BECKHOFF New Automation Technology

Documentation | EN

AX2000-B110

EtherCAT interface for AX2000

2023-10-24 | Version: 2.2

Table of Contents

1 Foreword

1.1 Notes on the documentation

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

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

Disclaimer

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

Trademarks

Beckhoff®, TwinCAT®, TwinCAT/BSD®, TC/BSD®, EtherCAT®, EtherCAT G®, EtherCAT G10®, EtherCAT P®, Safety over EtherCAT®, TwinSAFE®, XFC®, XTS® and XPlanar® are registered and licensed trademarks of Beckhoff Automation GmbH.
If third parties make use of designations or trademarks used in this publication for their own purposes, this could infringe upon the rights of the owners of the said designations.

Patents

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

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

Copyright

1.2 For your safety

Safety regulations

Read the following explanations for your safety.
Always observe and follow product-specific safety instructions, which you may find at the appropriate places in this document.

Exclusion of liability

All the components are supplied in particular hardware and software configurations which are 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 technology who are familiar with the applicable national standards.

Signal words

The signal words used in the documentation are classified below. In order to prevent injury and damage to persons and property, read and follow the safety and warning notices.

Personal injury warnings

⚠ DANGER

Hazard with high risk of death or serious injury.

⚠ WARNING

Hazard with medium risk of death or serious injury.

⚠ CAUTION

There is a low-risk hazard that could result in medium or minor injury.

Warning of damage to property or environment

NOTICE

The environment, equipment, or data may be damaged.

Information on handling the product

This information includes, for example:
recommendations for action, assistance or further information on the product.

1.3 Notes on information security

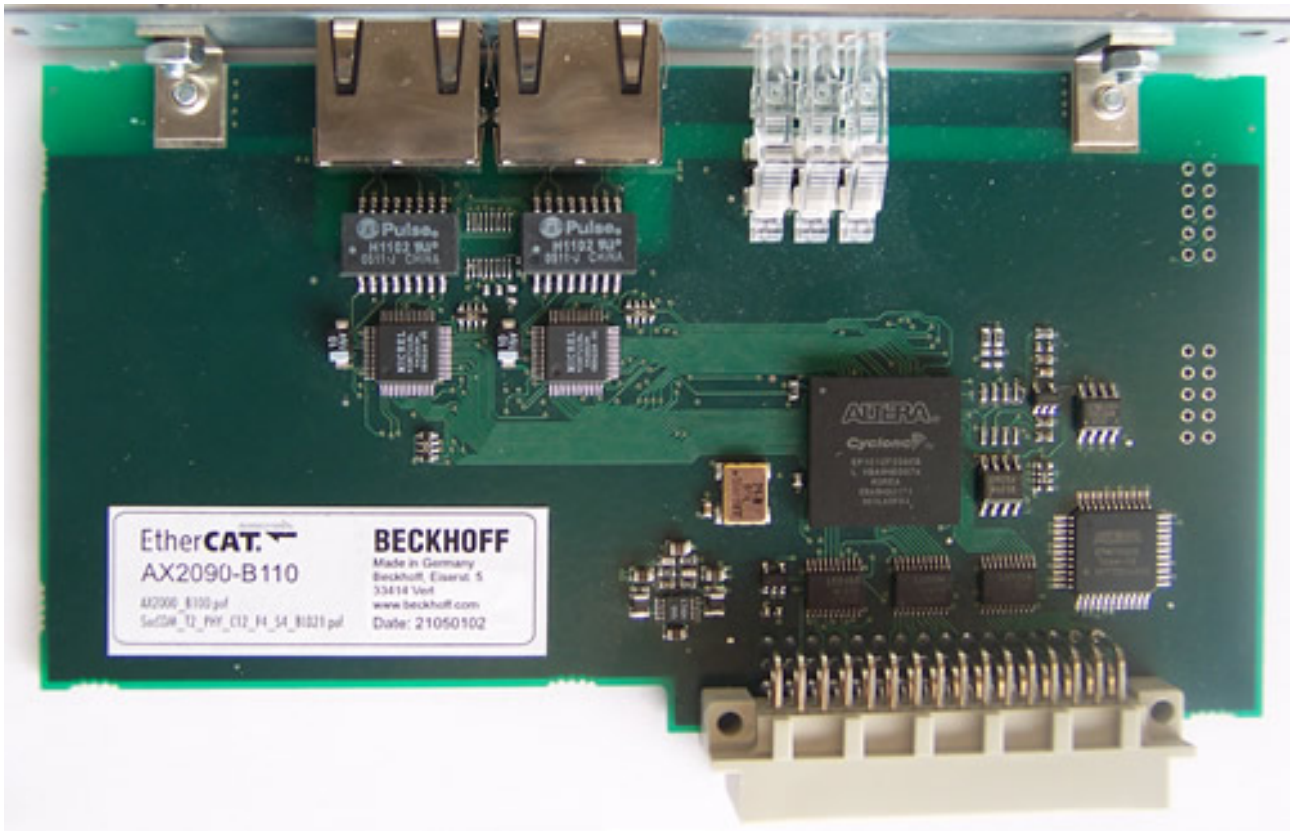
The products of Beckhoff Automation GmbH & Co. KG (Beckhoff), insofar as they can be accessed online, are equipped with security functions that support the secure operation of plants, systems, machines and networks. Despite the security functions, the creation, implementation and constant updating of a holistic security concept for the operation are necessary to protect the respective plant, system, machine and networks against cyber threats. The products sold by Beckhoff are only part of the overall security concept. The customer is responsible for preventing unauthorized access by third parties to its equipment, systems, machines and networks. The latter should be connected to the corporate network or the Internet only if appropriate protective measures have been set up.

