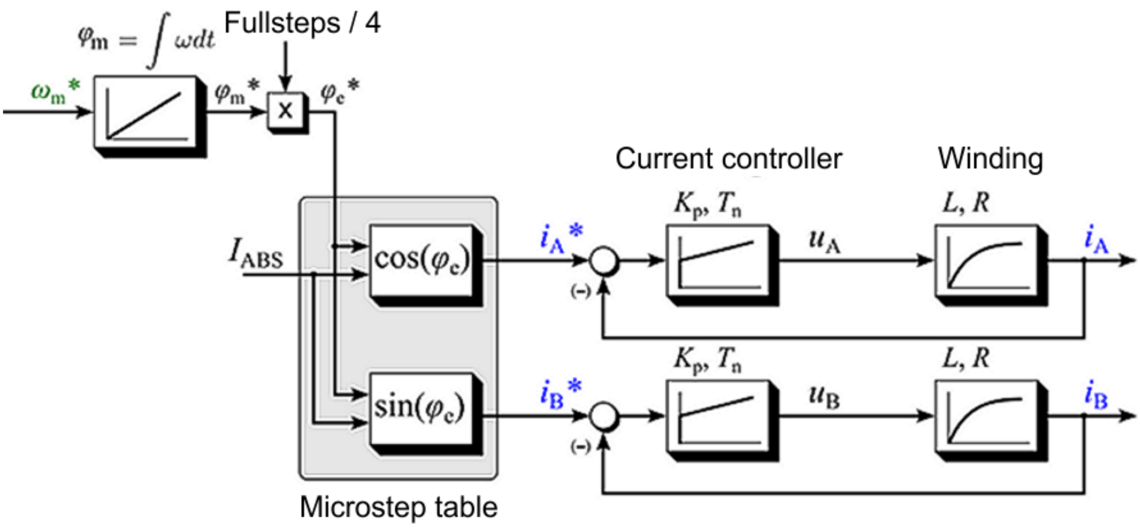


Fig. 2: *Control structure of a standard stepper motor drive*

Neglecting the sampling resulting from the microstepping, the motor current I as function of the electrical angle φe and of the magnitude of the motor current I_{ABS} (when using a current controller) can be described as follows:

$I(\varphi_e) = I_A + jI_B = I_{ABS}\cos(\varphi_e) + jI_{ABS}\sin(\varphi_e)$

Represented by magnitude and angle:

$I(\varphi_e) = I_{ABS} \cdot e^{j\varphi e}$

It follows that a rotation of the electrical angle φe is equivalent to four full steps. (A stepper motor with 200 full steps therefore has 50 pole pairs).

The shaft aligns itself if a constant current is set with no load at the motor shaft. Within a pole pairs the shaft points in the direction of the active stator field.

If an external load is applied to the motor shaft, the shaft is turned out of the field direction, resulting in a load angle (also referred to as angular displacement) (relative to an electric rotation of the angle φe). The load angle depends on the design of the stepper motor itself, the motor current and the torque acting on the shaft. The relationship is non-linear!

If the load angle exceeds a motor-dependent maximum value (i.e. if the maximum machine torque under these boundary conditions is exceeded), the load torque can no longer be maintained by the motor. If the shaft is turned further out of the rotary field, it "tips", resulting in one or more step losses. The "tip angle" may vary between motor types. Often, it lies between around 45° and 65°.

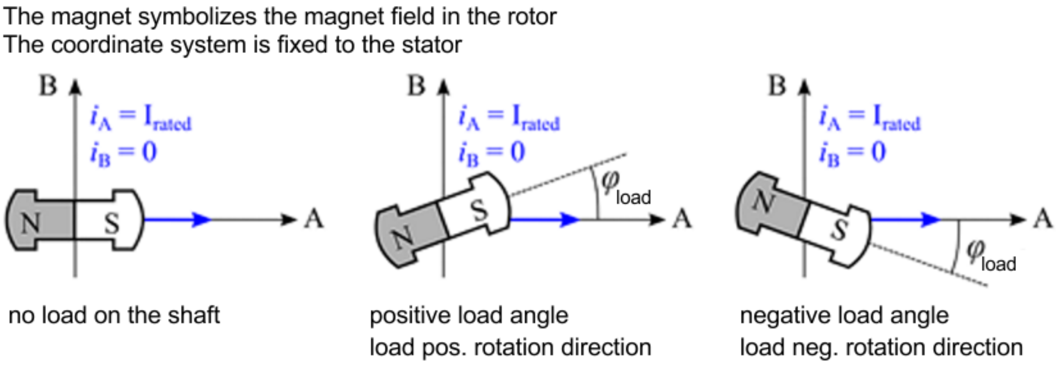


Fig. 3: *Behaviour of the rotor under load*

The load angle is of interest for the user, because it allows conclusions about the load on the shaft. It is measured by evaluating the induced countervoltage* and can be used to optimise the drive system.

2.5.4 Field-oriented control

In the *Extended Operation Modes* the stepper motor is operated like a servomotor, based on the principle of field-oriented control.

Function

The operating behaviour of the motor corresponds to that of a traditional DC motor, with commutation via a mechanical commutator. With a constant exciter field, the torque of the DC machine is directly proportional to the stator current and can be directly influenced by it. The exciter field is generated, depending on the machine type, by permanent magnets or, with a separately excited DC machine, for example, via a separate excitation winding.

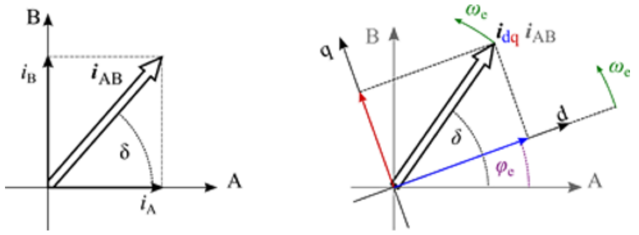


Fig. 4: *Coordinate transformation of field-oriented control*

For servomotors and also hybrid stepper motors, initially there is no direct link between the phase currents and the torque. Field and torque are decoupled mathematically via Park's transformation. Two current components, "d" for "direct" in field direction and "q" for "quadrature" in torque-forming direction, are calculated from the phase currents. Via the torque-forming current component i_q, the torque of the machine can now be regulated directly, like for a DC machine.

A prerequisite is that the rotor position is available with sufficiently high accuracy. For a stepper motor the encoder resolution should be at least 4000 increments per mechanical revolution, in order to achieve adequate positioning accuracy. The minimum encoder resolution also depends on the number of full steps and can be calculated approximately as follows.

$$ENCRESmin\left[\frac{inc}{360°}\right] \geq fullsteps \cdot 12 \geq 4000\left[\frac{inc}{360°}\right]$$

Fig. 5: *Calculation of the resolution*

Commutation determination for Extended Operation Modes

Because the absolute actual position is not available for incremental encoders, on system start-up there is no direct reference to the rotor position, which is required for field-oriented operation. Therefore, the reference between the actual position and the rotor position must be generated at start-up via a commutation determination process. During this process the rotor is moved forward and back several times up to two full steps.

> **Commutation determination**
> - The maximum current should be set just below the rated motor current.
> - During commutation determination the rotor shaft should not be subject to an external torque. If this condition is not met, the Extended Operation Modes cannot be used.

Control structure

The drive control structure is a cascade control structure with a position control loop and a lower-level speed and current control loop. If a speed setpoint is specified, the external position control loop can be omitted.

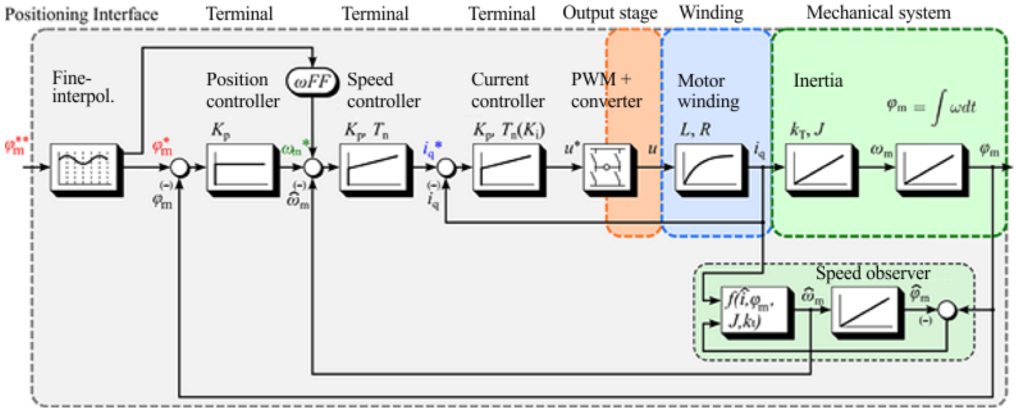


Fig. 6: *Cascade control structure with field-oriented control (Extended Operating modes)*

Motor dependency

Due to the fact that the control is strongly dependent on the motor parameters, the controller parameters and motor behaviour itself, field-oriented control is limited to Beckhoff motors. This mode is not supported for motors from other manufacturers.

Main advantages compared with standard mode

- Low current consumption (almost full load-dependence)
- High efficiency
- Consistent dynamics compared with standard mode
- Step losses are inherently avoided

Requirement

- Encoder with sufficiently high resolution required (minimum 4000 [INC/360°])
- Slightly higher parametrisation effort required (speed controller)
- Commutation determination at startup (due to incremental encoder)
- Only possible with stepper motors from Beckhoff Automation (AS10xx)

3 Mounting and connections

3.1 Mounting

3.1.1 Dimensions

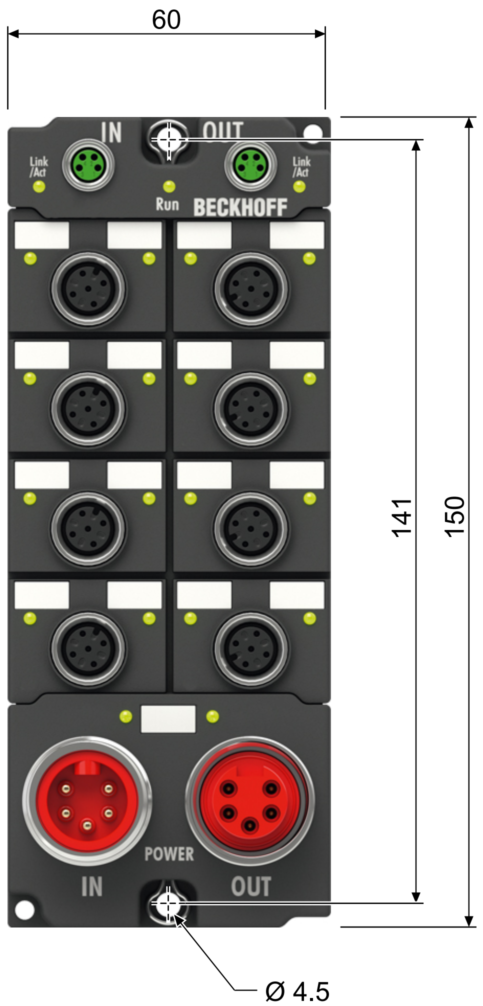


Fig. 7: Dimensions

All dimensions are given in millimeters.

Housing features

Housing material	PA6 (polyamide)
Sealing compound	polyurethane
Mounting	two fastening holes Ø 4.5 mm for M4
Metal parts	brass, nickel-plated
Contacts	CuZn, gold-plated
Power feed through	max. 16 A at 40°C (according to IEC 60512-3)
Installation position	variable
Protection class	IP65, IP66, IP67 (conforms to EN 60529) when screwed together
Dimensions (H x W x D)	approx. 150 x 60 x 26.5 mm (without connectors)

3.1.2 Fixing

NOTE

Dirt during assembly

Dirty connectors can lead to malfunctions. Protection class IP67 can only be guaranteed if all cables and connectors are connected.

- Protect the plug connectors against dirt during the assembly.

Mount the module with two M4 screws in the centrally located fastening holes.

3.1.3 Functional earth (FE)

The fastening holes [▶ 28] also serve as connections for the functional earth (FE).

Make sure that the box is earthed with low impedance via both fastening screws. You can achieve this, for example, by mounting the box on a grounded machine bed.

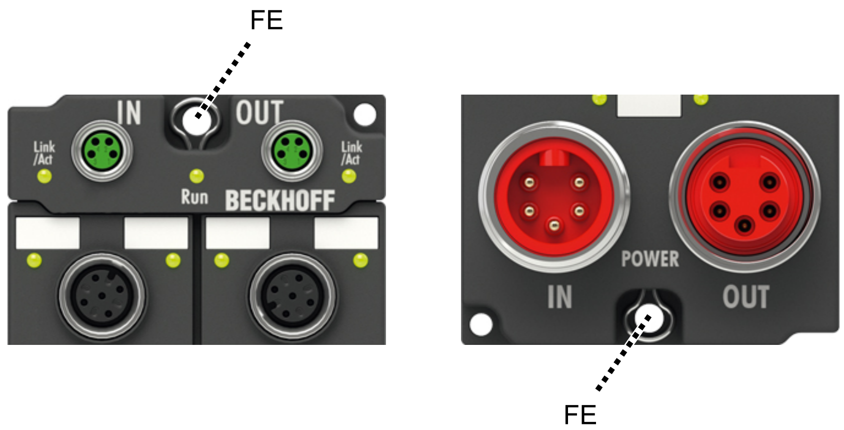


Fig. 8: Functional earth via the fastening holes

3.2 Connections

NOTE

Risk of confusion with M12 sockets

The M12 sockets X01 to X08 are assigned very different functions. Connecting a plug connector to the wrong socket can result in damage.

3.2.1 Connector overview

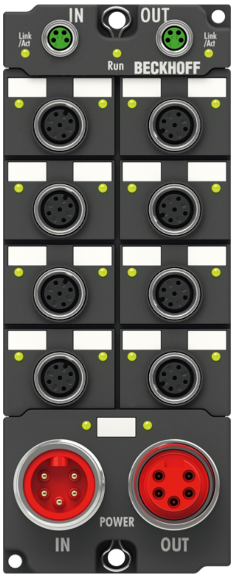


Fig. 9: Connector overview

Name	Function	Connector type	Tightening torque
X01	-	M12 socket	0.6 Nm 1)
X02	-	M12 socket	0.6 Nm 1)
X03	Incremental encoder [▶ 34] with 5 V supply	M12 socket	0.6 Nm 1)
X04	Incremental encoder [▶ 34] with 24 V supply	M12 socket	0.6 Nm 1)
X05	Digital inputs for limit switches [▶ 35]	M12 socket	0.6 Nm 1)
X06	Latch input [▶ 36]	M12 socket	0.6 Nm 1)
X07	Digital output for the motor brake [▶ 37]	M12 socket	0.6 Nm 1)
X08	Stepper motor connection [▶ 38]	M12 socket	0.6 Nm 1)
X40	EtherCAT input [▶ 30]	M8 socket	0.4 Nm 1)
X41	EtherCAT-Weiterleitung [▶ 30]	M8 socket	0.4 Nm 1)
X60	Supply voltage input [▶ 32]	7/8“ plug connector	1.5 Nm
X61	Supply voltage downstream connection [▶ 32]	7/8“ socket	1.5 Nm

1) Mount plugs on these connectors using a torque wrench, e.g. ZB8801 from Beckhoff.

Protective caps

- Seal unused connectors with protective caps.
- Ensure the correct seating of pre-assembled protective caps.
  Protective caps are pre-assembled at the factory to protect connectors during transport. They may not be tight enough to ensure IP67 protection.

3.2.2 EtherCAT: X40 and X41

3.2.2.1 Connectors

EtherCAT Box Modules have two green M8 sockets for the incoming and downstream EtherCAT connections.

Fig. 10: EtherCAT connectors

Connection

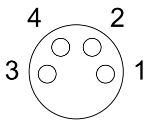


Fig. 11: M8 socket

EtherCAT	M8 connector	Core colors		
Signal	**Contact**	**ZB9010, ZB9020, ZB9030, ZB9032, ZK1090-6292, ZK1090-3xxx-xxxx**	**ZB9031 and old versions of ZB9030, ZB9032, ZK1090-3xxx-xxxx**	**TIA-568B**
Tx +	1	yellow[1)]	orange/white	white/orange
Tx -	4	orange[1)]	orange	orange
Rx +	2	white[1)]	blue/white	white/green
Rx -	3	blue[1)]	blue	green
Shield	Housing	Shield	Shield	Shield

[1)] Core colors according to EN 61918

Adaptation of core colors for cables ZB9030, ZB9032 and ZK1090-3xxxx-xxxx

For standardization, the core colors of the ZB9030, ZB9032 and ZK1090-3xxx-xxxx cables have been changed to the EN61918 core colors: yellow, orange, white, blue. So there are different color codes in circulation. The electrical properties of the cables have been retained when the core colors were changed.

3.2.2.2 Status LEDs

Fig. 12: EtherCAT Status LEDs

L/A (Link/Act)

A green LED labelled "L/A" is located next to each EtherCAT socket. The LED indicates the communication state of the respective socket:

LED	Meaning
off	no connection to the connected EtherCAT device
lit	LINK: connection to the connected EtherCAT device
flashes	ACT: communication with the connected EtherCAT device

Run

Each EtherCAT slave has a green LED labelled "Run". The LED signals the status of the slave in the EtherCAT network:

LED	Meaning
off	Slave is in "Init" state
flashes uniformly	Slave is in "Pre-Operational“ state
flashes sporadically	Slave is in "Safe-Operational" state
lit	Slave is in "Operational" state

Description of the EtherCAT slave states

3.2.2.3 Cables

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

EtherCAT uses four wires for signal transmission.
Thanks to automatic line detection ("Auto MDI-X"), both symmetrical (1:1) or cross-over cables can be used between Beckhoff EtherCAT.

Detailed recommendations for the cabling of EtherCAT devices

3.2.3 Supply voltages: X60 and X61

EP7047 requires two supply voltages:

- Control voltage U_S
- DC link voltage U_P

3.2.3.1 Connectors

Two 7/8 " connectors at the low-end of the modules are used for feeding and routing the supply voltages:

- "IN" (male): left connector for feeding the supply voltages
- "OUT" (female): right connector for downstream connection

Pin assignment

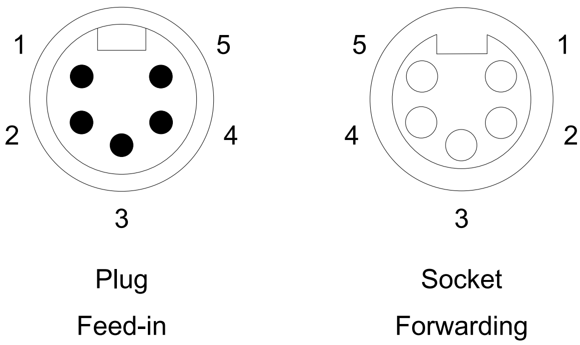


Fig. 13: 7/8 " connector pin assignment

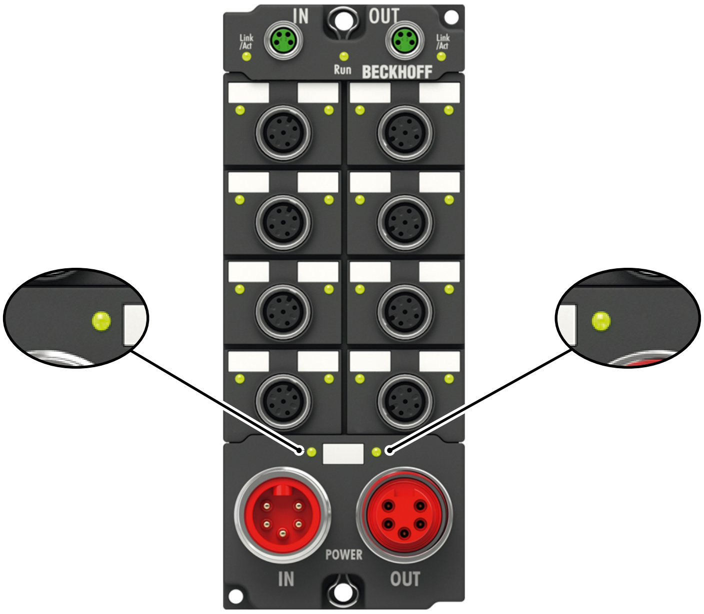
> ***NOTE***
>
> **The input for U_P is not protected against reverse polarity.**
>
> Defect possible through polarity reversal.

Pin	Name	Comment	Core colors [1)]
1	GND_P	GND to U_P	Black
2	GND_S	GND to U_S	Blue
3	FE	Functional earth	Grey
4	+24 V_{DC} U_S	Control voltage U_S	Brown
5	+48 V_{DC} U_P	DC link voltage U_P	White

[1)] The core colors apply to cables of the type: Beckhoff ZK203x-xxxx.

3.2.3.2 Status LEDs

The status of the supply voltages is signaled by two LEDs. A Status LED lights up green when the respective supply voltage is present on the connector for the supply.

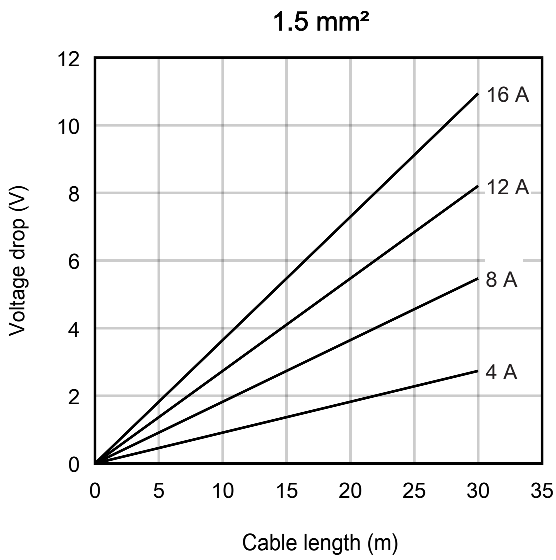


3.2.3.3 Conductor losses

Take into account the voltage drop on the supply line when planning a system. Avoid the voltage drop being so high that the supply voltage at the box lies below the minimum nominal voltage.

Variations in the voltage of the power supply unit must also be taken into account.

Voltage drop on the supply line



3.2.4 Incremental encoders: X03 or X04

EP7047 has two connectors for incremental encoders, but only one of these may be used:

- X03 for incremental encoders that require 5 V supply voltage.
- X04 for incremental encoders that require 24 V supply voltage.

NOTE

Only connect *one* encoder

Connecting two encoders simultaneously can result in damage.

NOTE

The encoder supply at X04 is not short-circuit proof (24 V)

Risk of damage due to short circuit.

- Avoid short-circuiting the encoder supply voltage.

Pin assignment

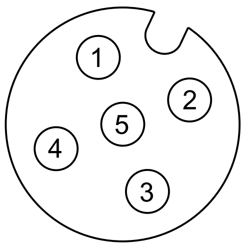


Fig. 14: M12 socket

Pin	Function	X03	X04	Core color [1)]
1	0 V encoder supply	GND_S	GND_S	brown
2	Encoder supply	5 V	24 V U_S	white
3	Encoder signal input A	ENC_A	ENC_A	blue
4	Encoder signal input B	ENC_B	ENC_B	black
5	Reference pulse / zero pulse	ENC_C	ENC_C	grey

[1)] The wire colors apply to M12 encoder cables from Beckhoff: ZK4000-5100-2xxx, ZK4000-5151-0xxx.