In addition, the recommendations from Beckhoff regarding appropriate protective measures should be observed. Further information regarding information security and industrial security can be found in our https://www.beckhoff.com/secguide.

Beckhoff products and solutions undergo continuous further development. This also applies to security functions. In light of this continuous further development, Beckhoff expressly recommends that the products are kept up to date at all times and that updates are installed for the products once they have been made available. Using outdated or unsupported product versions can increase the risk of cyber threats.

To stay informed about information security for Beckhoff products, subscribe to the RSS feed at https://www.beckhoff.com/secinfo.

2 Product Overview



The EtherCAT AX2000-B110 interface card allows servo drives from the AX2000 series to be integrated into an EtherCAT network.

2.1 Technical data

Technical data	AX2000-B110
Fieldbus	EtherCAT
Transmission rate	100 Mbaud
Delay	approx. 1 µs
Protocol	EtherCAT
Fieldbus connections	X1 IN: EtherCAT signal input X2 OUT: EtherCAT signal output
Bus connection technology	2 x RJ45
Data transfer medium	Ethernet CAT-5 cable
Electrical isolation	500 V_{rms} (EtherCAT/servo drive)
Distance between 2 modules	max. 100 m (100BASE-TX)
Hardware diagnosis	4 LEDs: Act In, Act Out, Run, Error
Power supply	From the servo drive
Permissible ambient temperature during operation	0°C ... +55°C
Permissible ambient temperature during storage	-25°C ... +85°C
Relative humidity	95% (no condensation)
Dimensions	approx. 140mm x 89mm

3 Installation

3.1 Requirements

The following conditions must be satisfied in order to operate a servo drive from the AX2000 series on EtherCAT.

Hardware

Servo drive

The AX2090-B110 interface card allows servo drives from the AX2000 series, with serial numbers of 780 266 0000 and above, to be used.
You will find the serial number on the servo drive's type plate.
In addition, a hardware status 29.02 is required as a minimum. These numbers indicate the production week; the first two numbers are the calendar week, while the last two numbers are the year of production.

The hardware status is printed on the interface board and can be read through the ventilation slots on the top side of the servo drive.