Connection example

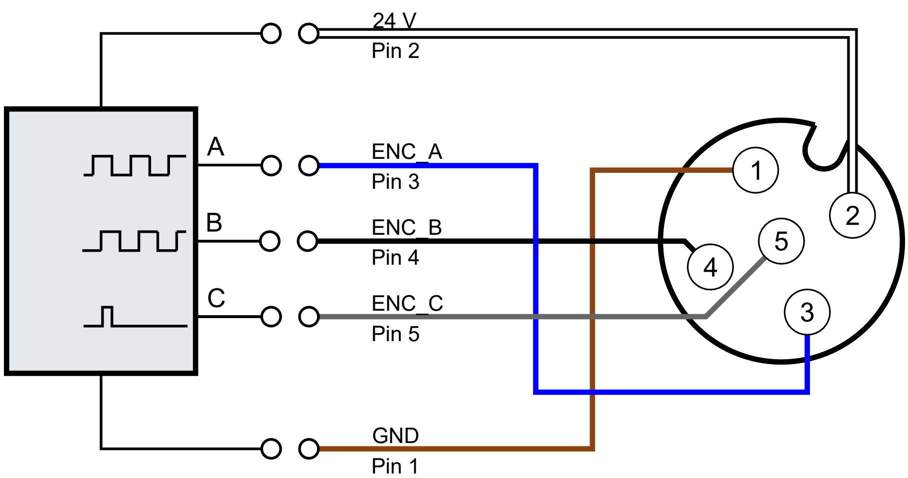


Fig. 15: Connection example: Incremental encoders

3.2.5 Limit switch: X05

You can connect up to two limit switches to X05.

Pin assignment

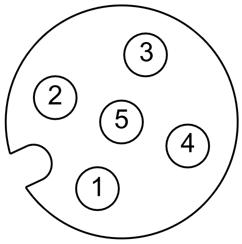


Fig. 16: M12 socket

Pin	Function	Symbol	Core color [1]
1	Limit switch supply 24 V_{DC}	U_{S1} [2]	brown
2	Digital input 2	Di2	white
3	Limit switch supply 0 V	GND_S	blue
4	Digital input 1	Di1	black
5	Functional earth	FE	grey

[1] The core colors apply to M12 cables from Beckhoff: ZK2000-5xxx, ZK2000-6xxx, ZK2000-7xxx

[2] U_{S1} is branched off from the supply voltage U_S.

Connection example

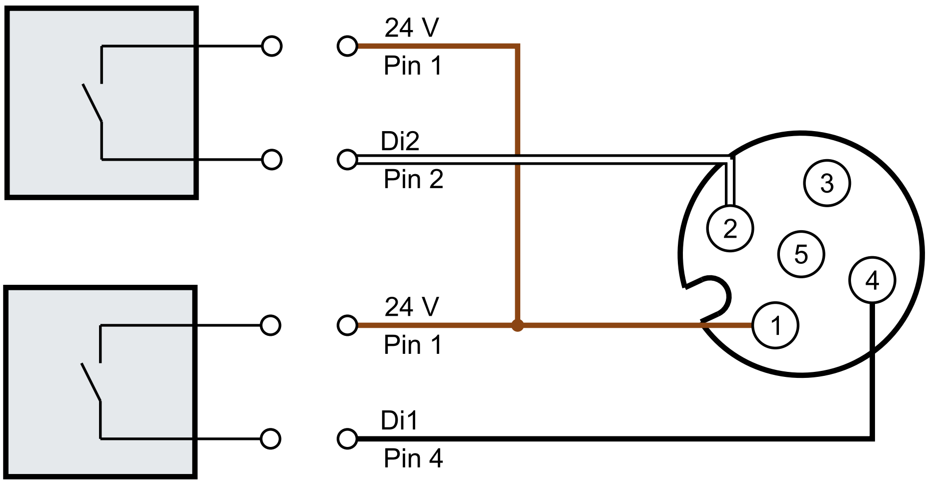


Fig. 17: Connection example: Two limit switches, two-wire connection

Status LEDs

X05 has two green LEDs. An LED lights up when a high level is detected at the respective input.

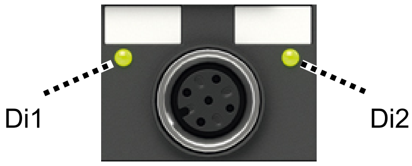


Fig. 18: Status LEDs for limit switch

3.2.6 Latch input: X06

Pin assignment

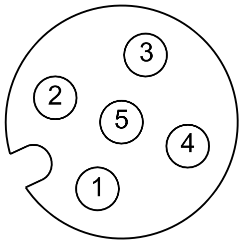


Fig. 19: M12 socket

Pin	Function	Symbol	Core color [1)]
1	Supply output 24 V_{DC}	U_{S1} [2)]	brown
2	-	-	white
3	Supply output 0 V_{DC}	GND_S	blue
4	Latch input	LTC	black
5	Functional earth	FE	grey

[1)] The core colors apply to M12 cables from Beckhoff: ZK2000-5xxx, ZK2000-6xxx, ZK2000-7xxx

[2)] U_{S1} is branched off from the supply voltage U_S.

3.2.7 Motor brake: X07

Pin assignment

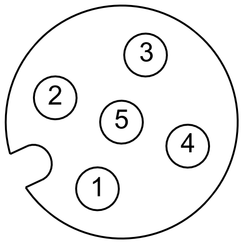


Fig. 20: M12 socket

Pin	Function	Symbol	Core color [1)]
1	-	-	brown
2	-	-	white
3	Ground	GND_S	blue
4	Brake output	BRK	black
5	Functional earth	FE	grey

[1)] The core colors apply to M12 cables from Beckhoff: ZK2000-5xxx, ZK2000-6xxx, ZK2000-7xxx

3.2.8 Stepper motor: X08

Pin assignment

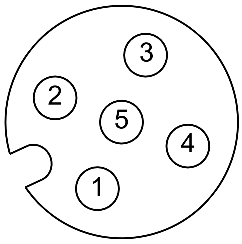


Fig. 21: M12 socket

Pin	Function	Symbol	Core color [1)]
1	Motor winding A	A1	brown
2		A2	white
3	Motor winding B	B1	blue
4		B2	black
5	Functional earth	FE	grey

[1)] The core colors apply to M12 cables from Beckhoff: ZK2000-5xxx, ZK2000-6xxx, ZK2000-7xxx

Connection examples

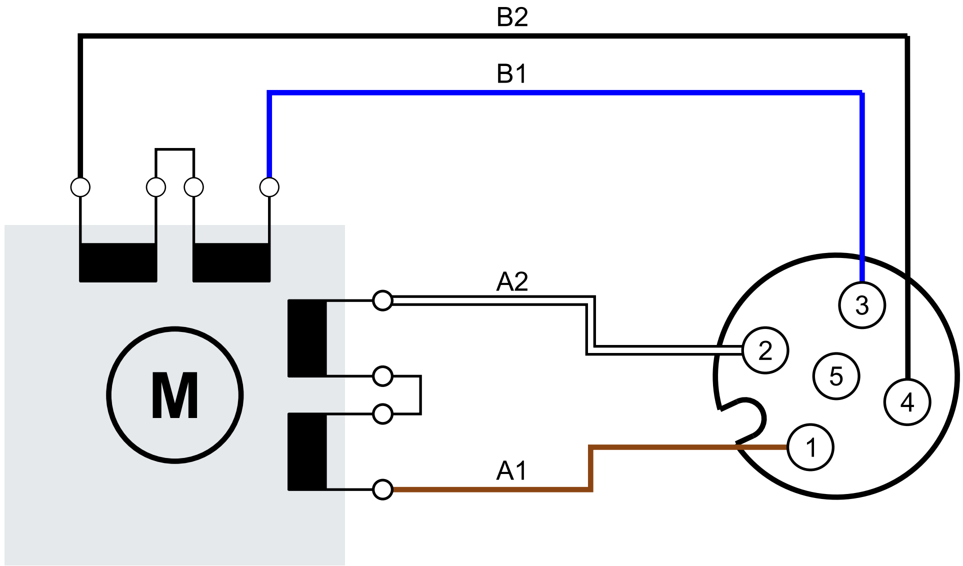


Fig. 22: Connection example: Bipolar stepper motor, serial connection

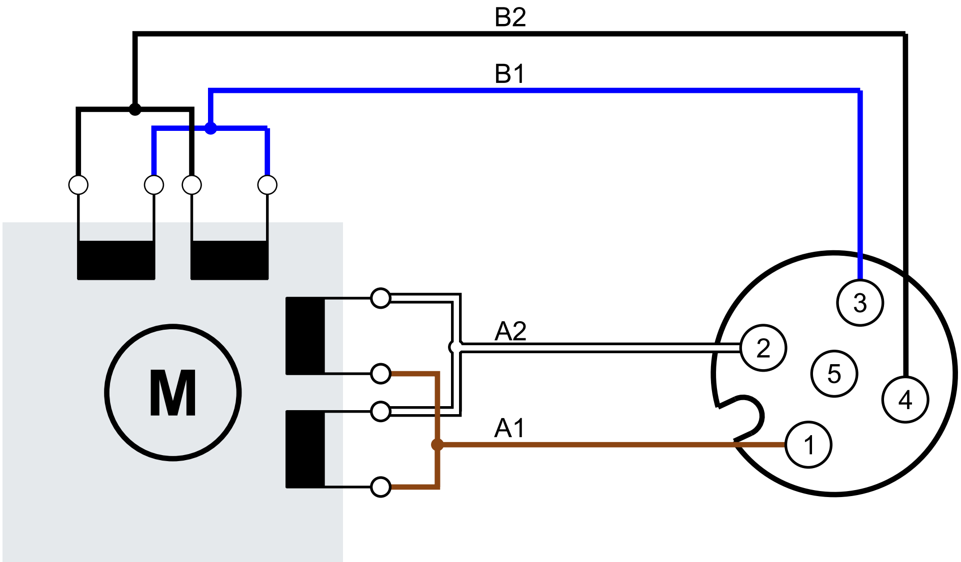


Fig. 23: Connection example: Bipolar stepper motor, parallel connection

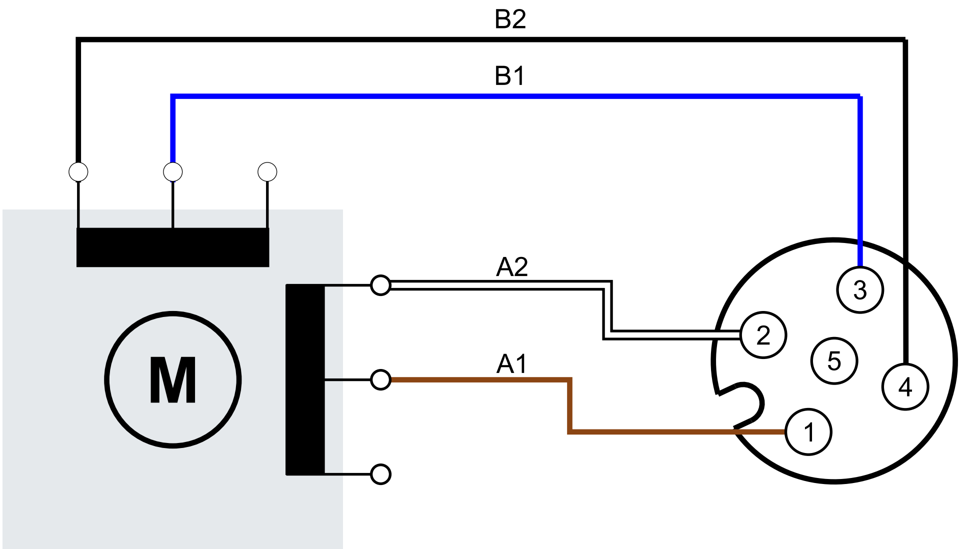


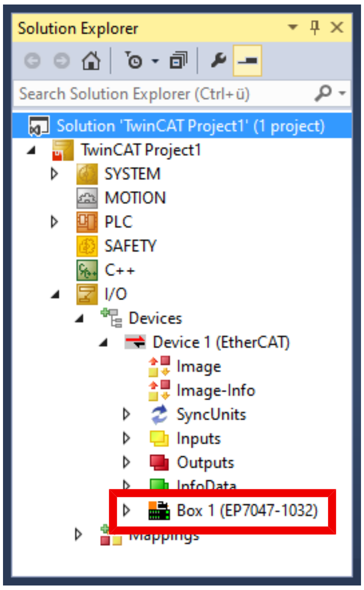
Fig. 24: Connection example: Unipolar stepper motor

In unipolar stepper motors only half of each winding is energized.

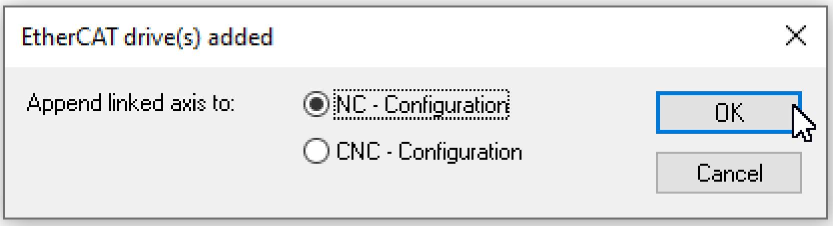
4 Commissioning and configuration

4.1 Integrating EP7047 into a TwinCAT project

1. Integrate EP7047-1032 as an I/O module in TwinCAT (Quick-Start Guide).



⇨ A dialog box appears:



You now have two options:

- Click "OK" (recommended) …
  - … if you want to use the TwinCAT NC functions and you have not yet created the axis to be controlled in the current TwinCAT project.
- Click "Cancel" …
  - … if you have already created the axis to be controlled in TwinCAT.
  - … if you do not want to use the TwinCAT NC functions.

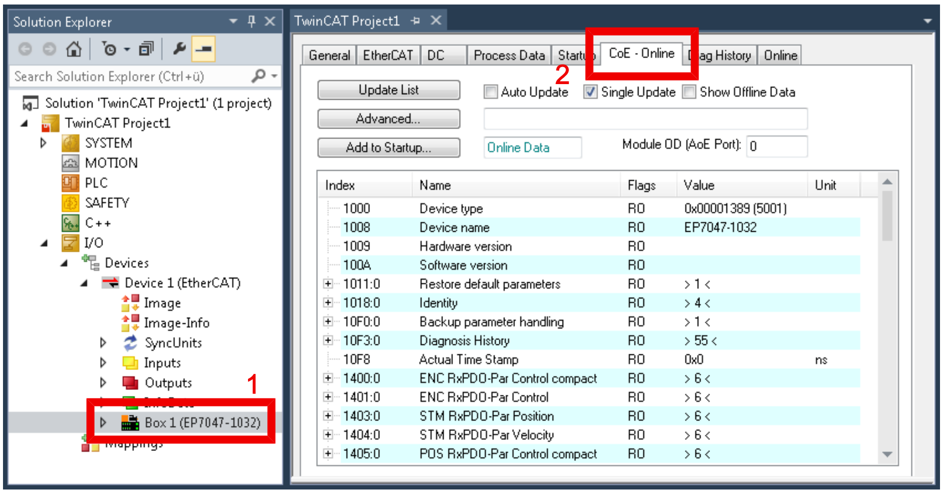
Note: This information is not binding. In other words, you can link an NC axis with EP7047 [▶ 75] at a later stage or disconnect the link.

When you click "OK":

- In the Solution Explorer under the entry "MOTION", a new NC task "NC-Task 1 SAF" is created if no NC task is available there yet.
- A new NC axis is created in the NC task under "Axes": „Axis *n*".
- The newly created NC axis is automatically linked to EP7047.

4.2 Parameterizing EP7047

4.2.1 Open the parameter directory (CoE)



1. In the Solution Explorer: double-click EP7047-1032.
2. Click on the "CoE - Online" tab.

⇨ You will see the CoE directory of EP7047-1032 where you can check and change the parameter values.

Resetting parameters to factory settings

If you do not know whether parameters have already been changed by the present EP7047, you can reset all parameters to the factory settings [▶ 77].

4.2.2 Setting important motor parameters

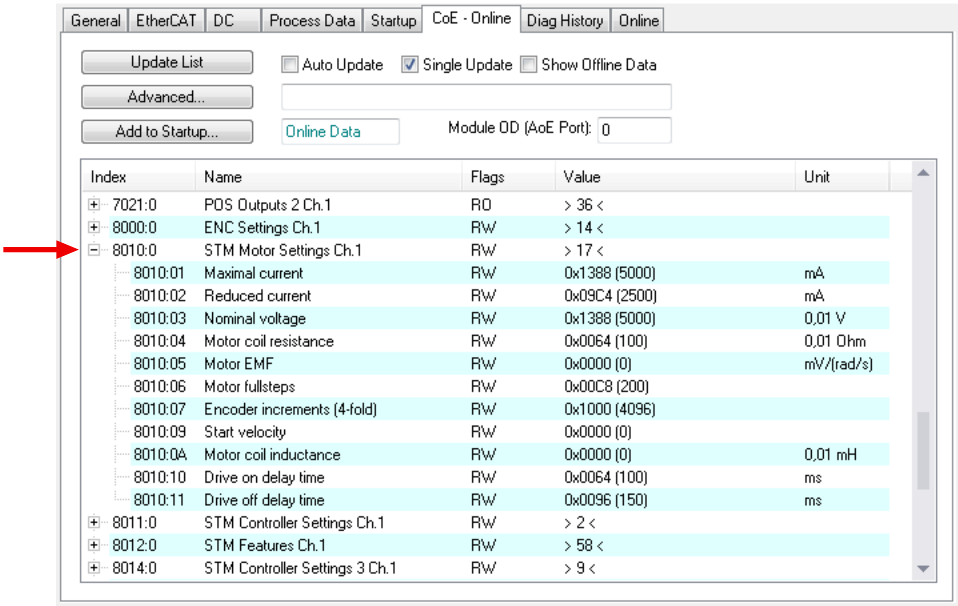
NOTE

Some motor parameters are not fault-tolerant

Incorrect motor parameters can result in damage.

- Take care when setting the motor parameters.

The motor parameters are stored in CoE object 8010_{hex}.



To ensure safe commissioning, it is sufficient to set the following parameters correctly. Further motor parameters are described under CoE object 8010_{hex}: STM Motor Settings Ch.1 [▶ 92].

8010:01 "Maximal current"

The maximum current that the current controller outputs per motor winding.

Unit: mA
Factory setting: 5000_{dec}

The maximum value that should be entered here is the nominal motor current. The nominal current can usually be found in the data sheet of the motor.

8010:02 "Reduced current"

Winding current at motor standstill.

Unit: mA
Factory setting: 1000_{dec}

Criteria for setting this parameter:

- A lower value results in a lower power loss when the motor is at standstill.
- A higher value leads to a higher breakdown torque when the motor is at standstill.

8010:03 "Nominal voltage"

The DC link voltage U_P, which you connect to X60 [▶ 32].

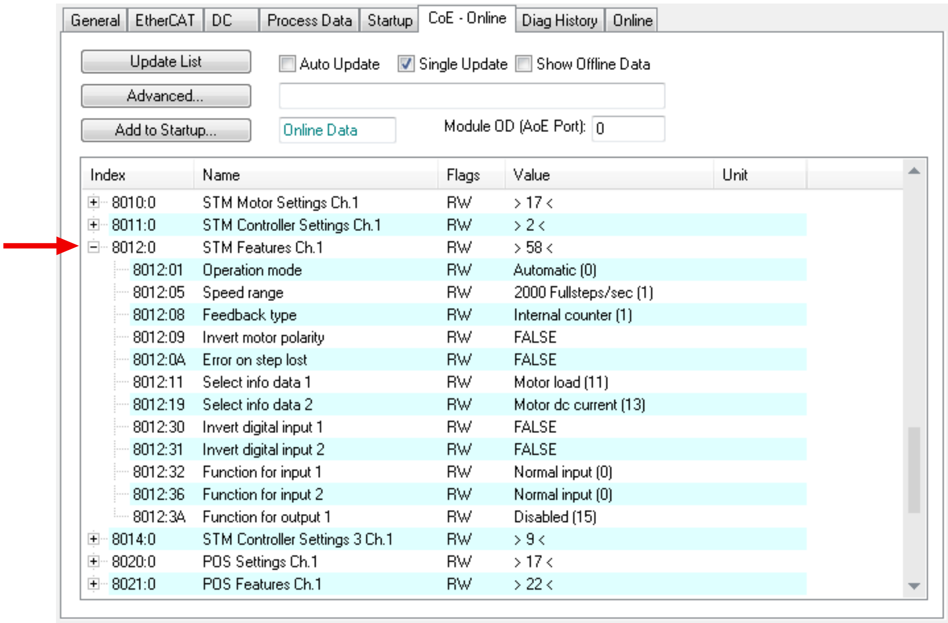
Risk of confusion: DC link voltage and nominal motor voltage

- Do *not* enter the nominal motor voltage here.

Unit: 10 mV
Factory setting: 5000_{dec}

4.2.3 Setting other important parameters

Other important parameters are stored in CoE object 8012_{hex}.



Index	Name	Flags	Value	Unit
8010:0	STM Motor Settings Ch.1	RW	> 17 <	
8011:0	STM Controller Settings Ch.1	RW	> 2 <	
8012:0	STM Features Ch.1	RW	> 58 <	
8012:01	Operation mode	RW	Automatic (0)	
8012:05	Speed range	RW	2000 Fullsteps/sec (1)	
8012:08	Feedback type	RW	Internal counter (1)	
8012:09	Invert motor polarity	RW	FALSE	
8012:0A	Error on step lost	RW	FALSE	
8012:11	Select info data 1	RW	Motor load (11)	
8012:19	Select info data 2	RW	Motor dc current (13)	
8012:30	Invert digital input 1	RW	FALSE	
8012:31	Invert digital input 2	RW	FALSE	
8012:32	Function for input 1	RW	Normal input (0)	
8012:36	Function for input 2	RW	Normal input (0)	
8012:3A	Function for output 1	RW	Disabled (15)	
8014:0	STM Controller Settings 3 Ch.1	RW	> 9 <	
8020:0	POS Settings Ch.1	RW	> 17 <	
8021:0	POS Features Ch.1	RW	> 22 <	

8012:05 "Speed range"

When changing "Speed range": adjust "Reference velocity"

Recalculate the parameter "Reference velocity" [▸ 52] if you have changed the parameter "Speed range".

The "Speed range" parameter has several functions:

- Upper limit of the output step frequency.
- Reference value for speed setpoints:
  Speed setpoints are given in % of the "Speed range".

Unit: Full steps per second
Factory setting: "2000 Fullsteps/sec"

The following formula can be used to determine the maximum achievable speed for a "Speed range":

$$n_{max} = f_{max} \times \frac{\varphi}{6}$$

n_{max}: Maximum achievable speed [rpm]
f_{max}: "Speed range" [full steps/s]
φ: Step angle of the motor [°]

8012:08 "Feedback type"

When changing the "Feedback type": adjust the "Scaling factor"

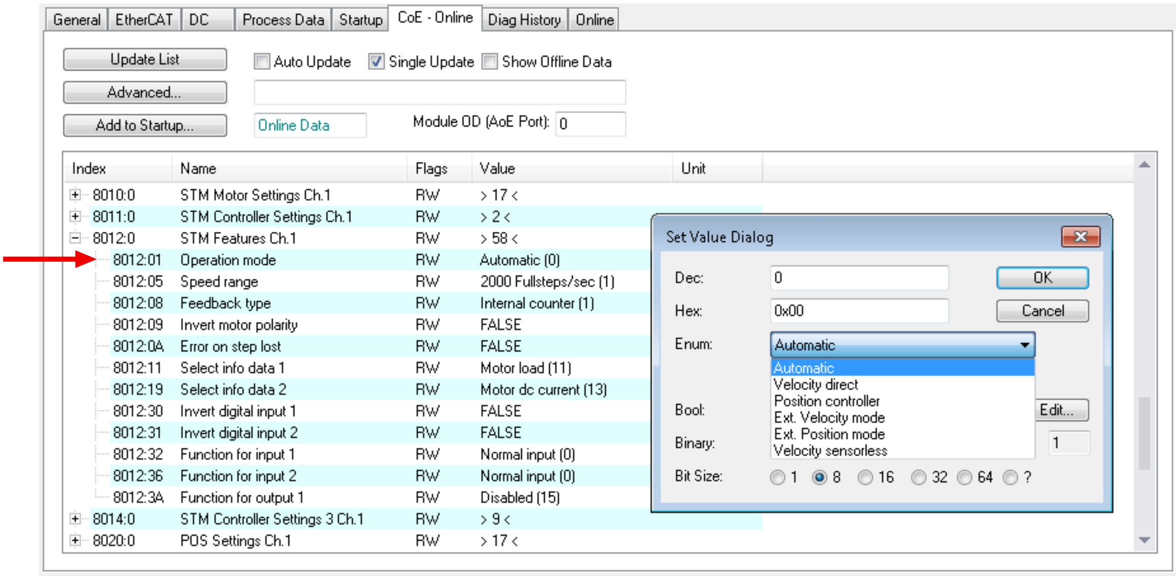
Recalculate the parameter Scaling factor [▸ 54] if you have changed the "Feedback type" parameter.

Factory setting: "Internal counter"

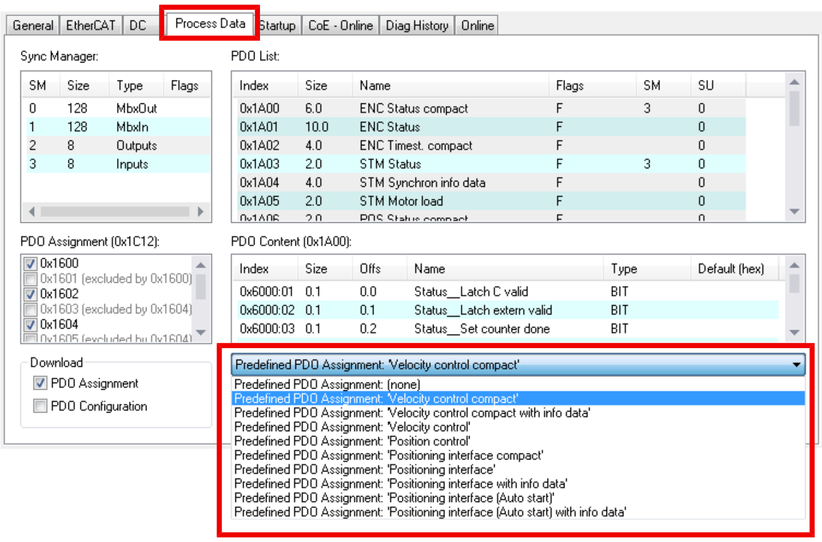
- If you are using an encoder, set this parameter to "Encoder". Parameterize the encoder [▸ 54].
- Otherwise set this parameter to "Internal counter".

4.3 Setting the operating mode

1. Decide which operating mode is required for your application. Selection wizard [▶ 46]
2. Set the operating mode via CoE parameter 8012:01$_{hex}$.



3. Click the "Process data" tab.



4. Select a suitable "Predefined PDO Assignment" for the selected operating mode.
Suitable "Predefined PDO Assignments" for the individual operating modes can be found in chapter Operating modes [▶ 46].
Note:
- if you have set the "Automatic" [▶ 47] operating mode, the selection of the "Predefined PDO Assignment" determines the actual operating mode.
- if you select "Positioning Interface [...]", the link to an NC axis is broken.
5. Set all parameters required for the selected operating mode [▶ 46].

4.3.1 Operating modes

"Automatic" [▶ 47] (factory setting)
"Velocity direct" [▶ 48]
"Position Controller" [▶ 49]
"Ext. Velocity mode" [▶ 50]
"Ext. Position mode" [▶ 51]

4.3.1.1 Selection wizard

As a rule, the operating modes differ in whether the setpoint is a position or a speed.

Operating modes with position setpoint:

- "Position Controller" [▶ 49]
- "Ext. Position mode" [▶ 51]

Operating modes with speed setpoint:

- "Velocity direct" [▶ 48]
- "Ext. Velocity mode" [▶ 50]

Requirements

	Velocity direct	Position controller	Ext. Velocity mode	Ext. Position mode
Motor from Beckhoff required?	No	No	Yes	Yes
Encoder required?	No	No	Yes	Yes

Pros and cons

	Velocity direct	Position controller	Ext. Velocity mode	Ext. Position mode
Commutation finding [1)]	No	No	Yes	Yes
Control dynamics	+	+	++	++
Step loss detection	Yes	Yes	n/a [2)]	n/a [2)]
Load angle detection	Yes	Yes	n/a [3)]	n/a [3)]
Load-dependent current	No	No	Yes	Yes
Energy efficiency	o	o	++	++
Use of the Positioning Interface [▶ 60] possible	No	Yes	No	Yes

[1)] After the output stage is enabled, the rotor slightly moves in both directions.
During commutation determination the rotor shaft should not be subject to an external torque. See also [▶ 25]

[2)] Step losses are avoided

[3)] The load angle is always 90°.

4.3.1.2 "Automatic" operating mode

If the "Automatic" operating mode is set, EP7047-1032 selects the actual operating mode according to the set "Predefined PDO assignment" [▸ 11]:

Predefined PDO Assignment	Operation mode
Position Control	Position controller [▸ 49]
Positioning Interface	Position controller [▸ 49]
Positioning Interface (Auto start)	Position controller [▸ 49]
Positioning Interface (Auto start) with info data	Position controller [▸ 49]
Positioning interface compact	Position controller [▸ 49]
Velocity control	Velocity direct [▸ 48]
Velocity control compact (*factory setting*)	Velocity direct [▸ 48]
Velocity control compact with info data	Velocity direct [▸ 48]

4.3.1.3 "Velocity direct" operating mode

Properties

- Speed control
- Specification of the speed via the "Velocity" variable in process data object STM Velocity [▸ 17].

Possible "Predefined PDO Assignments"

- Velocity control [▸ 12]

Parameter

Index (hex)	Name	Description	Unit	Data type	Default value
8010:03	Nominal voltage	The DC link voltage U_P	10 mV	UINT	5000_{dec}
8011:01	Kp factor (curr.)	Proportional component of the current controller		UINT	150_{dec}
8011:02	Ki factor (curr.)	Integral component of the current controller		UINT	10_{dec}

Optional parameters

To use step loss detection and/or load angle detection without encoder, set the following parameters additionally:

Index (hex)	Name	Description	Unit	Data type	Default value
8010:05	Motor EMF	The voltage constant k_e for calculating the back electromotive force (BEMF) The voltage constant can be found in the data sheet of the motor. Alternatively, you can determine it experimentally [▸ 76].	mV/ (rad/s)	UINT	0
8010:0A	Motor coil inductance	The winding inductance of the motor.	0.01 mH	UINT	0

4.3.1.4 "Position controller" operating mode

Properties

- Position specification via the variable "Position" in process data object STM Position [▸ 17].
- If you do not want to use the TwinCAT NC, you can use the Positioning Interface [▸ 60].

Possible "Predefined PDO Assignments"

- Position control [▸ 11]
- Positioning interface [▸ 11]
- Positioning interface (Auto start) [▸ 11]
- Positioning interface (Auto start) with info data [▸ 11]
- Positioning interface compact [▸ 12]

Parameter

Index (hex)	Name	Description	Unit	Data type	Default value
8010:03	Nominal voltage	The DC link voltage U_P	10 mV	UINT	5000_{dec}
8010:04	Motor coil resistance	The winding resistance of the motor.	0.01 Ω	UINT	100_{dec}
8011:01	Kp factor (curr.)	Proportional component of the current controller		UINT	150_{dec}
8011:02	Ki factor (curr.)	Integral component of the current controller		UINT	10_{dec}
8014:01	Feed forward (pos.)	Pre-control of the position controller.		UDINT	100000_{dec}
8014:02	Kp factor (pos.)	Proportional component of the position controller.		UINT	500_{dec}

Optional parameters

To use step loss detection and/or load angle detection without encoder, set the following parameters additionally:

Index (hex)	Name	Description	Unit	Data type	Default value
8010:05	Motor EMF	The voltage constant k_e for calculating the back electromotive force (BEMF) The voltage constant can be found in the data sheet of the motor. Alternatively, you can determine it experimentally [▸ 76].	mV/ (rad/s)	UINT	0
8010:0A	Motor coil inductance	The winding inductance of the motor.	0.01 mH	UINT	0

4.3.1.5 "Ext. Velocity mode" operating mode

Properties

- Velocity control
- Field-oriented control [▸ 25]
- Specification of the speed via the "Velocity" variable in process data object STM Velocity [▸ 17].

Possible "Predefined PDO Assignments"

- Velocity control [▸ 12]
- Velocity control compact [▸ 12]
- Velocity control compact with info data [▸ 12]

Parameter

Index (hex)	Name	Description	Unit	Data type	Default value
8010:03	Nominal voltage	The DC link voltage U_P	10 mV	UINT	5000_{dec}
8010:07	Encoder increments (4-fold)	Number of encoder increments per revolution with 4-fold evaluation. Usually this is the resolution (ppr) of the encoder multiplied by 4.	-	UINT	4096_{dec}
8011:01	Kp factor (curr.)	Proportional component of the current controller		UINT	150_{dec}
8011:02	Ki factor (curr.)	Integral component of the current controller		UINT	10_{dec}
8014:03	Kp factor (velo.)	Proportional component of the velocity controller.	0.1 mA / (rad/s)	UDINT	50_{dec}
8014:04	Tn (velo.)	Time constant Tn of the velocity controller.	0.01 ms	UINT	50000_{dec}

4.3.1.6 "Ext. Position mode" operating mode

Properties

- Position control
- Field-oriented control [▶ 25]
- Position specification via the variable "Position" in process data object STM Position [▶ 17].

Possible "Predefined PDO Assignments"

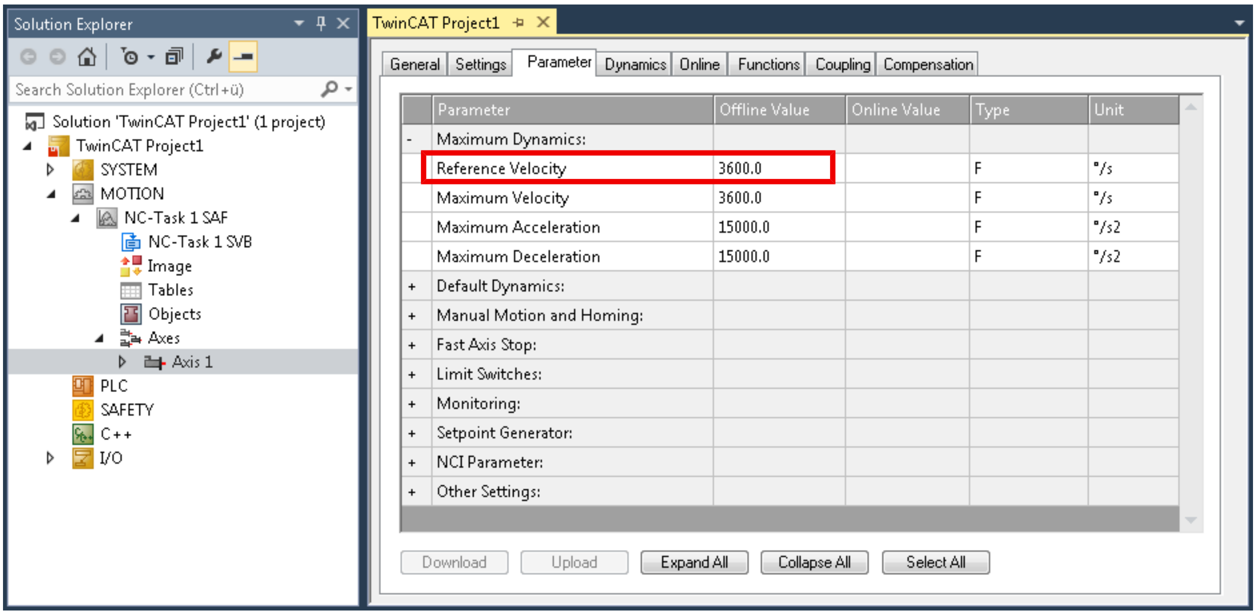
- Position control [▶ 11]
- Positioning Interface [▶ 11]
- Positioning Interface compact [▶ 12]
- Positioning interface (Auto start) [▶ 11]
- Positioning interface (Auto start) with info data [▶ 11]

Parameter

Index (hex)	Name	Description	Unit	Data type	Default value
8010:03	Nominal voltage	The DC link voltage U_P	10 mV	UINT	5000_{dec}
8010:04	Motor coil resistance	The winding resistance of the motor.	0.01 Ω	UINT	100_{dec}
8010:07	Encoder increments (4-fold)	Number of encoder increments per revolution with 4-fold evaluation. Usually this is the resolution (ppr) of the encoder multiplied by 4.	-	UINT	4096_{dec}
8011:01	Kp factor (curr.)	Proportional component of the current controller		UINT	150_{dec}
8011:02	Ki factor (curr.)	Integral component of the current controller		UINT	10_{dec}
8014:01	Feed forward (pos.)	Pre-control of the position controller.		UDINT	100000_{dec}
8014:02	Kp factor (pos.)	Proportional component of the position controller.		UINT	500_{dec}
8014:03	Kp factor (velo.)	Proportional component of the velocity controller.	0.1 mA / (rad/s)	UDINT	50_{dec}
8014:04	Tn (velo.)	Time constant Tn of the velocity controller.	0.01 ms	UINT	50000_{dec}

4.4 Parameterizing the NC axis

Parameter "Reference Velocity"



Unit: °/s
Factory setting: 2200_{dec}

Calculate the "Reference Velocity" using this formula:

$$n_{ref} = f_{max} \times \varphi$$

n_{ref}: "Reference Velocity" [°/s]

f_{max}: "Speed range" [▶ 44] [full steps/s]

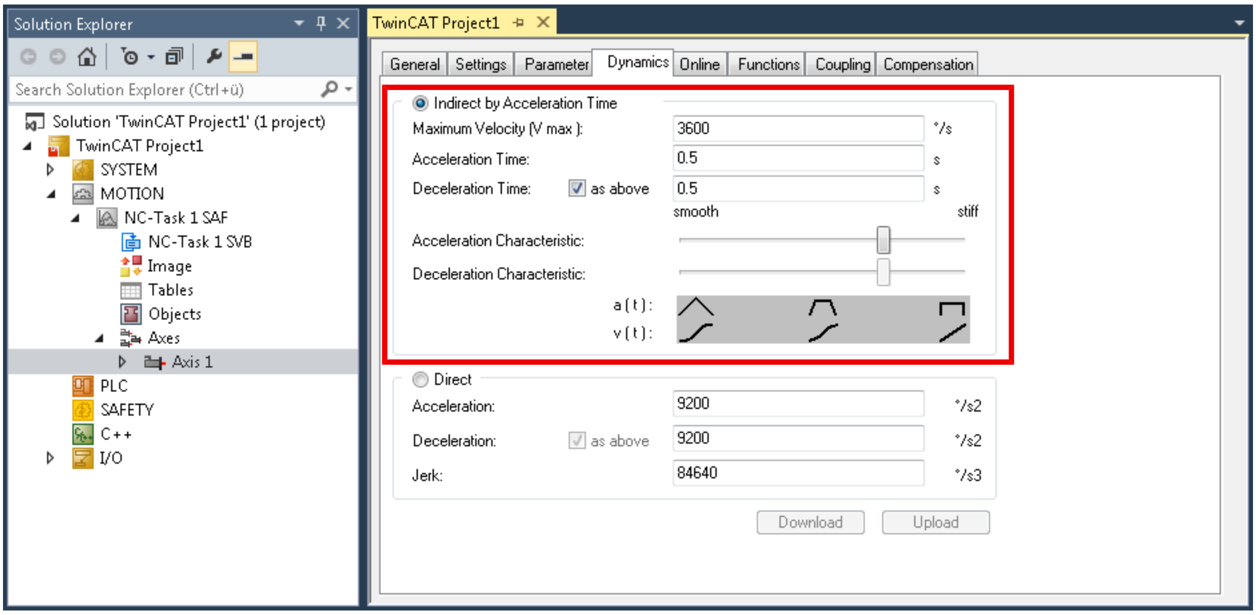
φ: Step angle of the motor [°]

Example for an AS1050-0120 motor:

$$n_{ref} = 2000\,\frac{1}{s} \times 1{,}8^{\circ} = 3600\,\frac{^{\circ}}{s}$$

Setting the acceleration time

In order to pass through any resonances that may occur as quickly as possible, the ramps for the acceleration time and the deceleration time should be as steep as possible.



NOTE

Short braking times can lead to overvoltages in the DC link.

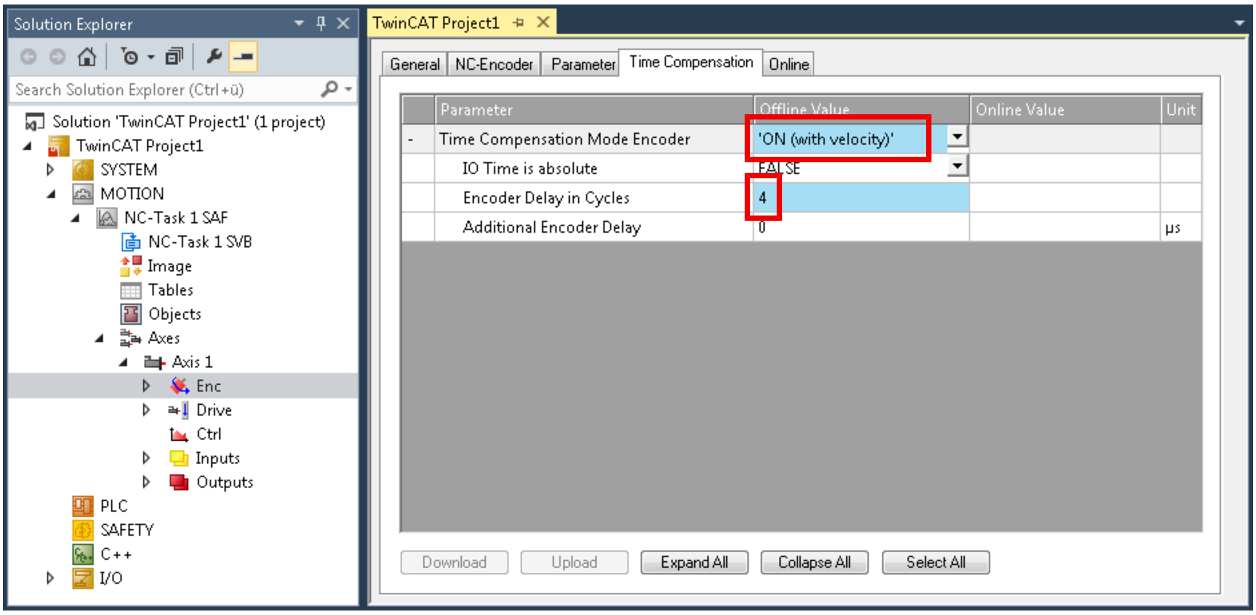
In the event of an overvoltage in the DC link, a protective mechanism switches off the motor output stage. The "Error" status bit in the process data object STM status [▶ 15] is set.

- Check whether impermissibly high voltages occur in the DC link during braking.
- If necessary, connect EP9576-1032 in parallel with EP7047-1032 to prevent overvoltages in the DC link. EP9576-1032 contains a brake resistor to dissipate drive-related overvoltages.

4.4.1 Parameterizing the encoder

Dead time compensation

The dead time compensation of the axis can be set in the *Time Compensation* tab of the *Axis1_ENC* encoder settings. It should, in theory, be 3 cycles of the NC cycle time, although in practice 4 cycles were found to be preferable. The parameter *Time Compensation Mode Encoder* should be set to 'ON (with velocity)', the parameter *Encoder Delay in Cycles* to 4.



Scaling factor

The scaling factor can be changed by selecting "Axis 1_Enc" and tab "Parameter" in the NC (see *"Setting the Scaling Factor*"). The value can be calculated with the formulas specified below.

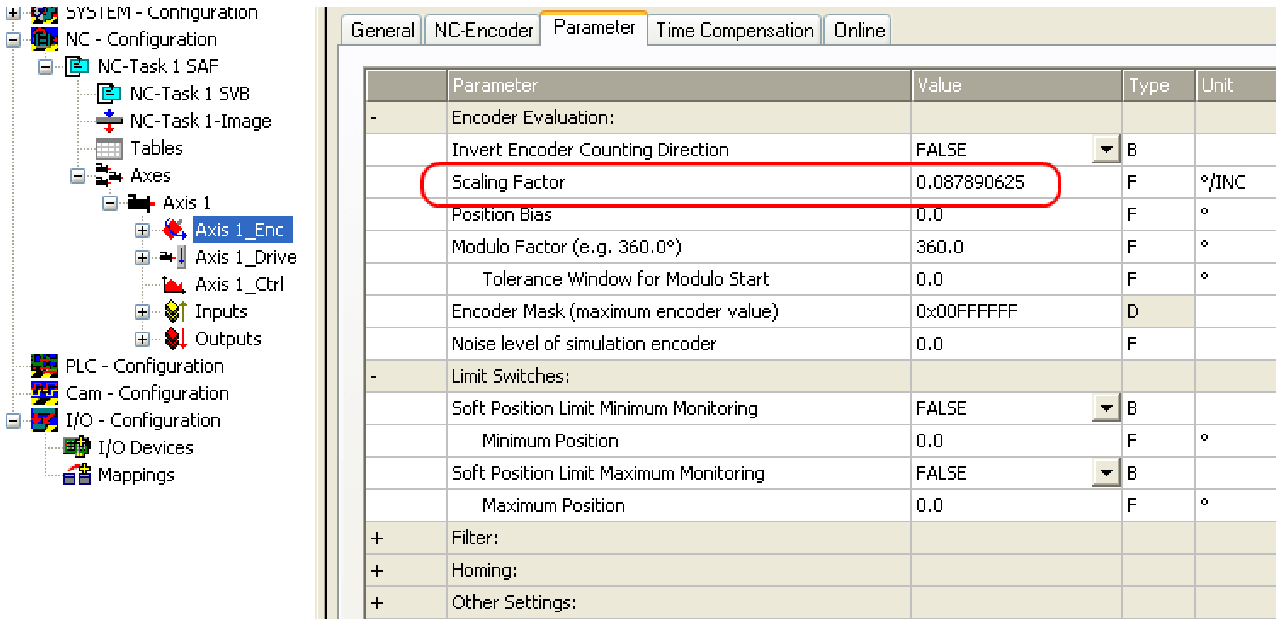


Fig. 25: *Setting the Scaling Factor*

Adaptation of the scaling factor

The feedback system is directly related to the scaling factor of the TwinCAT NC, so that the scaling factor always has to be adjusted when the feedback system is changed.

Calculation of the scaling factor

with encoder, 4-fold evaluation:

SF = distance per revolution / (increments x 4) = 360° / (1024 x 4) = 0.087890625 ° / INC

without encoder:

SF = distance per revolution / (full steps x microsteps) = 360° / (200 x 64) = 0.028125 ° / INC

4.4.2 Parameterizing the controller

K_v factors

In the NC two proportional factors K_v can be set under "Axis 1_Ctrl " in tab "Parameter". First select the position controller *Type* with two P constants (with K_a) under the “NC Controller” tab. The two P constants are for the *Standstill* range and for the *Moving* range (see Fig. *"Setting the proportional factor K_v"*). The factors can be used to set the start-up torque and the braking torque to a different value than the drive torque. The threshold value can be set directly below (Position control: Velocity threshold V dyn) between 0.0 (0%) and 1.0 (100%). Fig. *"Velocity ramp with K factor limit values"* shows a speed ramp with thresholds of 30%. The K_v factor for Standstill (t_1 and t_3) can be different than the K_v factor for Moving (t_2). In this case the same factor was used, since for stepper motors this function is less crucial than for DC motors.

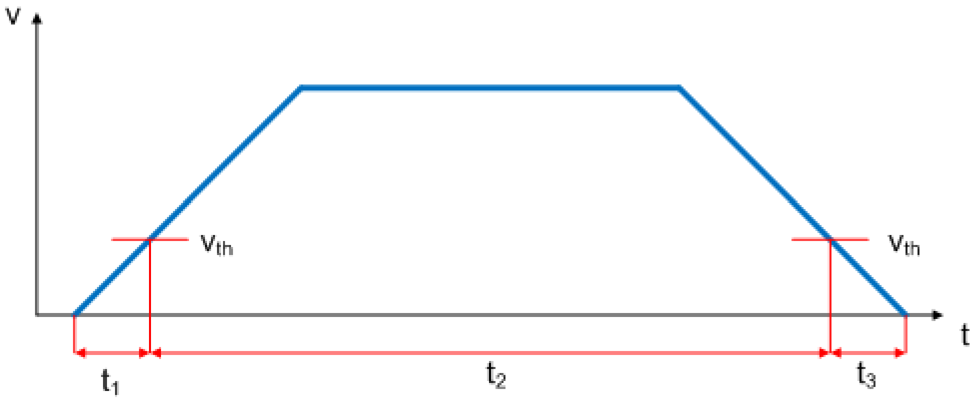
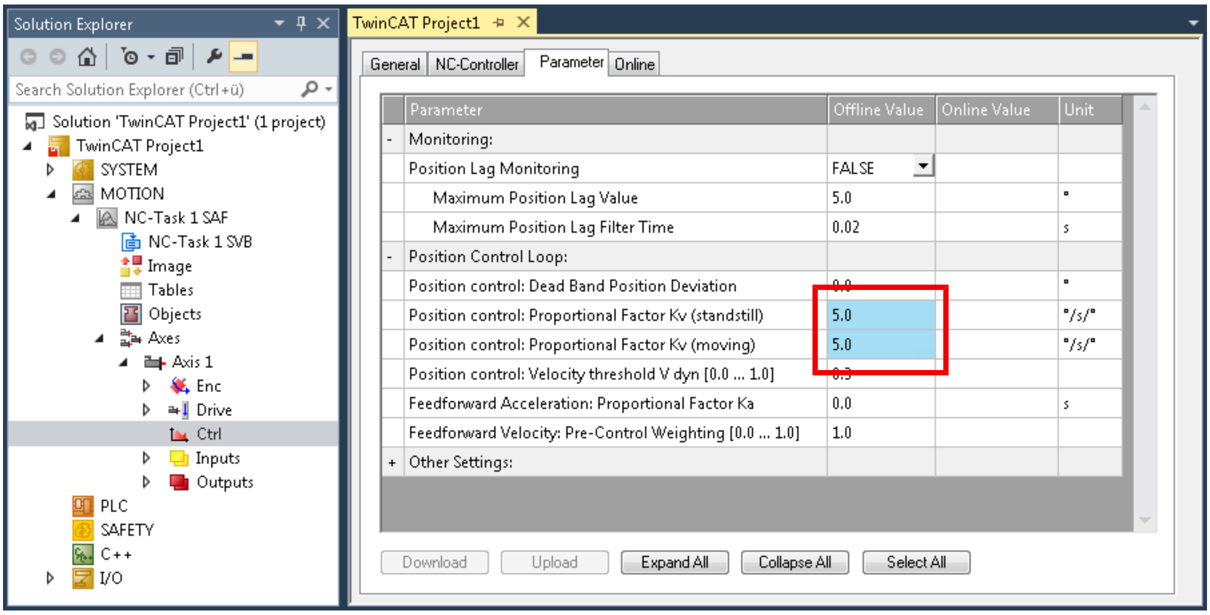


Fig. 26: *Speed ramp with K factor limit values*



Position lag monitoring

The position lag monitoring function checks whether the current position lag of an axis has exceeded the limit value. The position lag is the difference between the set value (control value) and the actual value reported back. If the parameters of EP7047-1032 are set inadequately, the position lag monitoring function may report an error when the axis is moved. During commissioning it may therefore be advisable to increase the limits of the *Position lag monitoring* slightly.

NOTE

ATTENTION: Damage to equipment, machines and peripheral components possible!

Setting the position lag monitoring parameters too high may result in damage to equipment, machines and peripheral components.

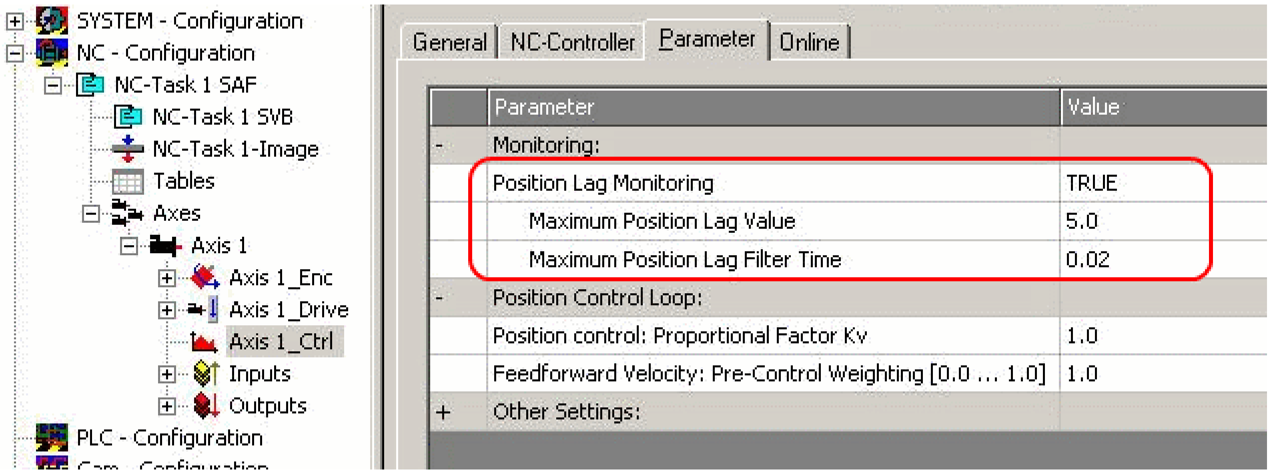


Fig. 27: *Position lag monitoring parameters*

Dead band for position errors

Microstepping can be used to target 200 * 64 = 12800 positions. Since the encoder can only scan 1024 * 4 = 4096 positions, positions between two encoder scan points may not be picked up correctly, in which case the controller will control around this position The dead band for position errors is a tolerance range within which the position is regarded as reached (Fig. "*Dead band for position errors*").

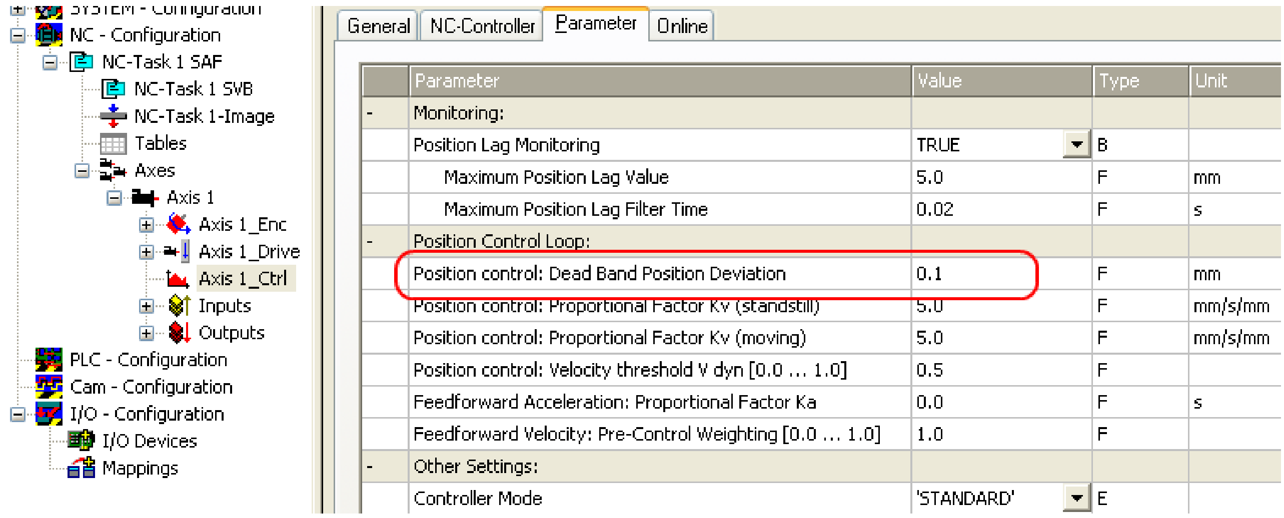


Fig. 28: *Dead band for position errors*

4.5 Performing a test run

NOTE

Important parameters must be set before the test run.

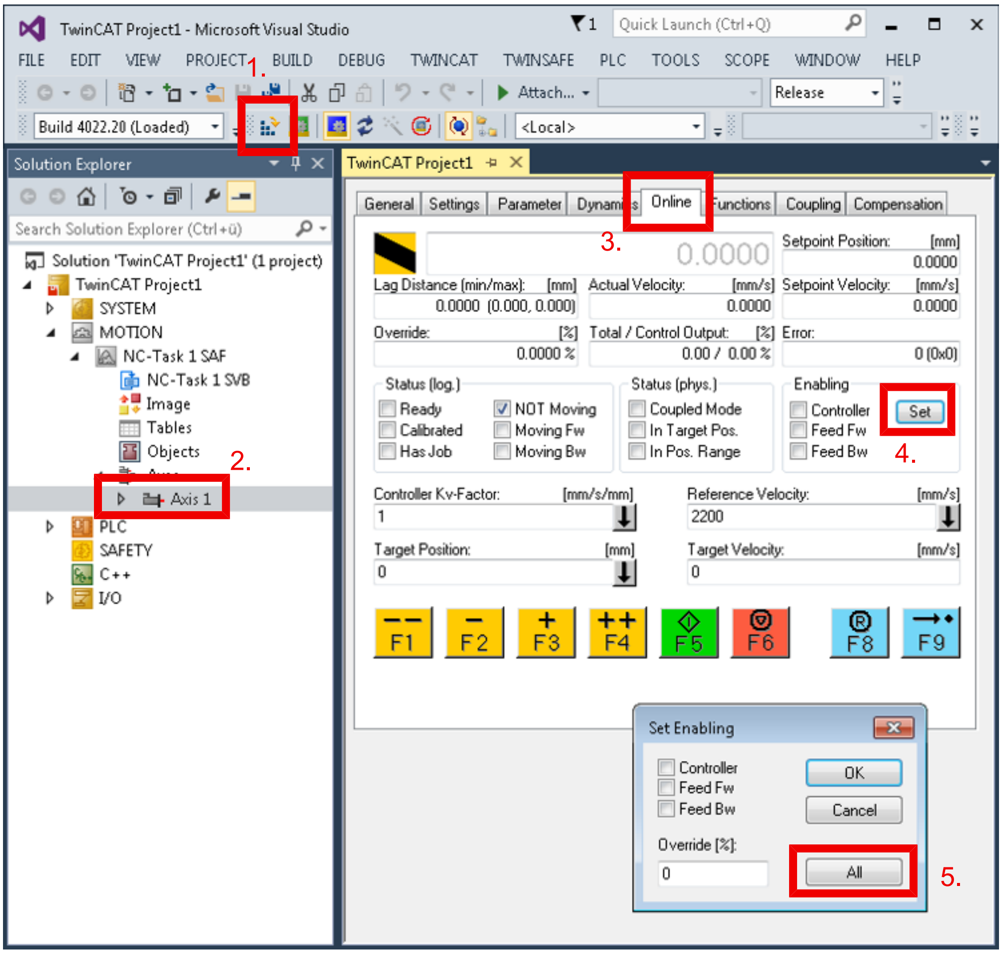
Risk of defect.

- Before the test run, carefully set the important motor parameters [▶ 42].

The procedure for a test run depends on whether you are using TwinCAT NC or not.

- Test run with TwinCAT NC [▶ 58]
- Test run without the TwinCAT NC [▶ 59]

4.5.1 Test run with TwinCAT NC



✓ Requirement: The I/O module of EP7047-1032 is linked to an NC axis.

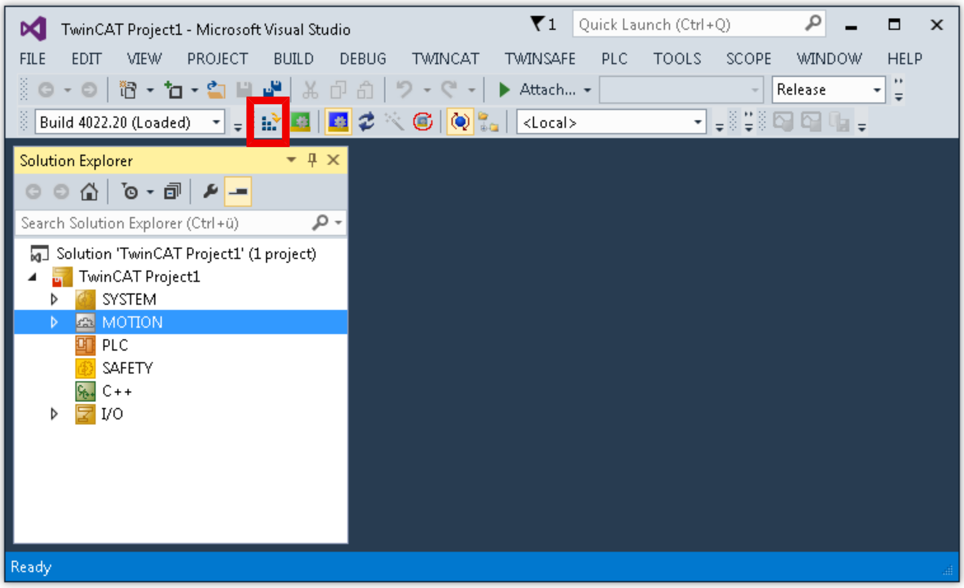
1. Activate the TwinCAT configuration.
2. Double-click the NC axis.
3. Click the "Online" tab.
4. Click the "Set" button in the "Enabling" field.
5. Click the "All" button in the window that appears.
   ⇨ The output stage is enabled.

⇨ You can use the colored buttons to move the axis for testing purposes.

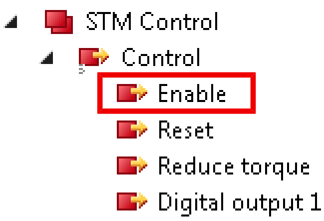
4.5.2 Test run without the TwinCAT NC

✓ Requirement: you are *not* using the "Positioning Interface".

1. Activate the TwinCAT configuration.



2. Set the variable "Enable" in the process data object "STM Control" to 1.



⇨ The output stage is enabled.

3. Specify a setpoint, depending on the operating mode [▸ 45]:

Operation mode	Process data object for specifying a setpoint
Velocity direct	"STM Velocity" [▸ 17]
Position controller	"STM Position" [▸ 17]
Ext. Velocity mode	"STM Velocity" [▸ 17]
Ext. Position mode	"STM Position" [▸ 17]

4.6 Further applications

4.6.1 Using the "Positioning Interface"

The "Positioning interface" can be used to execute motion commands without TwinCAT NC.

4.6.1.1 Basic principles: "Positioning interface"

Predefined PDO Assignment

The "Predefined PDO Assignment" enables a simplified selection of the process data. Select the function “*Positioning interface*” or “*Positioning interface compact*” in the lower part of the Process data tab. As a result, all necessary PDOs are automatically activated and the unnecessary PDOs are deactivated.

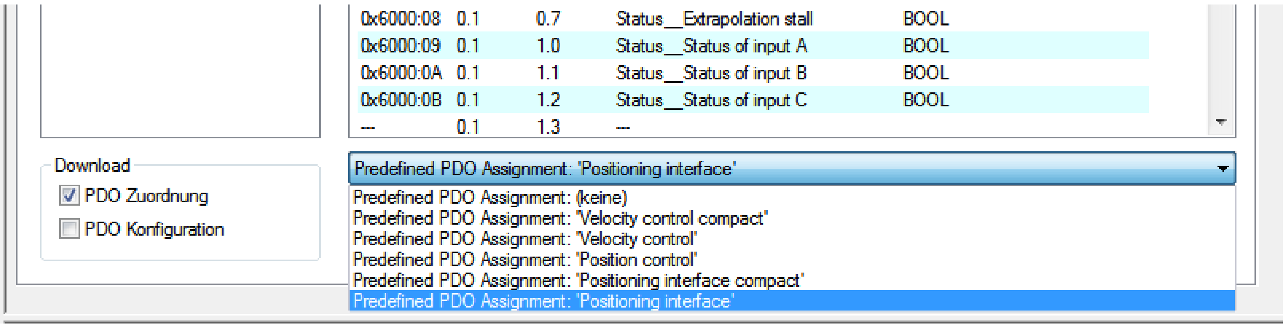


Fig. 29: *Predefined PDO Assignment*

Parameter set

Two objects are at the user’s disposal in the CoE for the configuration – the “POS Settings” (Index 8020) and the “POS Features” (Index 8021).

Index	Name	Flags	Wert
8020:0	POS Settings Ch.1	RW	> 15 <
8020:01	Velocity min.	RW	100
8020:02	Velocity max.	RW	10000
8020:03	Acceleration pos.	RW	0x03E8 (1000)
8020:04	Acceleration neg.	RW	0x03E8 (1000)
8020:05	Deceleration pos.	RW	0x03E8 (1000)
8020:06	Deceleration neg.	RW	0x03E8 (1000)
8020:07	Emergency deceleration	RW	0x0064 (100)
8020:08	Calibration position	RW	0x00000000 (0)
8020:09	Calibration velocity (towards plc cam)	RW	200
8020:0A	Calibration Velocity (off plc cam)	RW	50
8020:0B	Target window	RW	0x0014 (20)
8020:0C	In-Target timeout	RW	0x03E8 (1000)
8020:0D	Dead time compensation	RW	50
8020:0E	Modulo factor	RW	0x00000000 (0)
8020:0F	Modulo tolerance window	RW	0x00000000 (0)
8021:0	POS Features Ch.1	RW	> 20 <
8021:01	Start type	RW	Absolute (1)
8021:11	Time information	RW	Elapsed time (0)
8021:13	Invert calibration cam search direction	RW	TRUE
8021:14	Invert sync impulse search direction	RW	FALSE

Fig. 30: *Settings objects in the CoE*

POS Settings

Velocity min.:

For reasons of performance when ramping down to the target position, EP7047-1032 needs a safety margin of 0.5%. That means that, depending on the maximum velocity reached and the configured deceleration, the time is calculated at which the deceleration ramp begins. In order to always reach the destination reliably, 0.5% is subtracted from the position determined. If the deceleration ramp has ended and the destination has not yet been reached, EP7047-1032 drives at the velocity “*Velocity min*.” to the destination. It must be configured in such a way that the motor is able to stop abruptly and without a step loss at this velocity.

Velocity max.:

The maximum velocity with which the motor drives during a travel command.

"Speed range" (index 8012:05)

Velocity min./max. are standardised to the configured "Speed range" (Index 8012:05). This means that for a "Speed range" of 4000 full steps/second, for example, for a speed output of 100% (i.e. 4000 full steps/second) 10,000 should be entered under "Velocity max.", and 5,000 for 50% (i.e. 2000 full steps/second).

Acceleration pos.:

Acceleration time in the positive direction of rotation.

The 5 parameters for acceleration also refer to the set “*Speed range*” and are given in ms. With a setting of 1000, EP7047-1032 accelerates the motor from 0 to 100% in 1000 ms. At a speed of 50% the acceleration time is linearly reduced to half accordingly.

Acceleration neg.:

Acceleration time in the negative direction of rotation.

Deceleration pos.:

Deceleration time in the positive direction of rotation.

Deceleration neg.:

Deceleration time in the negative direction of rotation.

Emergency deceleration:

Emergency deceleration time (both directions of rotation). If “*Emergency stop*” is set in the appropriate PDO, the motor is stopped within this time.

Calibration position:

The current counter value is loaded with this value after calibration.

Calibration velocity (towards plc cam):

Velocity with which the motor travels towards the cam during calibration.

Calibration velocity (off plc cam):

Velocity with which the motor travels away from the cam during calibration.

Target window:

Target window of the travel distance control. “*In-Target*” is set if the motor comes to a stop within this target window.

In-Target timeout:

“*In-Target*” is not set if the motor is not within the target window after the expiry of the travel distance control after this set time. This condition can be recognised only by checking the falling edge of “*Busy*”.

Dead time compensation:

Compensation of the internal propagation delays. This parameter does not have to be changed with standard applications.

Modulo factor:

The “*Modulo factor*” is referred to for the calculation of the target position and the direction of rotation in the modulo operating modes. It refers to the controlled system.

Modulo tolerance window:

Tolerance window for the determination of the start condition of the modulo operating modes.

POS Features

Start type:

The “*Start type*” specifies the type of calculation used to determine the target position (see below).

Time information:

The meaning of the “*Actual drive time*” displayed is configured by this parameter. At present this value cannot be changed, since there are no further selection options. The elapsed time of the travel command is displayed.

Invert calibration cam search direction:

In relation to a positive direction of rotation, the direction of the search for the calibration cam is configured here (travel towards the cam).

Invert sync impulse search direction:

In relation to a positive direction of rotation, the direction of the search is configured here in accordance with the HW sync pulse (travel away from the cam).

Information and diagnostic data

Information and diagnostic data

Via the information and diagnostic data, the user can obtain a more exact statement about which error occurred during a travel command.

Index	Name	Flags	Wert
9020:0	POS Info data Ch.1	RO	> 3 <
9020:01	Status word	RO	0x0000 (0)
9020:03	State (drive controller)	RO	Idle (1)
A010:0	STM Diag data Ch.1	RO	> 17 <
A020:0	POS Diag data Ch.1	RO	> 3 <
A020:01	Command rejected	RO	FALSE
A020:02	Command aborted	RO	FALSE
A020:03	Target overrun	RO	FALSE

Fig. 31: *Diagnostic objects in the CoE*

POS Info data

Status word:

The “*Status word*” reflects the status bits used in *Index A020* in a data word, in order to be able to process them more simply in the PLC. The positions of the bits correspond to the number of the subindex-1.

Bit 0: Command rejected
Bit 1: Command aborded
Bit 2: Target overrun

State (drive controller):

The current status of the internal state machine is displayed here (see below).

POS Diag data:

Command rejected:

A dynamic change of the target position is not accepted each time by EP7047-1032, since this is then not possible. The new command is rejected in this case and indicated by the setting of this bit.

These 3 diagnostic bits are transmitted synchronously to the controller by setting “*Warning*” in the PDO.

Command aborted:

If the current travel command is prematurely aborted due to an internal error or by an “Emergency stop”.

Target overrun:

In the case of a dynamic change of the target position, the change may take place at a relatively late point in time. The consequence of this may be that a change in the direction of rotation is necessary and that the new target position may be overrun. “*Target overrun*” is set if this occurs.

States of the internal state machine

States of the internal state machine

The state (drive controller) (Index 9020:03) provides information about the current state of the internal state machine. For diagnostic purposes this can be read out by the PLC for the propagation delay. The internal cycle works constantly with 250 µs. A connected PLC cycle is very probably slower (e.g. 1 ms). For this reason it may be the case that some states are not visible at all in the PLC, since these will sometimes run through only one internal cycle.

Name	ID	Description
INIT	0x0000	Initialisation/preparation for the next travel command
IDLE	0x0001	Wait for the next travel command
START	0x0010	The new command is evaluated and the corresponding calculations are performed
ACCEL	0x0011	Acceleration phase
CONST	0x0012	Constant phase
DECEL	0x0013	Deceleration phase
EMCY	0x0020	An "*Emergency stop*" has been triggered
STOP	0x0021	The motor has stopped
CALI_START	0x0100	Start of a calibration command
CALI_GO_CAM	0x0110	The motor is being driven towards the cam
CALI_ON_CAM	0x0111	The cam has been reached
CALI_GO_SYNC	0x0120	The motor is being driven in the direction of the HW sync pulse
CALI_LEAVE_CAM	0x0121	The motor is being driven away from the cam
CALI_STOP	0x0130	End of the calibration phase
CALIBRATED	0x0140	The motor is calibrated
NOT_CALIBRATED	0x0141	The motor is not calibrated
PRE_TARGET	0x1000	The set position has been reached; the position controller "pulls" the motor further into the target; "*In-Target timeout*" is started here
TARGET	0x1001	The motor has reached the target window within the timeout
TARGET_RESTART	0x1002	A dynamic change of the target position is processed here
END	0x2000	End of the positioning phase
WARNING	0x4000	A warning state occurred during the travel command; this is processed here
ERROR	0x8000	An error state occurred during the travel command; this is processed here
UNDEFINED	0xFFFF	Undefined state (can occur, for example, if the driver stage has no control voltage)

States of the internal state machine

Standard sequence of a travel command

Standard sequence of a travel command

The "normally" sequence of a travel command is shown in the following flow diagram.
Coarse distinction is made between these four stages:

StartUp:

Test the system and the ready status of the motor.

Start positioning:

Write all variables and calculate the desired target position with the appropriate "*Start type*". Subsequently, start the travel command.

Evaluate status:

Monitor the internal state of EP7047-1032 and, if necessary, dynamically change the target position.

Error handling:

In case of error, procure the necessary information from the CoE and evaluate it.

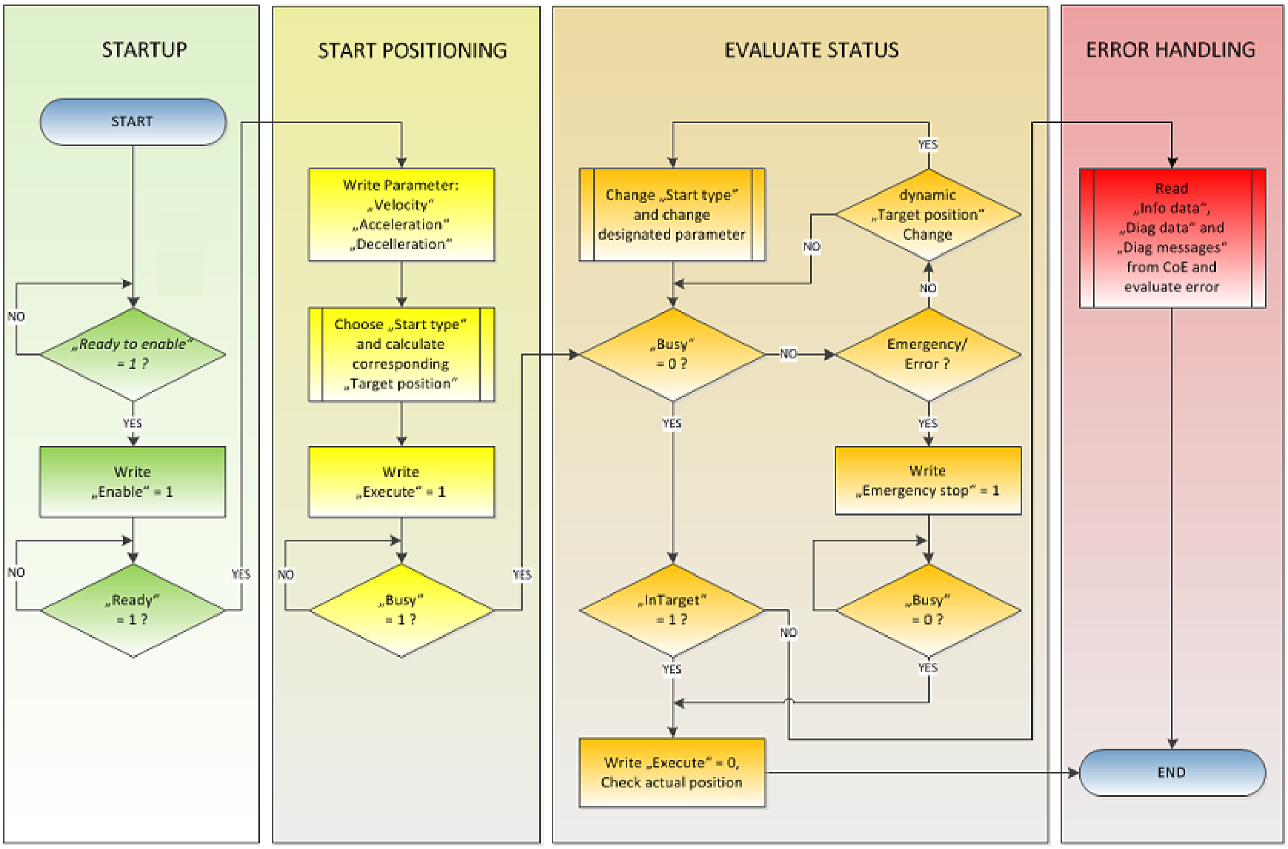


Fig. 32: *Flow diagram for a travel command*

Start types

The “*Positioning interface*” offers different types of positioning. The following table contains all commands supported; these are divided into 4 groups.

Name	Command	Group	Description
ABSOLUTE	0x0001	Standard [▸ 66]	Absolute positioning to a specified target position
RELATIVE	0x0002		Relative positioning to a calculated target position; a specified position difference is added to the current position
ENDLESS_PLUS	0x0003		Endless travel in the positive direction of rotation (direct specification of a speed)
ENDLESS_MINUS	0x0004		Endless travel in the negative direction of rotation (direct specification of a speed)
ADDITIVE	0x0006		Additive positioning to a calculated target position; a specified position difference is added to the last target position
ABSOLUTE_CHANGE	0x1001	Standard Ext. [▸ 68]	Dynamic change of the target position during a travel command to a new absolute position
RELATIVE_CHANGE	0x1002		Dynamic change of the target position during a travel command to a new relative position (the current changing position value is used here also)
ADDITIVE_CHANGE	0x1006		Dynamic change of the target position during a travel command to a new additive position (the last target position is used here)
MODULO_SHORT	0x0105	Modulo [▸ 69]	Modulo positioning along the shortest path to the modulo position (positive or negative), calculated by the "*Modulo factor*" (Index 8020:0E)
MODULO_SHORT_EXT	0x0115		Modulo positioning along the shortest path to the modulo position; the "*Modulo tolerance window*" (Index 8020:0F) is ignored
MODULO_PLUS	0x0205		Modulo positioning in the positive direction of rotation to the calculated modulo position
MODULO_PLUS_EXT	0x0215		Modulo positioning in the positive direction of rotation to the calculated modulo position; the "*Modulo tolerance window*" is ignored
MODULO_MINUS	0x0305		Modulo positioning in the negative direction of rotation to the calculated modulo position
MODULO_MINUS_EXT	0x0315		Modulo positioning in the negative direction of rotation to the calculated modulo position; the "*Modulo tolerance window*" is ignored
MODULO_CURRENT	0x0405		Modulo positioning in the last direction of rotation to the calculated modulo position
MODULO_CURRENT_EXT	0x0415		Modulo positioning in the last direction of rotation to the calculated modulo position; the "*Modulo tolerance window*" is ignored
CALI_PLC_CAM	0x6000	Calibration [▸ 68]	Start a calibration with cam (digital inputs)
CALI_HW_SYNC	0x6100		start a calibration with cam and HW sync pulse (C-track)
SET_CALIBRATION	0x6E00		Manually set the flag "*Calibrated*"
SET_CALIBRATION_AUTO	0x6E01		Automatically set the flag "*Calibrated*" on the first rising edge on "*Enable*"
CLEAR_CALIBRATION	0x6F00		Manually delete the calibration

Supported "Start types" of the "Positioning interface"

ABSOLUTE:

The absolute positioning represents the simplest positioning case. A position B is specified and travelled to from the start point A.

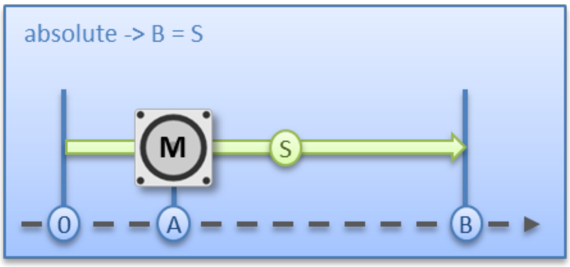


Fig. 33: *Absolute positioning*

RELATIVE:

In relative positioning, the user specifies a position delta S, which is added to the current position A, producing the target position B.

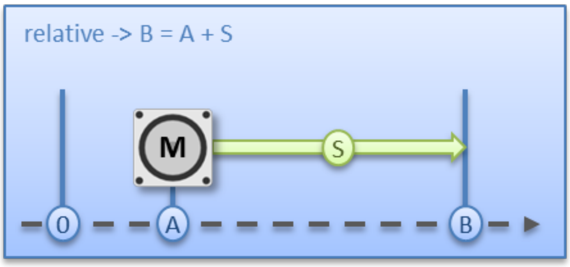


Fig. 34: *Relative positioning*

ENDLESS_PLUS / ENDLESS_MINUS:

The two start types “*ENDLESS_PLUS*” and “*ENDLESS_MINUS*” offer the possibility in the “*Positioning interface*” to specify a direct motor velocity in order to travel endlessly in the positive or negative direction with the specified accelerations.

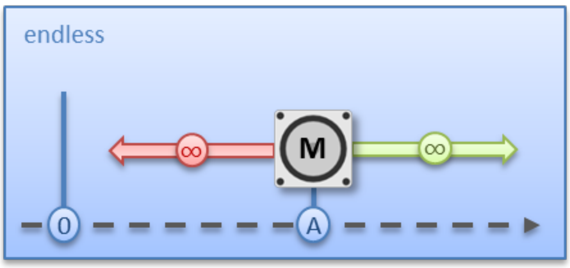


Fig. 35: *Endless travel*

ADDITIVE:

For additive positioning, the position delta S specified by the user is added to the target position E used for the last travel command in order to calculate the target position B.

This kind of positioning resembles the relative positioning, but there is a difference. If the last travel command was completed successfully, the new target position is the same. If there was an error, however, be it that the motor entered a stall state or an “*Emergency stop*” was triggered, the current position is arbitrary and not foreseeable. The user now has the advantage that he can use the last target position for the calculation of the following target position.

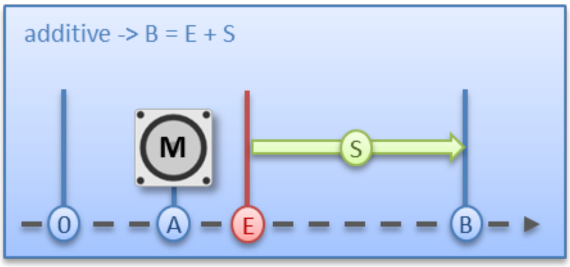


Fig. 36: *Additive positioning*

ABSOLUTE_CHANGE / RELATIVE_CHANGE / ADDITIVE_CHANGE:

These three kinds of positioning are completely identical to those described above. The important difference thereby is that the user uses these commands during an active travel command in order to dynamically specify a new target position.

The same rules and conditions apply as to the “normal” start types. “*ABSOLUTE_CHANGE*” and “*ADDITIVE_CHANGE*” are unique in the calculation of the target position i.e. in absolute positioning an absolute position is specified and in additive positioning a position delta is added to the momentarily active target position.

NOTE

Caution when using the “RELATIVE_CHANGE” positioning

The change by means of "RELATIVE_CHANGE" must be used with caution, since the current position of the motor is also used here as the start position. Due to propagation delays in the system, the position indicated in the PDO never corresponds to the actual position of the motor! Therefore a difference to the desired target position always results in the calculation of the transferred position delta.

Time of the change of the target position

A change of the target position cannot take place at an arbitrary point in time. If the calculation of the output parameters shows that the new target position cannot be readily reached, the command is rejected and the “Command rejected” bit is set. This is the case, for example, at standstill (since a standard positioning is expected here) and in the acceleration phase (since at this point the braking time cannot be calculated yet).

CALI_PLC_CAM / CALI_HW_SYNC / SET_CALIBRATION / SET_CALIBRATION_AUTO / CLEAR_CALIBRATION:

The simplest calibration case is calibration by cam only (connected to one digital input).

Here, the motor travels in the 1st step with velocity 1 (Index 0x8020:09) in direction 1 (Index 0x8021:13) towards the cam. Subsequently, in the 2nd step, it travels with velocity 2 (Index 0x8020:0A) in direction 2 (Index 8021:14) away from the cam. After the "*In-Target timeout"* (Index 8020:0C) has elapsed, the calibration position (Index 0x8020:08) is taken on as the current position.

NOTE

Observe the switching hysteresis of the cam switch

With this simple calibration it must be noted that the position detection of the cam is only exact to a certain degree. The digital inputs are not interrupt-controlled and are “only” polled. The internal propagation delays may therefore result in a system-related position difference.

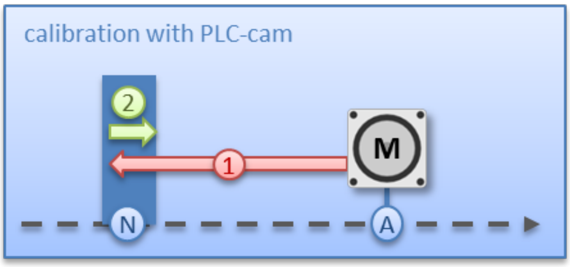


Fig. 37: *Calibration with cam*

For a more precise calibration, an HW sync pulse (C-track) is used in addition to the cam. This calibration proceeds in exactly the same way as described above, up to the point at which the motor travels away from the cam. The travel is not stopped immediately; instead, the sync pulse is awaited. Subsequently, the "*In-Target timeout*" runs down again and the calibration position is taken on as the current position.

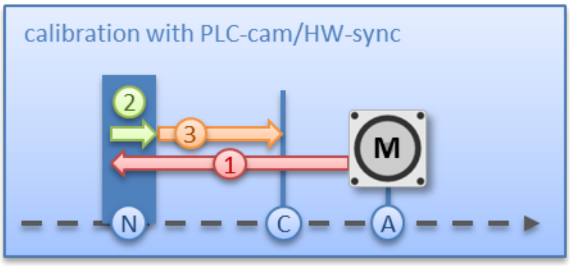


Fig. 38: *Calibration with cam and C-track*

If calibration by hardware is not possible due to the circumstances of the application, the user can also set the "*Calibrated*" bit manually or automatically. The manual setting or deletion takes place with the commands "*SET_CALIBRATION*" and "*CLEAR_CALIBRATION*".

It is simpler, however, if the standard start types (Index 0x8021:01) are set to "*SET_CALIBRATION_AUTO*". The "*Calibrated*" bit will now be set automatically by the first rising edge on "*Enable*". The command is conceived only for this purpose; therefore, it does not make sense to use it via the synchronous data exchange.

MODULO:

The modulo position of the axis is a piece of additional information about the absolute axis position. Modulo positioning represents the required target position in a different way. Contrary to the standard types of positioning, the modulo positioning has several pitfalls, since the desired target position can be interpreted differently.

The modulo positioning refers in principle to the "*Modulo factor*" (Index 0x8020:0E), which can be set in the CoE. In the following examples, a rotary axis with a "*Modulo factor*" equivalent to 360 degrees is assumed.

The "*Modulo tolerance window*" (Index 0x8020:0F) defines a position window around the current modulo target position of the axis. The window width is twice the specified value (set position ± tolerance value). A detailed description of the tolerance window is provided below.

The positioning of an axis is always referenced to its current actual position. The actual position of an axis is normally the target position of the last travel command. Under certain circumstances (incorrect positioning due to the axis stalling, or a very coarse resolution of the connected encoder), however, a position not expected by the user may arise. If this possibility is not considered, subsequent positioning may lead to unexpected behaviour.

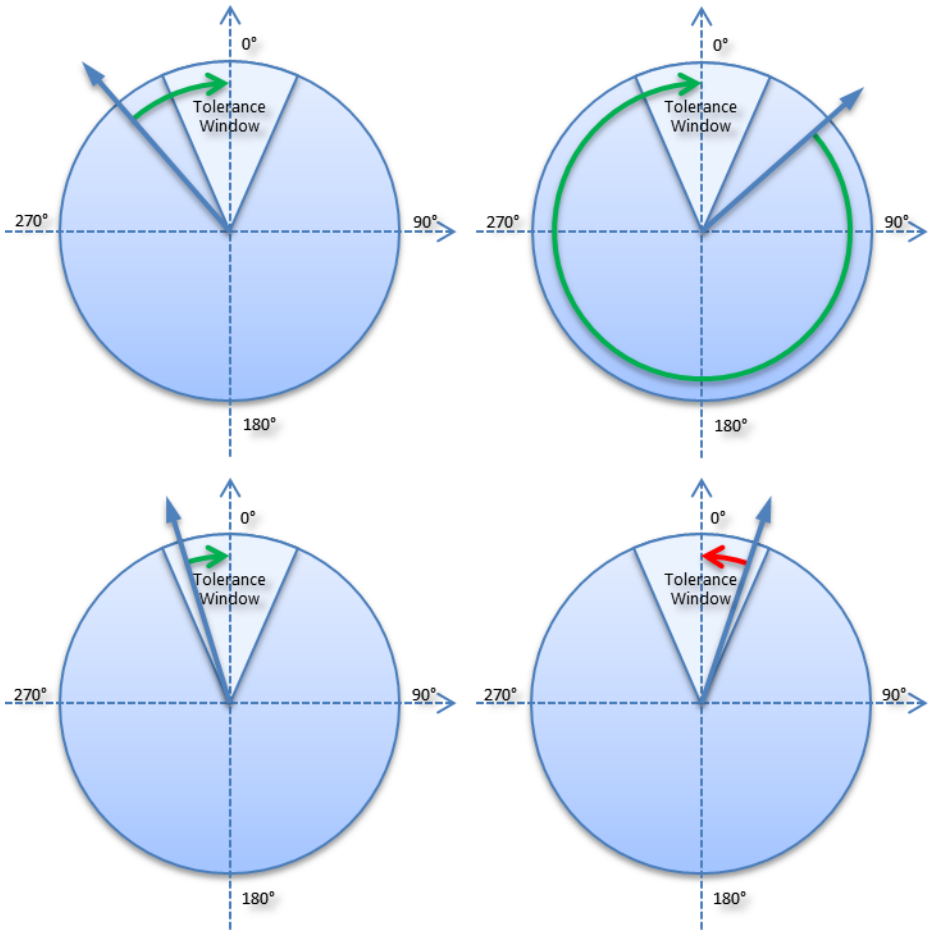


Fig. 39: *Effect of the modulo tolerance window - modulo target position 0° in positive direction*

Example:

An axis is positioned to 0°, with the result that subsequently the actual position of the axis is exactly 0°. A further modulo travel command to 360° in *positive direction* results in a full turn, with the subsequent modulo position of the axis of once again being exactly 0°. If the axis comes to a stop somewhat in front of or behind the target position for mechanical reasons, the next travel command does not behave as one would expect. If the actual position lies slightly below 0° (see fig. 9, below left), a new travel command to 0° in the *positive direction* leads only to a minimal movement. The deviation that arose beforehand is compensated and the position is subsequently exactly 0° once more. If the position lies slightly above 0°, however, the same travel command leads to a full revolution in order to reach the exact position of 0° again. This problem occurs if complete turns by 360° or multiples of 360° were initiated. For positioning to an angle that is significantly different from the current modulo position, the travel command is unambiguous.

In order to solve the problem, a "*Modulo tolerance window*" (Index 0x8020:0F) can be parameterized. This ensures that small deviations from the position that are within the window do not lead to different axis behavior. If, for example, a window of 1° is parameterized, in the case described above the axis will behave identically, as long the actual position is between 359° and 1°. If the position exceeds 0° by less than 1°, the axis is re-positioned in *positive direction* at a modulo start. In both cases, a target position of 0° therefore leads to minimum movement to exactly 0°. A target position of 360° leads to a full turn in both cases.

For values that are within the window range, the modulo tolerance window can therefore lead to movements against the specified direction. For small windows this is usually not a problem, because system deviations between set and actual position are compensated in both directions. This means that the tolerance window may also be used for axes that may only be moved in one direction due to their construction.

Modulo positioning by less than one turn

Modulo positioning from a starting position to a non-identical target position is unambiguous and requires no special consideration. A modulo target position in the range [0 ≤; position < 360] reaches the required target in less than one whole turn. No motion occurs if target position and starting position are identical. Target positions of more than 360 ° lead to one or more full turns before the axis travels to the required target position.

For a movement from 270° to 0°, a modulo target position of 0° (not 360°) should therefore be specified, because 360° is outside the basic range and would lead to an additional turn.

The modulo positioning distinguishes between three direction specifications: *positive direction, negative direction* and *along the shortest path* (*MODULO_PLUS, MODULO_MINUS, MODULO_SHORT*). For positioning along the shortest path, target positions of more than 360° are not sensible, because the movement towards the target is always direct. In contrast to positive or negative direction, it is therefore not possible to carry out several turns before the axis moves to the target.

NOTE

Only basic periods of less than 360° are permitted

For modulo positioning with start type "MODULO_SHORT", only modulo target positions within the basic period (e.g. less than 360°) are permitted, otherwise an error is returned.

Positioning without the modulo tolerance window

The Modulo tolerance window" (Index 0x8020:0F) is always taken into account in the “normal” types of modulo positioning. However, this is less desirable in some situations. In order to eliminate this "disadvantage", the comparable start types "MODULO_SHORT_EXT", "MODULO_PLUS_EXT", "MODULO_MINUS_EXT" and "MODULO_CURRENT_EXT" can be used, which ignore the modulo tolerance window.

The following table shows some positioning examples:

Modulo start type	Absolute start position	Modulo target position	Relative travel path	Absolute end position	Modulo end position
MODULO_PLUS	90°	0°	270°	360°	0°
MODULO_PLUS	90°	360°	630°	720°	0°
MODULO_PLUS	90°	720°	990°	1080°	0°
MODULO_MINUS	90°	0°	-90°	0°	0°
MODULO_MINUS	90°	360°	-450°	-360°	0°
MODULO_MINUS	90°	720°	-810°	-720°	0°
MODULO_SHORT	90°	0°	-90°	0°	0°

Examples of modulo positioning with less than one revolution

Modulo positioning with full turns

In principle, modulo positioning by one or full turns are no different than positioning to an angle that differs from the starting position. No motion occurs if target position and starting position are identical. For a full turn, 360° has to be added to the starting position. The behaviour described in the example [▶ 70] shows that special attention must be paid to positionings with whole revolutions. The following table shows positioning examples for a starting position of approximately 90°. The modulo tolerance window is set to 1° here. Special cases for which the starting position is outside this window are identified.

Modulo start type	**Absolute start position**	**Modulo target position**	**Relative travel path**	**Absolute end position**	**Modulo end position**	**Note**
MODULO_PLUS	90.00°	90.00°	0.00°	90.00°	90.00°	
MODULO_PLUS	90.90°	90.00°	-0.90°	90.00°	90.00°	
MODULO_PLUS	91.10°	90.00°	358.90°	450.00°	90.00°	outside TF
MODULO_PLUS	89.10°	90.00°	0.90°	90.00°	90.00°	
MODULO_PLUS	88.90°	90.00°	1.10°	90.00°	90.00°	outside TF
MODULO_PLUS	90.00°	450.00	360.00°	450.00°	90.00°	
MODULO_PLUS	90.90°	450.00°	359.10°	450.00°	90.00°	
MODULO_PLUS	91.10°	450.00°	718.90°	810.00°	90.00°	outside TF
MODULO_PLUS	89.10°	450.00°	360.90°	450.00°	90.00°	
MODULO_PLUS	88.90°	450.00°	361.10°	450.00°	90.00°	outside TF
MODULO_PLUS	90.00°	810.00	720.00°	810.00°	90.00°	
MODULO_PLUS	90.90°	810.00	719.10°	810.00°	90.00°	
MODULO_PLUS	91.10°	810.00	1078.90°	1170.00°	90.00°	outside TF
MODULO_PLUS	89.10°	810.00	720.90°	810.00°	90.00°	
MODULO_PLUS	88.90°	810.00	721.10°	810.00°	90.00°	outside TF
MODULO_MINUS	90.00°	90.00°	0.00°	90.00°	90.00°	
MODULO_MINUS	90.90°	90.00°	-0.90°	90.00°	90.00°	
MODULO_MINUS	91.10°	90.00°	-1.10°	90.00°	90.00°	outside TF
MODULO_MINUS	89.10°	90.00°	0.90°	90.00°	90.00°	
MODULO_MINUS	88.90°	90.00°	-358.90°	-270.00°	90.00°	outside TF
MODULO_MINUS	90.00°	450.00°	-360.00°	-270.00°	90.00°	
MODULO_MINUS	90.90°	450.00°	-360.90°	-270.00°	90.00°	
MODULO_MINUS	91.10°	450.00°	-361.10°	-270.00°	90.00°	outside TF
MODULO_MINUS	89.10°	450.00°	-359.10°	-270.00°	90.00°	
MODULO_MINUS	88.90°	450.00°	-718.90°	-630.00°	90.00°	outside TF
MODULO_MINUS	90.00°	810.00°	-720.00°	-630.00°	90.00°	
MODULO_MINUS	90.90°	810.00°	-720.90°	-630.00°	90.00°	
MODULO_MINUS	91.10°	810.00°	-721.10°	-630.00°	90.00°	outside TF
MODULO_MINUS	89.10°	810.00°	-719.10°	-630.00°	90.00°	
MODULO_MINUS	88.90°	810.00°	-1078.90°	-990.00°	90.00°	outside TF

Examples of modulo positioning with whole revolutions

Examples of two travel commands with a dynamic change of the target position

Without overrun of the target position

Time	POS Outputs	POS Inputs	Description
t1:	Execute = 1 Target position = 200000 Velocity = 2000 Start type = 0x0001 Acceleration = 1000 Deceleration = 1000	Busy = 1 Accelerate = 1	- Specification of the first parameter - Start of the acceleration phase
t2:		Accelerate = 0	- End of the acceleration phase
t3:	Target position = 100000 Velocity = 1500 Start type = 0x1001 Acceleration = 2000 Deceleration = 2000		- Change of the parameters - Activation by new start types
t4:		Decelerate = 1	- Start of the deceleration phase
t5:	Execute = 0	Busy = 0 In-Target = 1 Decelerate = 0	- End of the deceleration phase - Motor is at the new target position
t6 - t9:			- Absolute travel back to the start position 0

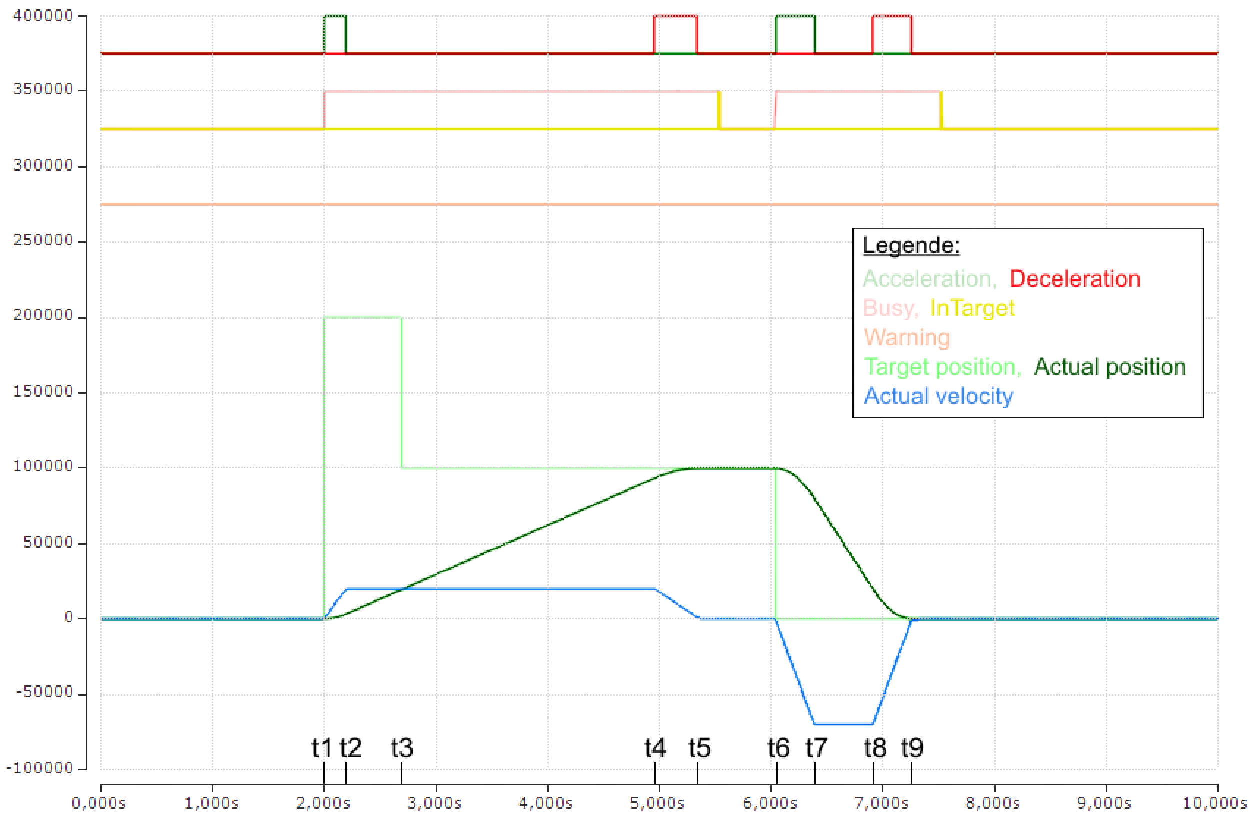


Fig. 40: *Scope recording of a travel command with a dynamic change of the target position, without overrunning the target position*
(The axis scaling refers only to the positions, not to the speed or the status bits)

With overrun of the target position

Time	POS Outputs	POS Inputs	Description
t1:	Execute = 1 Target position = 200000 Velocity = 5000 Start type = 0x0001 Acceleration = 3000 Deceleration = 5000	Busy = 1 Accelerate = 1	- Specification of the 1st parameter - Start of the 1st acceleration phase
t2:		Accelerate = 0	- End of the 1st acceleration phase
t3:	Target position = 100000 Velocity = 1500 Start type = 0x1001 Acceleration = 1000 Deceleration = 2000	Warning = 1 Decelerate = 1	- Change of the parameters - Activation by new start types - Warning of overrunning the target position - Start of the 1st deceleration phase
t4:		Accelerate = 1 Decelerate = 0	- End of the 1st deceleration phase - Start of the 2nd acceleration phase in the opposite direction
t5:		Accelerate = 0 Decelerate = 1	- End of the 2nd acceleration phase - Start of the 2nd deceleration phase
t6:	Execute = 0	Busy = 0 In-Target = 1 Decelerate = 0	- End of the 2nd deceleration phase - Motor is at the new target position
t7 - t10:			- Absolute travel back to the start position 0

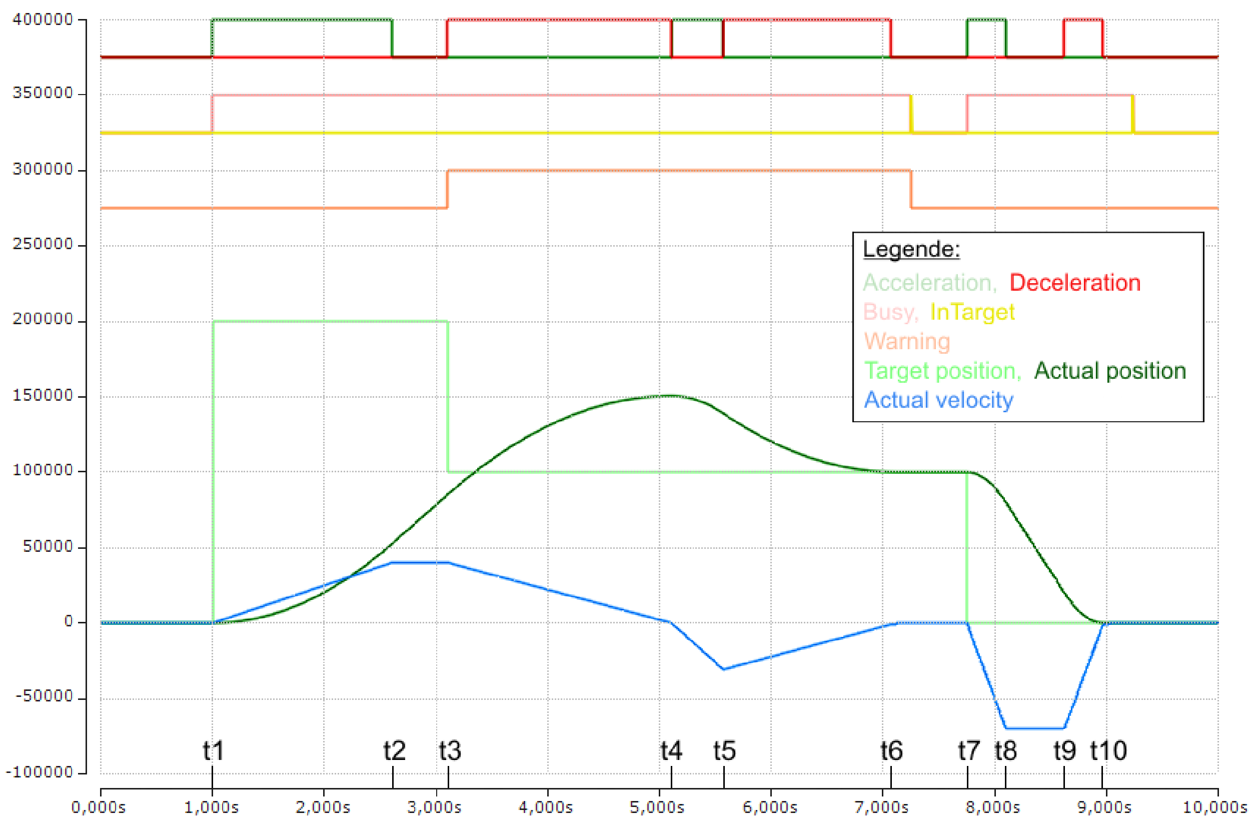
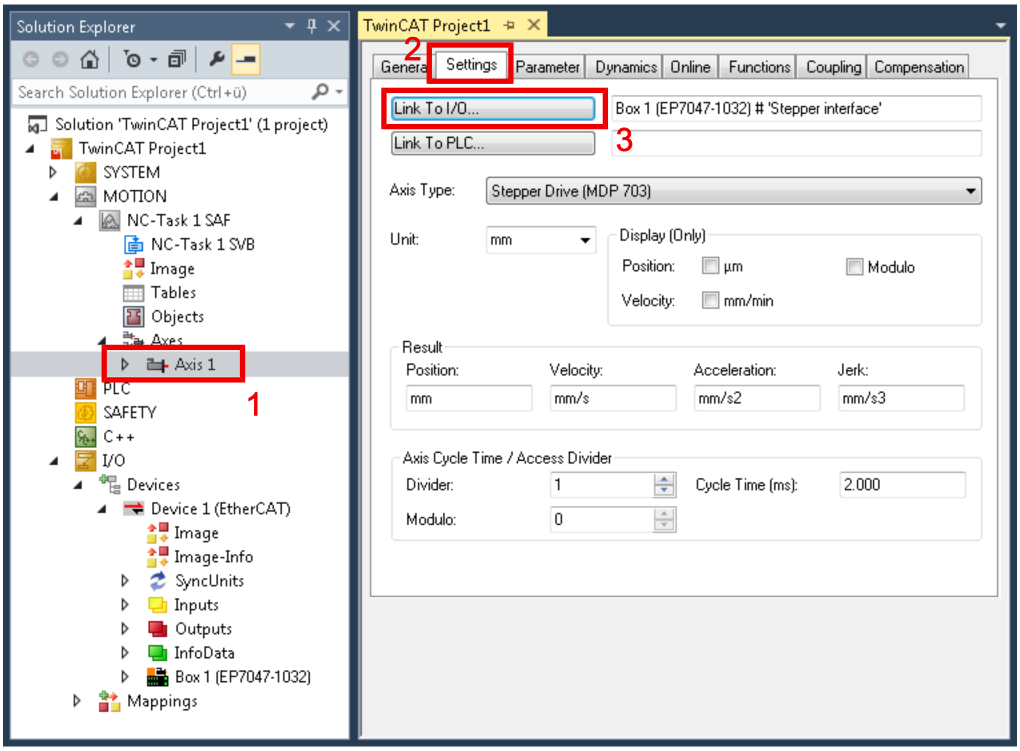


Fig. 41: *Scope recording of a travel command with a dynamic change of the target position, with overrunning of the final target position*
(The axis scaling refers only to the positions, not to the speed or the status bits)

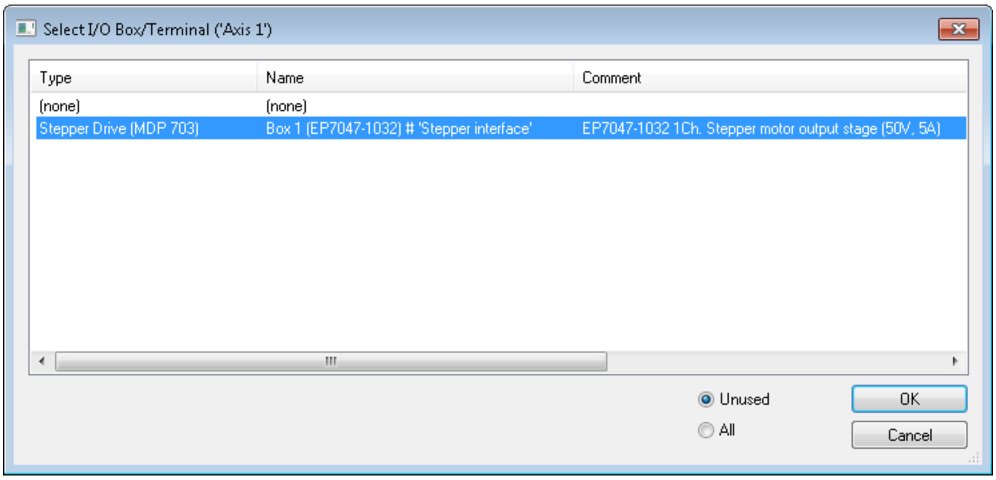
4.6.2 Linking an NC axis with EP7047

This step can usually be skipped

If you have carried out the commissioning in accordance with this documentation, an NC axis has already been linked to EP7047-1032. See chapter Integrating EP7047 into a TwinCAT project [▶ 40].



1. In the Solution Explorer: Double-click "Axis *n*".
2. Click on the "Settings" tab.
3. Click "Link to I/O".
   ⇨ A dialog box opens.



4. Select EP7047 and click "OK".
   Note: If EP7047 is not available for selection here, please check:
   - Is EP7047 included in the "I/O" section?
   - Is a predefined "Positioning interface ..." process image selected?

⇨ The process data from EP7047 are linked to the axis.

4.6.3 Determining the voltage constant of a motor experimentally

If the voltage constant k_e is not specified in the motor data sheet, you can determine it experimentally.

The voltage constant k_e is only required if you are not using an encoder but want to use one of the following functions:

- Load angle detection
- Step loss detection

The procedure is described in section "Induced countervoltage" [▶ 21].

4.6.4 Restoring the delivery state

To restore the delivery state for backup objects in ELxxxx terminals / EPxxxx- and EPPxxxx boxes, the CoE object *Restore default parameters, SubIndex 001* can be selected in the TwinCAT System Manager (Config mode).

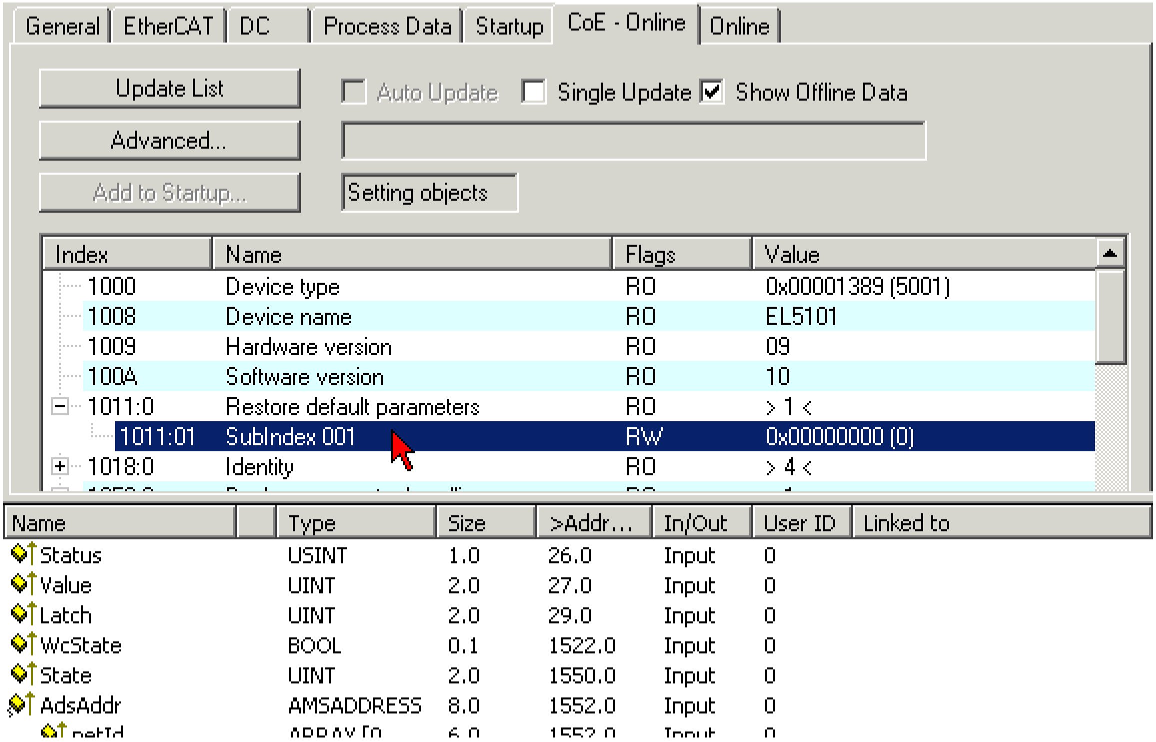


Fig. 42: Selecting the Restore default parameters PDO

Double-click on *SubIndex 001* to enter the Set Value dialog. Enter the value **1684107116** in field *Dec* or the value **0x64616F6C** in field *Hex* and confirm with OK.

All backup objects are reset to the delivery state.

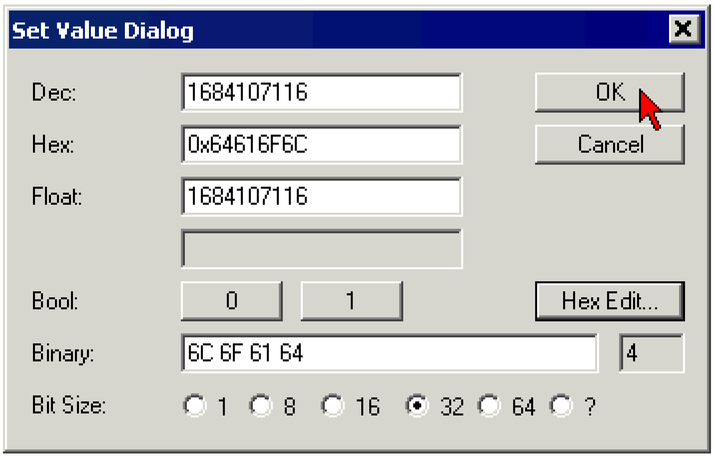


Fig. 43: Entering a restore value in the Set Value dialog

Alternative restore value

In some older terminals / boxes the backup objects can be switched with an alternative restore value:
Decimal value: 1819238756
Hexadecimal value: 0x6C6F6164

An incorrect entry for the restore value has no effect.

4.7 Decommissioning

⚠ WARNING

Risk of electric shock!

Bring the bus system into a safe, de-energized state before starting disassembly of the devices!

Disposal

In order to dispose of the device, it must be removed.

In accordance with the WEEE Directive 2012/19/EU, Beckhoff takes back old devices and accessories in Germany for proper disposal. Transport costs will be borne by the sender.

Return the old devices with the note "for disposal" to:

Beckhoff Automation GmbH & Co. KG
Service Department
Stahlstraße 31
D-33415 Verl

5 Diagnosis

5.1 Diagnostics – basic principles of diag messages

DiagMessages designates a system for the transmission of messages from an EtherCAT device to the EtherCAT Master/TwinCAT. The messages are stored by the EtherCAT device in its own CoE under 0x10F3 and can be read by the application or the System Manager. An error message referenced via a code is output for each event stored in the EtherCAT device (warning, error, status change).

Definition

The *DiagMessages* system is defined in the ETG (EtherCAT Technology Group) in the guideline ETG.1020, chapter 13 “Diagnosis handling”. It is used so that pre-defined or flexible diagnostic messages can be conveyed from an EtherCAT device to the Master. In accordance with the ETG, the process can therefore be implemented supplier-independently. Support is optional. The firmware can store up to 250 DiagMessages in its own CoE.

Each DiagMessage consists of

- Diag Code (4-byte)
- Flags (2-byte; info, warning or error)
- Text ID (2-byte; reference to explanatory text from the ESI/XML)
- Timestamp (8-byte, local time in the EtherCAT device or 64-bit Distributed Clock time, if available)
- Dynamic parameters added by the firmware

The DiagMessages are explained in text form in the ESI/XML file belonging to the EtherCAT device: on the basis of the Text ID contained in the DiagMessage, the corresponding plain text message can be found in the languages contained in the ESI/XML. In the case of Beckhoff products these are usually German and English.

Via the entry *NewMessagesAvailable* the user receives information that new messages are available.

DiagMessages can be confirmed in the EtherCAT device: the last/latest unconfirmed message can be confirmed by the user.

In the CoE both the control entries and the history itself can be found in the CoE object 0x10F3:

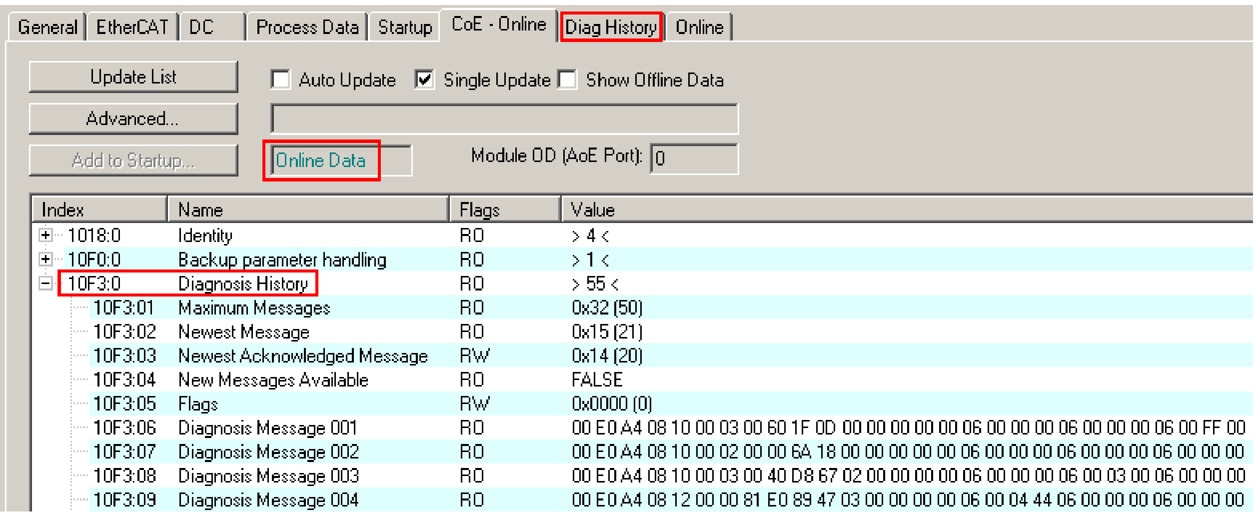


Fig. 44: DiagMessages in the CoE

The subindex of the latest *DiagMessage* can be read under 0x10F3:02.

Support for commissioning

The DiagMessages system is to be used above all during the commissioning of the plant. The diagnostic values e.g. in the StatusWord of the EtherCAT device (if available) are helpful for online diagnosis during the subsequent continuous operation.

TwinCAT System Manager implementation

From TwinCAT 2.11 DiagMessages, if available, are displayed in the EtherCAT device’s own interface. Operation (collection, confirmation) also takes place via this interface.

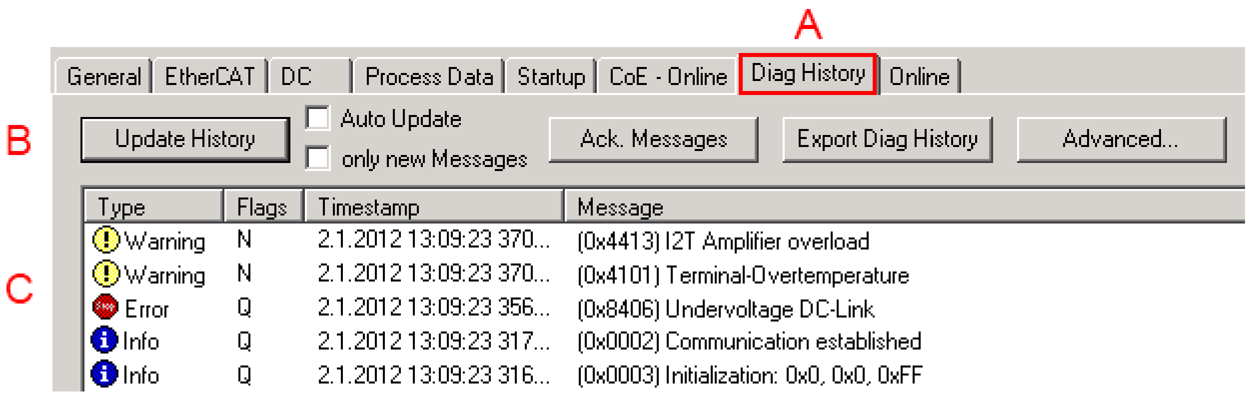


Fig. 45: Implementation of the DiagMessage system in the TwinCAT System Manager

The operating buttons (B) and the history read out (C) can be seen on the Diag History tab (A). The components of the message:

- Info/Warning/Error
- Acknowledge flag (N = unconfirmed, Q = confirmed)
- Time stamp
- Text ID
- Plain text message according to ESI/XML data

The meanings of the buttons are self-explanatory.

DiagMessages within the ADS Logger/Eventlogger

Since TwinCAT 3.1 build 4022 DiagMessages send by the EtherCAT device are shown by the TwinCAT ADS Logger. Given that DiagMessages are represented IO- comprehensive at one place, commissioning will be simplified. In addition, the logger output could be stored into a data file – hence DiagMessages are available long-term for analysis.

DiagMessages are actually only available locally in CoE 0x10F3 in the EtherCAT device and can be read out manually if required, e.g. via the DiagHistory mentioned above.

In the latest developments, the EtherCAT devices are set by default to report the presence of a DiagMessage as emergency via EtherCAT; the event logger can then retrieve the DiagMessage. The function is activated in the EtherCAT device via 0x10F3:05, so such EtherCAT devices have the following entry in the StartUp list by default:

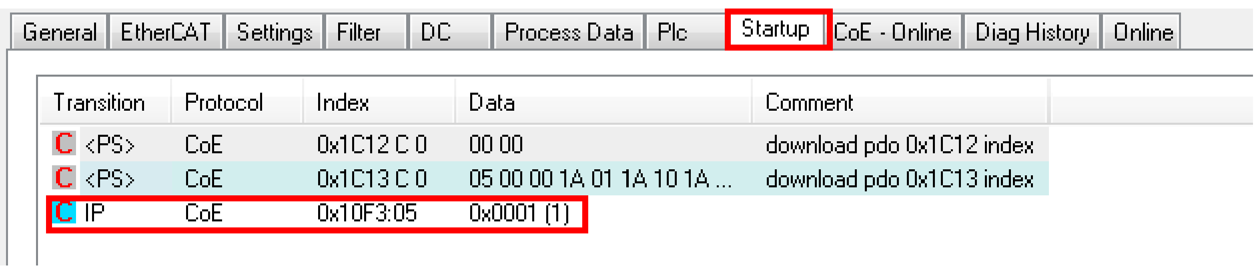


Fig. 46: Startup List

If the function is to be deactivated because, for example, many messages come in or the EventLogger is not used, the StartUp entry can be deleted or set to 0.

Reading messages into the PLC

- In preparation -

Interpretation

Time stamp

The time stamp is obtained from the local clock of the EtherCAT device at the time of the event. The time is usually the distributed clock time (DC) from register x910.

Please note: When EtherCAT is started, the DC time in the reference clock is set to the same time as the local IPC/TwinCAT time. From this moment the DC time may differ from the IPC time, since the IPC time is not adjusted. Significant time differences may develop after several weeks of operation without a EtherCAT restart. As a remedy, external synchronization of the DC time can be used, or a manual correction calculation can be applied, as required: The current DC time can be determined via the EtherCAT master or from register x901 of the DC slave.

Structure of the Text ID

The structure of the MessageID is not subject to any standardization and can be supplier-specifically defined. In the case of Beckhoff EtherCAT devices (EL, EP) it usually reads according to **xyzz**:

x	y	zz
0: Systeminfo 2: reserved 1: Info 4: Warning 8: Error	0: System 1: General 2: Communication 3: Encoder 4: Drive 5: Inputs 6: I/O general 7: reserved	Error number

Example: Message 0x4413 --> Drive Warning Number 0x13

Overview of text IDs

Specific text IDs are listed in the device documentation.

Text ID	Type	Place	Text Message	Additional comment
0x0001	Information	System	No error	No error
0x0002	Information	System	Communication established	Connection established
0x0003	Information	System	Initialization: 0x%X, 0x%X, 0x%X	General information; parameters depend on event. See device documentation for interpretation.
0x1000	Information	System	Information: 0x%X, 0x%X, 0x%X	General information; parameters depend on event. See device documentation for interpretation.
0x1012	Information	System	EtherCAT state change Init - PreOp	
0x1021	Information	System	EtherCAT state change PreOp - Init	
0x1024	Information	System	EtherCAT state change PreOp - Safe-Op	
0x1042	Information	System	EtherCAT state change SafeOp - PreOp	
0x1048	Information	System	EtherCAT state change SafeOp - Op	
0x1084	Information	System	EtherCAT state change Op - SafeOp	
0x1100	Information	General	Detection of operation mode completed: 0x%X, %d	Detection of the mode of operation ended
0x1135	Information	General	Cycle time o.k.: %d	Cycle time OK
0x1157	Information	General	Data manually saved (Idx: 0x%X, SubIdx: 0x%X)	Data saved manually
0x1158	Information	General	Data automatically saved (Idx: 0x%X, SubIdx: 0x%X)	Data saved automatically
0x1159	Information	General	Data deleted (Idx: 0x%X, SubIdx: 0x%X)	Data deleted
0x117F	Information	General	Information: 0x%X, 0x%X, 0x%X	Information
0x1201	Information	Communication	Communication re-established	Communication to the field side restored This message appears, for example, if the voltage was removed from the power contacts and re-applied during operation.
0x1300	Information	Encoder	Position set: %d, %d	Position set - StartInputhandler
0x1303	Information	Encoder	Encoder Supply ok	Encoder power supply unit OK
0x1304	Information	Encoder	Encoder initialization successfully, channel: %X	Encoder initialization successfully completed
0x1305	Information	Encoder	Sent command encoder reset, channel: %X	Send encoder reset command
0x1400	Information	Drive	Drive is calibrated: %d, %d	Drive is calibrated
0x1401	Information	Drive	Actual drive state: 0x%X, %d	Current drive status
0x1705	Information		CPU usage returns in normal range (< 85%%)	Processor load is back in the normal range
0x1706	Information		Channel is not in saturation anymore	Channel is no longer in saturation
0x1707	Information		Channel is not in overload anymore	Channel is no longer overloaded
0x170A	Information		No channel range error anymore	A measuring range error is no longer active
0x170C	Information		Calibration data saved	Calibration data were saved
0x170D	Information		Calibration data will be applied and saved after sending the command “0x5AFE”	Calibration data are not applied and saved until the command "0x5AFE" is sent.

Text ID	Type	Place	Text Message	Additional comment
0x2000	Information	System	%s: %s	
0x2001	Information	System	%s: Network link lost	Network connection lost
0x2002	Information	System	%s: Network link detected	Network connection found
0x2003	Information	System	%s: no valid IP Configuration - Dhcp client started	Invalid IP configuration
0x2004	Information	System	%s: valid IP Configuration (IP: %d.%d.%d.%d) assigned by Dhcp server %d.%d.%d.%d	Valid IP configuration, assigned by the DHCP server
0x2005	Information	System	%s: Dhcp client timed out	DHCP client timeout
0x2006	Information	System	%s: Duplicate IP Address detected (%d.%d.%d.%d)	Duplicate IP address found
0x2007	Information	System	%s: UDP handler initialized	UDP handler initialized
0x2008	Information	System	%s: TCP handler initialized	TCP handler initialized
0x2009	Information	System	%s: No more free TCP sockets available	No free TCP sockets available.

Text ID	Type	Place	Text Message	Additional comment
0x4000	Warning		Warning: 0x%X, 0x%X, 0x%X	General warning; parameters depend on event. See device documentation for interpretation.
0x4001	Warning	System	Warning: 0x%X, 0x%X, 0x%X	
0x4002	Warning	System	%s: %s Connection Open (IN:%d OUT:%d API:%dms) from %d.%d.%d.%d successful	
0x4003	Warning	System	%s: %s Connection Close (IN:%d OUT:%d) from %d.%d.%d.%d successful	
0x4004	Warning	System	%s: %s Connection (IN:%d OUT:%d) with %d.%d.%d.%d timed out	
0x4005	Warning	System	%s: %s Connection Open (IN:%d OUT:%d) from %d.%d.%d.%d denied (Error: %u)	
0x4006	Warning	System	%s: %s Connection Open (IN:%d OUT:%d) from %d.%d.%d.%d denied (Input Data Size expected: %d Byte(s) received: %d Byte(s))	
0x4007	Warning	System	%s: %s Connection Open (IN:%d OUT:%d) from %d.%d.%d.%d denied (Output Data Size expected: %d Byte(s) received: %d Byte(s))	
0x4008	Warning	System	%s: %s Connection Open (IN:%d OUT:%d) from %d.%d.%d.%d denied (RPI:%dms not supported -> API:%dms)	
0x4101	Warning	General	Terminal-Overtemperature	Overtemperature. The internal temperature of the EtherCAT device exceeds the parameterized warning threshold.
0x4102	Warning	General	Discrepancy in the PDO-Configuration	The selected PDOs do not match the set operating mode. Sample: Drive operates in velocity mode, but the velocity PDO is but not mapped in the PDOs.
0x417F	Warning	General	Warning: 0x%X, 0x%X, 0x%X	
0x428D	Warning	General	Challenge is not Random	
0x4300	Warning	Encoder	Subincrements deactivated: %d, %d	Sub-increments deactivated (despite activated configuration)
0x4301	Warning	Encoder	Encoder-Warning	General encoder error
0x4302	Warning	Encoder	Maximum frequency of the input signal is nearly reached (channel %d)	
0x4303	Warning	Encoder	Limit counter value was reduced because of the PDO configuration (channel %d)	
0x4304	Warning	Encoder	Reset counter value was reduced because of the PDO configuration (channel %d)	
0x4400	Warning	Drive	Drive is not calibrated: %d, %d	Drive is not calibrated
0x4401	Warning	Drive	Starttype not supported: 0x%X, %d	Start type is not supported
0x4402	Warning	Drive	Command rejected: %d, %d	Command rejected
0x4405	Warning	Drive	Invalid modulo subtype: %d, %d	Modulo sub-type invalid
0x4410	Warning	Drive	Target overrun: %d, %d	Target position exceeded
0x4411	Warning	Drive	DC-Link undervoltage (Warning)	The DC link voltage is lower than the parameterized minimum voltage. Activation of the output stage is prevented.
0x4412	Warning	Drive	DC-Link overvoltage (Warning)	The DC link voltage is higher than the parameterized maximum voltage. Activation of the output stage is prevented.
0x4413	Warning	Drive	I2T-Model Amplifier overload (Warning)	• The amplifier is being operated outside the specification. • The I2T-model of the amplifier is incorrectly parameterized.
0x4414	Warning	Drive	I2T-Model Motor overload (Warning)	• The motor is being operated outside the parameterized rated values.

Text ID	Type	Place	Text Message	Additional comment
				• The I2T-model of the motor is incorrectly parameterized.
0x4415	Warning	Drive	Speed limitation active	The maximum speed is limited by the parameterized objects (e.g. velocity limitation, motor speed limitation). This warning is output if the set velocity is higher than one of the parameterized limits.
0x4416	Warning	Drive	Step lost detected at position: 0x %X%X	Step loss detected
0x4417	Warning	Drive	Motor overtemperature	The internal temperature of the motor exceeds the parameterized warning threshold
0x4418	Warning	Drive	Limit: Current	Limit: current is limited
0x4419	Warning	Drive	Limit: Amplifier I2T-model exceeds 100%%	The threshold values for the maximum current were exceeded.
0x441A	Warning	Drive	Limit: Motor I2T-model exceeds 100%%	Limit: Motor I2T-model exceeds 100%
0x441B	Warning	Drive	Limit: Velocity limitation	The threshold values for the maximum speed were exceeded.
0x441C	Warning	Drive	STO while the axis was enabled	An attempt was made to activate the axis, despite the fact that no voltage is present at the STO input.
0x4600	Warning	General IO	Wrong supply voltage range	Supply voltage not in the correct range
0x4610	Warning	General IO	Wrong output voltage range	Output voltage not in the correct range
0x4705	Warning		Processor usage at %d %%	Processor load at %d %%
0x470A	Warning		EtherCAT Frame missed (change Settings or DC Operation Mode or Sync0 Shift Time)	EtherCAT frame missed (change DC Operation Mode or Sync0 Shift Time under Settings)

Text ID	Type	Place	Text Message	Additional comment
0x8000	Error	System	%s: %s	
0x8001	Error	System	Error: 0x%X, 0x%X, 0x%X	General error; parameters depend on event. See device documentation for interpretation.
0x8002	Error	System	Communication aborted	Communication aborted
0x8003	Error	System	Configuration error: 0x%X, 0x%X, 0x%X	General; parameters depend on event. See device documentation for interpretation.
0x8004	Error	System	%s: Unsuccessful FwdOpen-Response received from %d.%d.%d.%d (%s) (Error: %u)	
0x8005	Error	System	%s: FwdClose-Request sent to %d.%d.%d.%d (%s)	
0x8006	Error	System	%s: Unsuccessful FwdClose-Response received from %d.%d.%d.%d (%s) (Error: %u)	
0x8007	Error	System	%s: Connection with %d.%d.%d.%d (%s) closed	
0x8100	Error	General	Status word set: 0x%X, %d	Error bit set in the status word
0x8101	Error	General	Operation mode incompatible to PDO interface: 0x%X, %d	Mode of operation incompatible with the PDO interface
0x8102	Error	General	Invalid combination of Inputs and Outputs PDOs	Invalid combination of input and output PDOs
0x8103	Error	General	No variable linkage	No variables linked
0x8104	Error	General	Terminal-Overtemperature	The internal temperature of the EtherCAT device exceeds the parameterized error threshold. Activation of the EtherCAT device is prevented
0x8105	Error	General	PD-Watchdog	Communication between the fieldbus and the output stage is secured by a Watchdog. The axis is stopped automatically if the fieldbus communication is interrupted. • The EtherCAT connection was interrupted during operation. • The Master was switched to Config mode during operation.
0x8135	Error	General	Cycle time has to be a multiple of 125 µs	The IO or NC cycle time divided by 125 µs does not produce a whole number.
0x8136	Error	General	Configuration error: invalid sampling rate	Configuration error: Invalid sampling rate
0x8137	Error	General	Electronic type plate: CRC error	Content of the external name plate memory invalid.
0x8140	Error	General	Sync Error	Real-time violation
0x8141	Error	General	Sync%X Interrupt lost	Sync%X Interrupt lost
0x8142	Error	General	Sync Interrupt asynchronous	Sync Interrupt asynchronous
0x8143	Error	General	Jitter too big	Jitter limit violation
0x817F	Error	General	Error: 0x%X, 0x%X, 0x%X	
0x8200	Error	Communication	Write access error: %d, %d	Error while writing
0x8201	Error	Communication	No communication to field-side (Auxiliary voltage missing)	• There is no voltage applied to the power contacts. • A firmware update has failed.
0x8281	Error	Communication	Ownership failed: %X	
0x8282	Error	Communication	To many Keys founded	
0x8283	Error	Communication	Key Creation failed: %X	
0x8284	Error	Communication	Key loading failed	
0x8285	Error	Communication	Reading Public Key failed: %X	
0x8286	Error	Communication	Reading Public EK failed: %X	
0x8287	Error	Communication	Reading PCR Value failed: %X	
0x8288	Error	Communication	Reading Certificate EK failed: %X	
0x8289	Error	Communication	Challenge could not be hashed: %X	
0x828A	Error	Communication	Tickstamp Process failed	
0x828B	Error	Communication	PCR Process failed: %X	
0x828C	Error	Communication	Quote Process failed: %X	
0x82FF	Error	Communication	Bootmode not activated	Boot mode not activated
0x8300	Error	Encoder	Set position error: 0x%X, %d	Error while setting the position

Text ID	Type	Place	Text Message	Additional comment
0x8301	Error	Encoder	Encoder increments not configured: 0x%X, %d	Encoder increments not configured
0x8302	Error	Encoder	Encoder error	The amplitude of the resolver is too small
0x8303	Error	Encoder	Encoder power missing (channel %d)	
0x8304	Error	Encoder	Encoder communication error, channel: %X	Encoder communication error
0x8305	Error	Encoder	EnDat2.2 is not supported, channel: %X	EnDat2.2 is not supported
0x8306	Error	Encoder	Delay time, tolerance limit exceeded, 0x%X, channel: %X	Runtime measurement, tolerance exceeded
0x8307	Error	Encoder	Delay time, maximum value exceeded, 0x%X, channel: %X	Runtime measurement, maximum value exceeded
0x8308	Error	Encoder	Unsupported ordering designation, 0x%X, channel: %X (only 02 and 22 is supported)	Wrong EnDat order ID
0x8309	Error	Encoder	Encoder CRC error, channel: %X	Encoder CRC error
0x830A	Error	Encoder	Temperature %X could not be read, channel: %X	Temperature cannot be read
0x830C	Error	Encoder	Encoder Single-Cycle-Data Error, channel. %X	CRC error detected. Check the transmission path and the CRC polynomial
0x830D	Error	Encoder	Encoder Watchdog Error, channel. %X	The sensor has not responded within a predefined time period
0x8310	Error	Encoder	Initialisation error	
0x8311	Error	Encoder	Maximum frequency of the input signal is exceeded (channel %d)	
0x8312	Error	Encoder	Encoder plausibility error (channel %d)	
0x8313	Error	Encoder	Configuration error (channel %d)	
0x8314	Error	Encoder	Synchronisation error	
0x8315	Error	Encoder	Error status input (channel %d)	
0x8400	Error	Drive	Incorrect drive configuration: 0x %X, %d	Drive incorrectly configured
0x8401	Error	Drive	Limiting of calibration velocity: %d, %d	Limitation of the calibration velocity
0x8402	Error	Drive	Emergency stop activated: 0x%X, %d	Emergency stop activated
0x8403	Error	Drive	ADC Error	Error during current measurement in the ADC
0x8404	Error	Drive	Overcurrent	Overcurrent in phase U, V or W
0x8405	Error	Drive	Invalid modulo position: %d	Modulo position invalid
0x8406	Error	Drive	DC-Link undervoltage (Error)	The DC link voltage is lower than the parameterized minimum voltage. Activation of the output stage is prevented.
0x8407	Error	Drive	DC-Link overvoltage (Error)	The DC link voltage is higher than the parameterized maximum voltage. Activation of the output stage is prevented.
0x8408	Error	Drive	I2T-Model Amplifier overload (Error)	• The amplifier is being operated outside the specification. • The I2T-model of the amplifier is incorrectly parameterized.
0x8409	Error	Drive	I2T-Model motor overload (Error)	• The motor is being operated outside the parameterized rated values. • The I2T-model of the motor is incorrectly parameterized.
0x840A	Error	Drive	Overall current threshold exceeded	Total current exceeded
0x8415	Error	Drive	Invalid modulo factor: %d	Modulo factor invalid
0x8416	Error	Drive	Motor overtemperature	The internal temperature of the motor exceeds the parameterized error threshold. The motor stops immediately. Activation of the output stage is prevented.
0x8417	Error	Drive	Maximum rotating field velocity exceeded	Rotary field speed exceeds the value specified for dual use (EU 1382/2014).
0x841C	Error	Drive	STO while the axis was enabled	An attempt was made to activate the axis, despite the fact that no voltage is present at the STO input.
0x8550	Error	Inputs	Zero crossing phase %X missing	Zero crossing phase %X missing

Text ID	Type	Place	Text Message	Additional comment
0x8551	Error	Inputs	Phase sequence Error	Wrong direction of rotation
0x8552	Error	Inputs	Overcurrent phase %X	Overcurrent phase %X
0x8553	Error	Inputs	Overcurrent neutral wire	Overcurrent neutral wire
0x8581	Error	Inputs	Wire broken Ch %D	Wire broken Ch %d
0x8600	Error	General IO	Wrong supply voltage range	Supply voltage not in the correct range
0x8601	Error	General IO	Supply voltage to low	Supply voltage too low
0x8602	Error	General IO	Supply voltage to high	Supply voltage too high
0x8603	Error	General IO	Over current of supply voltage	Overcurrent of supply voltage
0x8610	Error	General IO	Wrong output voltage range	Output voltage not in the correct range
0x8611	Error	General IO	Output voltage to low	Output voltage too low
0x8612	Error	General IO	Output voltage to high	Output voltage too high
0x8613	Error	General IO	Over current of output voltage	Overcurrent of output voltage
0x8700	Error		Channel/Interface not calibrated	Channel/interface not synchronized
0x8701	Error		Operating time was manipulated	Operating time was manipulated
0x8702	Error		Oversampling setting is not possible	Oversampling setting not possible
0x8703	Error		No slave controller found	No slave controller found
0x8704	Error		Slave controller is not in Bootstrap	Slave controller is not in bootstrap
0x8705	Error		Processor usage to high (>= 100%%)	Processor load too high (>= 100%%)
0x8706	Error		Channel in saturation	Channel in saturation
0x8707	Error		Channel overload	Channel overload
0x8708	Error		Overloadtime was manipulated	Overload time was manipulated
0x8709	Error		Saturationtime was manipulated	Saturation time was manipulated
0x870A	Error		Channel range error	Measuring range error for the channel
0x870B	Error		no ADC clock	No ADC clock available
0xFFFF	Information		Debug: 0x%X, 0x%X, 0x%X	Debug: 0x%X, 0x%X, 0x%X

5.2 Diag Messages of EtherCAT devices for drive technology

„Ack. Message“ Button

The ‚Ack. Message’ button has no effect on the Drive State Machine, pressing the button does not make an axis reset.
The Drive State Machine has no influence on the error list, an axis reset also does not remove any entries from the error list, however, this can be done by pressing the ‚Ack. Message’ button.

6 CoE parameters

6.1 Object directory

CoE parameters are grouped into logical groups called "objects".

Object index (hex)	Name
1000	Device type [▸ 97]
1008	Device name [▸ 97]
1009	Hardware version [▸ 97]
100A	Software version [▸ 97]
1011	Restore default parameters [▸ 97]
1018	Identity [▸ 98]
10F0	Backup parameter handling
10F3	Diagnosis History
10F8	Actual Time Stamp
1400	ENC RxPDO-Par Control compact
1401	ENC RxPDO-Par Control
1403	STM RxPDO-Par Position
1404	STM RxPDO-Par Velocity
1405	POS RxPDO-Par Control compact
1406	POS RxPDO-Par Control
1407	POS RxPDO-Par Control 2
1600	ENC RxPDO-Map Control compact
1601	ENC RxPDO-Map Control
1602	STM RxPDO-Map Control
1603	STM RxPDO-Map Position
1604	STM RxPDO-Map Velocity
1605	POS RxPDO-Map Control compact
1606	POS RxPDO-Map Control
1607	POS RxPDO-Map Control 2
1800	ENC TxPDO-Par Status compact
1801	ENC TxPDO-Par Status
1806	POS TxPDO-Par Status compact
1807	POS TxPDO-Par Status
1A00	ENC TxPDO-Map Status compact
1A01	ENC TxPDO-Map Status
1A02	ENC TxPDO-Map Timest. compact
1A03	STM TxPDO-Map Status
1A04	STM TxPDO-Map Synchron info data
1A05	STM TxPDO-Map Motor load
1A06	POS TxPDO-Map Status compact
1A07	POS TxPDO-Map Status
1A08	STM TxPDO-Map Internal position
1A09	STM TxPDO-Map External position
1A0A	POS TxPDO-Map Actual position lag

Index (hex)	Name
1C00	Sync manager type
1C12	RxPDO assign
1C13	TxPDO assign
1C32	SM output parameter
1C33	SM input parameter
6000	ENC Inputs Ch.1
6010	STM Inputs Ch.1
6020	POS Inputs Ch.1
7000	ENC Outputs Ch.1
7010	STM Outputs Ch.1
7020	POS Outputs Ch.1
7021	POS Outputs 2 Ch.1
8000	ENC Settings Ch.1 [▸ 92]
8010	STM Motor Settings Ch.1 [▸ 93]
8011	STM Controller Settings Ch.1 [▸ 93]
8012	STM Features Ch.1 [▸ 94]
8014	STM Controller Settings 3 Ch.1 [▸ 95]
8020	POS Settings Ch.1 [▸ 95]
8021	POS Features Ch.1 [▸ 95]
9010	STM Info data Ch.1
9020	POS Info data Ch.1
A010	STM Diag data Ch.1
A020	POS Diag data Ch.1
F000	Modular device profile
F008	Code word
F010	Module list
F081	Download revision
F083	BTN
F80F	STM Vendor data
F900	STM Info data
FB00	STM Command
FB40	Memory interface

6.2 Data format of CoE parameters

CoE parameters have different data formats.

The data format of the CoE parameters is specified by data type identifiers in the chapter Object description [▶ 92]:

Data type identifier	Format	Size
BOOL	True / false	8-bit
SINT	Short integer	8-bit
USINT	Unsigned short integer	8-bit
INT	Integer	16-bit
UINT	Unsigned integer	16-bit
DINT	Double integer	32-bit
UDINT	Unsigned double integer	32-bit
STRING	String	max. 255 characters, 1 byte per character

The data type identifiers correspond to the data types that can also be used in TwinCAT in a PLC program.

6.3 Object description

6.3.1 Objects for parameterization

Index 8000: ENC Settings Ch.1

Access rights: read/write

Index (hex)	Name	Description	Unit	Data type	Default value
8000:08	Disable filter	Deactivates the input filter.	-	BOOL	FALSE
8000:0A	Enable micro increments	Enables extrapolation of the "Counter value". The lower 8 bits of the counter value are extrapolated.	-	BOOL	FALSE
8000:0E	Reversion of rotation	Inverts the counting direction of the encoder.	-	BOOL	FALSE

Index 8010: STM Motor Settings Ch.1

Access rights: read/write

Index (hex)	Name	Description	Unit	Data type	Default value
8010:01	Maximal current	The maximum current that the current controller outputs per motor winding. The maximum value that should be entered here is the nominal motor current.	mA	UINT	1000_{dec}
8010:02	Reduced current	Setpoint for the winding current when the motor is at standstill. [▶ 42]	mA	UINT	1000_{dec}
8010:03	Nominal voltage	The DC link voltage U_P	10 mV	UINT	5000_{dec}
8010:04	Motor coil resistance	The winding resistance of the motor.	0.01 Ω	UINT	100_{dec}
8010:05	Motor EMF	The voltage constant k_e for calculating the back electromotive force (BEMF) The voltage constant can be found in the data sheet of the motor. Alternatively, you can determine it experimentally [▶ 76].	mV/ (rad/s)	UINT	0
8010:06	Motor fullsteps	Number of full steps per motor revolution.	-	UINT	200_{dec}
8010:07	Encoder increments (4-fold)	Number of encoder increments per revolution with 4-fold evaluation. Usually this is the resolution (ppr) of the encoder multiplied by 4.	-	UINT	4096_{dec}
8010:09	Start velocity	This value is a threshold value. EP7047 keeps the motor at standstill, as long as the speed setting "velocity" is smaller than this value. It is specified in 0.01 % of the parameter 8012:05 "Speed range" [▶ 94].	0.01 %	UINT	0
8010:0A	Motor coil inductance	The winding inductance of the motor.	0.01 mH	UINT	0
8010:10	Drive on delay time	Delay between enabling of the driver stage (variable "Enable") and setting the "Ready" status bit to 1.	ms	UINT	100_{dec}
8010:11	Drive off delay time	Delay between setting the "Ready" status bit to 0 and disabling the driver stage.	ms	UINT	150_{dec}

Index 8011: STM Controller Settings Ch.1

Access rights: read/write

Subindex (hex)	Name	Description	Unit	Data type	Default value
8011:01	Kp factor (curr.)	Proportional component of the current controller		UINT	150_{dec}
8011:02	Ki factor (curr.)	Integral component of the current controller		UINT	10_{dec}

Index 8012: STM Features Ch.1

Access rights: read/write

Subindex (hex)	Name	Description	Unit	Data type	Default value
01	Operation mode	Operation mode [▶ 45] 0_{dec}: Automatic 1_{dec}: Velocity direct 2_{dec}: Position controller 3_{dec}: Ext. Velocity mode 4_{dec}: Ext. Position mode 5_{dec}: Velocity sensorless (not recommended)	-	USINT	0_{dec}
05	Speed range	The maximum step frequency [▶ 44] that EP7047-1032 outputs.	Full steps / s	USINT	1_{dec}
08	Feedback type	Possible values: 0: "Encoder" 1: "Internal counter"	-	USINT	1_{dec}
09	Invert motor polarity	Reverses the direction of rotation of the motor.	-	BOOL	FALSE
0A	Error on step lost	Activates the error message for step loss: If this parameter is TRUE and a step loss is detected: • The output stage is switched off • The variable "Error" in the process data object "STM Status" [▶ 15] is set to TRUE.	-	BOOL	FALSE
11	Select info data 1	This value determines the content of the variable "Info data 1" in the process data object "STM Synchron info data" [▶ 15]. Possible values: 0_{dec}: Status word 7_{dec}: Motor velocity 11_{dec}: Motor load 13_{dec}: Motor dc current 101_{dec}: Internal temperature 103_{dec}: control voltage 104_{dec}: Motor supply voltage 150_{dec}: Drive – Status word 151_{dec}: Drive – State 152_{dec}: Drive - Position lag (low word) 153_{dec}: Drive - Position lag (high word)	-	USINT	11_{hex}
19	Select info data 2	This value determines the content of the variable "Info data 2" in the process data object "STM Synchron info data" [▶ 15]. Possible values: see subindex 11 "Select info data 1"	-	USINT	13_{dec}

Index 8014: STM Controller Settings 3 Ch.1

Access rights: read/write

Index (hex)	Name	Description	Unit	Data type	Default value
8014:01	Feed forward (pos.)	Pre-control of the position controller.		UDINT	100000_{dec}
8014:02	Kp factor (pos.)	Proportional component of the position controller.		UINT	500_{dec}
8014:03	Kp factor (velo.)	Proportional component of the velocity controller.	0.1 mA / (rad/s)	UDINT	50_{dec}
8014:04	Tn (velo.)	Time constant Tn of the velocity controller.	0.01 ms	UINT	50000_{dec}

Index 8020: POS Settings Ch.1

Access rights: read/write

See Positioning Interface [▶ 60].

Index 8021: POS Features Ch.1

Access rights: read/write

See Positioning Interface [▶ 60].

6.3.2 Status objects

Index 9010: STM Info data Ch.1

Access rights: read only

Subindex (hex)	Name	Description	Unit	Data type	Default value
0B	Motor load	Current load angle / angular displacement (see chapter Standard mode [▶ 23].)	0.01 ms	UINT	0
0E	Tn (curr.)	Internally calculated time constant of the current controller. Controller structure [▶ 23]	0.01 ms	UINT	0

6.3.3 Standard objects

Index 1000 Device type

Access rights: read only

Subindex (hex)	Name	Description	Unit	Data type	Value
-	Device type	Bit 0 .. 15: Device profile number Bit 16 .. 31: Module profile number (Device profile number 5001: Modular Device Profile MDP)	-	UDINT	5001_{dec}

Index 1008 Device name

Access rights: read only

Subindex (hex)	Name	Description	Unit	Data type	Value
-	Device name	Name of the EtherCAT device	-	STRING	EP7047-1032

Index 1009 Hardware version

Access rights: read only

Subindex (hex)	Name	Description	Unit	Data type	Value
-	Hardware version	Hardware version of the EtherCAT device	-	STRING	[1)]

[1)] Refer to Firmware and hardware versions [▶ 7].

Index 100A Software version

Access rights: read only

Subindex (hex)	Name	Description	Unit	Data type	Value
-	Software version	Firmware version of the EtherCAT device	-	STRING	[1)]

[1)] Refer to Firmware and hardware versions [▶ 7].

Index 1011 Restore default parameters

Access rights: read/write

Subindex (hex)	Name	Description	Data type	Default
1	Subindex 001	Resets the CoE parameters to the factory settings. To do this, write the value 0x64616F6C in this parameter.	UDINT	0

Index 1018 Identity

Access rights: read only

Subindex (hex)	Name	Description	Data type	Value
01	Vendor ID	Vendor identifier (2: Beckhoff Automation)	UDINT	2_{dec}
02	Product code	Product code	UDINT	$1B874052_{hex}$
03	Revision	Bit 0...15: Index number of the product version Bit 16...31: Revision of the device description (ESI)	UDINT	Bit 0...15: 1032_{dec}
04	Serial number	Reserved	UDINT	0

7 Appendix

7.1 General operating conditions

Protection degrees (IP-Code)

The standard IEC 60529 (DIN EN 60529) defines the degrees of protection in different classes.

1. Number: dust protection and touch guard	Definition
0	Non-protected
1	Protected against access to hazardous parts with the back of a hand. Protected against solid foreign objects of Ø 50 mm
2	Protected against access to hazardous parts with a finger. Protected against solid foreign objects of Ø 12.5 mm.
3	Protected against access to hazardous parts with a tool. Protected against solid foreign objects Ø 2.5 mm.
4	Protected against access to hazardous parts with a wire. Protected against solid foreign objects Ø 1 mm.
5	Protected against access to hazardous parts with a wire. Dust-protected. Intrusion of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the device or to impair safety.
6	Protected against access to hazardous parts with a wire. Dust-tight. No intrusion of dust.

2. Number: water* protection	Definition
0	Non-protected
1	Protected against water drops
2	Protected against water drops when enclosure tilted up to 15°.
3	Protected against spraying water. Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects.
4	Protected against splashing water. Water splashed against the disclosure from any direction shall have no harmful effects
5	Protected against water jets
6	Protected against powerful water jets
7	Protected against the effects of temporary immersion in water. Intrusion of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water for 30 min. in 1 m depth.

*) These protection classes define only protection against water!

Chemical Resistance

The Resistance relates to the Housing of the IP 67 modules and the used metal parts. In the table below you will find some typical resistance.

Character	Resistance
Steam	at temperatures >100°C: not resistant
Sodium base liquor (ph-Value > 12)	at room temperature: resistant > 40°C: not resistant
Acetic acid	not resistant
Argon (technical clean)	resistant

Key

- resistant: Lifetime several months
- non inherently resistant: Lifetime several weeks
- not resistant: Lifetime several hours resp. early decomposition

7.2 Accessories

Protective caps for connectors

Ordering information	Description
ZS5000-0010	Protective cap for M8 sockets, IP67 (50 pieces)
ZS5000-0020	Protective cap M12, IP67 (50 pieces)

Labelling material

Ordering information	Description
ZS5100-0000	Inscription labels, unprinted, 4 strips of 10
ZS5000-xxxx	Printed inscription labels on enquiry

Cables

A complete overview of pre-assembled cables for fieldbus components can be found here.

Ordering information	Description	Link
ZK1090-3xxx-xxxx	EtherCAT cable M8, green	Website
ZK2000-6xxx-xxxx	Sensor cable M12, 4-pin	Website
ZK2000-5xxx-xxxx ZK2000-71xx-xxxx	Sensor cable M12 5-pin	Website
ZK203x-xxxx-xxxx	Power cable 7/8 ", 5-pin	Website
ZK4000-5151-0xxx	Encoder cable, shielded	Website
ZK4000-6768-0xxx	Motor cable, shielded	Website

Tools

Ordering information	Description
ZB8801-0000	Torque wrench for plugs, 0.4…1.0 Nm
ZB8801-0001	Torque cable key for M8 / wrench size 9 for ZB8801-0000
ZB8801-0002	Torque cable key for M12 / wrench size 13 for ZB8801-0000

Further accessories

Further accessories can be found in the price list for fieldbus components from Beckhoff and online at https://www.beckhoff.com.

7.3 Version identification of EtherCAT devices

Designation

A Beckhoff EtherCAT device has a 14-digit designation, made up of

- family key
- type
- version
- revision

Example	Family	Type	Version	Revision
EL3314-0000-0016	EL terminal (12 mm, non-pluggable connection level)	3314 (4-channel thermocouple terminal)	0000 (basic type)	0016
ES3602-0010-0017	ES terminal (12 mm, pluggable connection level)	3602 (2-channel voltage measurement)	0010 (high-precision version)	0017
CU2008-0000-0000	CU device	2008 (8-port fast ethernet switch)	0000 (basic type)	0000

Notes

- The elements mentioned above result in the **technical designation**. EL3314-0000-0016 is used in the example below.
- EL3314-0000 is the order identifier, in the case of “-0000” usually abbreviated to EL3314. “-0016” is the EtherCAT revision.
- The **order identifier** is made up of
  - family key (EL, EP, CU, ES, KL, CX, etc.)
  - type (3314)
  - version (-0000)
- The **revision** -0016 shows the technical progress, such as the extension of features with regard to the EtherCAT communication, and is managed by Beckhoff.
  In principle, a device with a higher revision can replace a device with a lower revision, unless specified otherwise, e.g. in the documentation.
  Associated and synonymous with each revision there is usually a description (ESI, EtherCAT Slave Information) in the form of an XML file, which is available for download from the Beckhoff web site.
  From 2014/01 the revision is shown on the outside of the IP20 terminals, see Fig. *“EL5021 EL terminal, standard IP20 IO device with batch number and revision ID (since 2014/01)”*.
- The type, version and revision are read as decimal numbers, even if they are technically saved in hexadecimal.

Identification number

Beckhoff EtherCAT devices from the different lines have different kinds of identification numbers:

Production lot/batch number/serial number/date code/D number

The serial number for Beckhoff IO devices is usually the 8-digit number printed on the device or on a sticker. The serial number indicates the configuration in delivery state and therefore refers to a whole production batch, without distinguishing the individual modules of a batch.

Structure of the serial number: **KK YY FF HH**

KK - week of production (CW, calendar week)
YY - year of production
FF - firmware version
HH - hardware version

Example with
Ser. no.: 12063A02: 12 - production week 12 06 - production year 2006 3A - firmware version 3A 02 - hardware version 02

Exceptions can occur in the **IP67 area**, where the following syntax can be used (see respective device documentation):

Syntax: D ww yy x y z u

D - prefix designation
ww - calendar week
yy - year
x - firmware version of the bus PCB
y - hardware version of the bus PCB
z - firmware version of the I/O PCB
u - hardware version of the I/O PCB

Example: D.22081501 calendar week 22 of the year 2008 firmware version of bus PCB: 1 hardware version of bus PCB: 5 firmware version of I/O PCB: 0 (no firmware necessary for this PCB) hardware version of I/O PCB: 1

Unique serial number/ID, ID number

In addition, in some series each individual module has its own unique serial number.

See also the further documentation in the area

- IP67: EtherCAT Box
- Safety: TwinSafe
- Terminals with factory calibration certificate and other measuring terminals

Examples of markings

Fig. 47: EL5021 EL terminal, standard IP20 IO device with serial/ batch number and revision ID (since 2014/01)

Fig. 48: EK1100 EtherCAT coupler, standard IP20 IO device with serial/ batch number

Fig. 49: CU2016 switch with serial/ batch number

Fig. 50: EL3202-0020 with serial/ batch number 26131006 and unique ID-number 204418

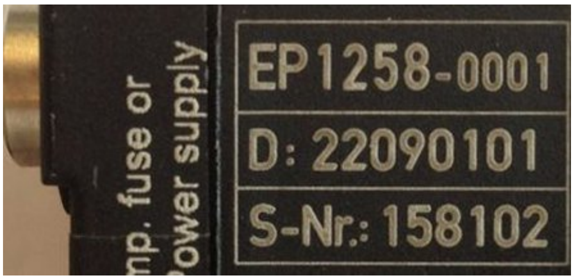


Fig. 51: EP1258-00001 IP67 EtherCAT Box with batch number/ date code 22090101 and unique serial number 158102

Fig. 52: EP1908-0002 IP67 EtherCAT Safety Box with batch number/ date code 071201FF and unique serial number 00346070

Fig. 53: EL2904 IP20 safety terminal with batch number/ date code 50110302 and unique serial number 00331701

Fig. 54: ELM3604-0002 terminal with unique ID number (QR code) 100001051 and serial/ batch number 44160201

7.3.1 Beckhoff Identification Code (BIC)

The Beckhoff Identification Code (BIC) is increasingly being applied to Beckhoff products to uniquely identify the product. The BIC is represented as a Data Matrix Code (DMC, code scheme ECC200), the content is based on the ANSI standard MH10.8.2-2016.

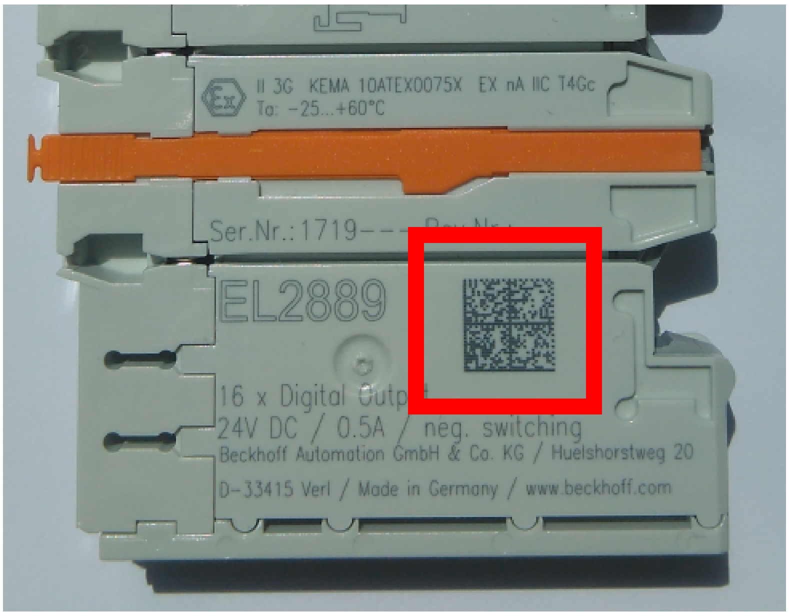


Fig. 55: BIC as data matrix code (DMC, code scheme ECC200)

The BIC will be introduced step by step across all product groups.

Depending on the product, it can be found in the following places:

- on the packaging unit
- directly on the product (if space suffices)
- on the packaging unit and the product

The BIC is machine-readable and contains information that can also be used by the customer for handling and product management.

Each piece of information can be uniquely identified using the so-called data identifier (ANSI MH10.8.2-2016). The data identifier is followed by a character string. Both together have a maximum length according to the table below. If the information is shorter, spaces are added to it. The data under positions 1 to 4 are always available.

The following information is contained:

Item no.	Type of information	Explanation	Data identifier	Number of digits incl. data identifier	Example
1	Beckhoff order number	**Beckhoff order number**	1P	8	1P072222
2	Beckhoff Traceability Number (BTN)	**Unique serial number, see note below**	S	12	SBTNk4p562d7
3	Article description	**Beckhoff article description, e.g. EL1008**	1K	32	1KEL1809
4	Quantity	**Quantity in packaging unit, e.g. 1, 10, etc.**	Q	6	Q1
5	Batch number	Optional: Year and week of production	2P	14	2P401503180016
6	ID/serial number	Optional: Present-day serial number system, e.g. with safety products	51S	12	51S678294104
7	Variant number	Optional: Product variant number on the basis of standard products	30P	32	30PF971, 2*K183
...					

Further types of information and data identifiers are used by Beckhoff and serve internal processes.

Structure of the BIC

Example of composite information from item 1 to 4 and 6. The data identifiers are marked in red for better display:

BTN

An important component of the BIC is the Beckhoff Traceability Number (BTN, item no. 2). The BTN is a unique serial number consisting of eight characters that will replace all other serial number systems at Beckhoff in the long term (e.g. batch designations on IO components, previous serial number range for safety products, etc.). The BTN will also be introduced step by step, so it may happen that the BTN is not yet coded in the BIC.

NOTE

This information has been carefully prepared. However, the procedure described is constantly being further developed. We reserve the right to revise and change procedures and documentation at any time and without prior notice. No claims for changes can be made from the information, illustrations and descriptions in this information.

7.4 Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

Beckhoff's branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: https://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:

- support
- design, programming and commissioning of complex automation systems
- and extensive training program for Beckhoff system components

Hotline:	+49 5246 963 157
Fax:	+49 5246 963 9157
e-mail:	support@beckhoff.com

Beckhoff Service

The Beckhoff Service Center supports you in all matters of after-sales service:

- on-site service
- repair service
- spare parts service
- hotline service

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