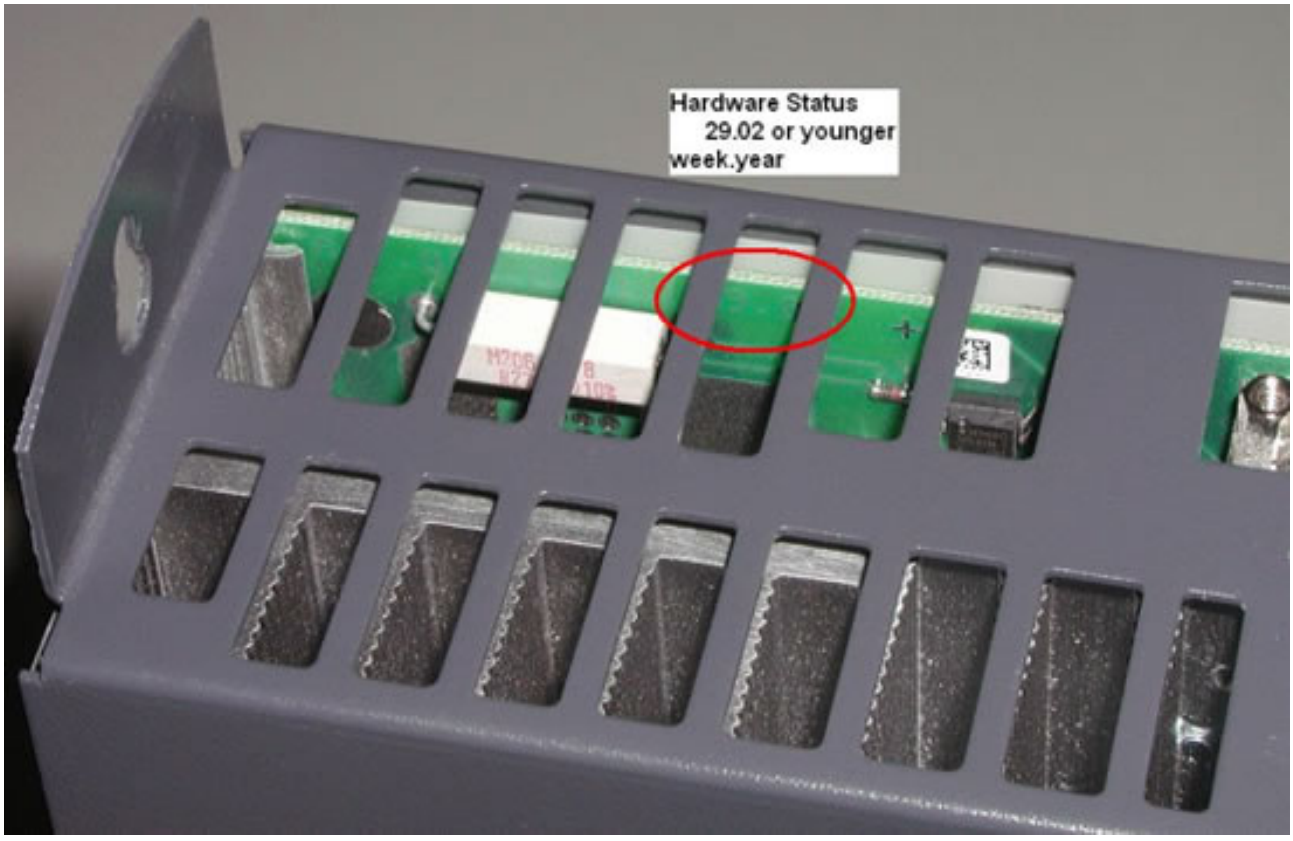
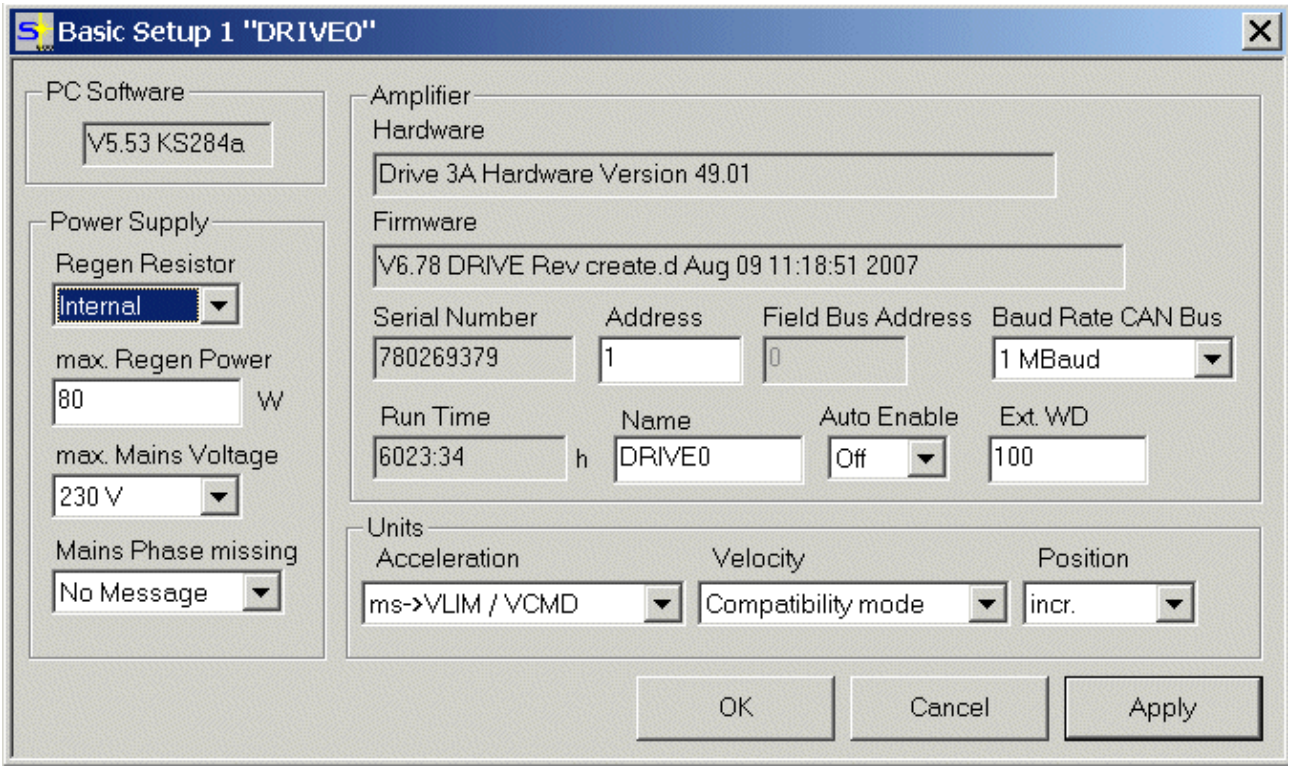


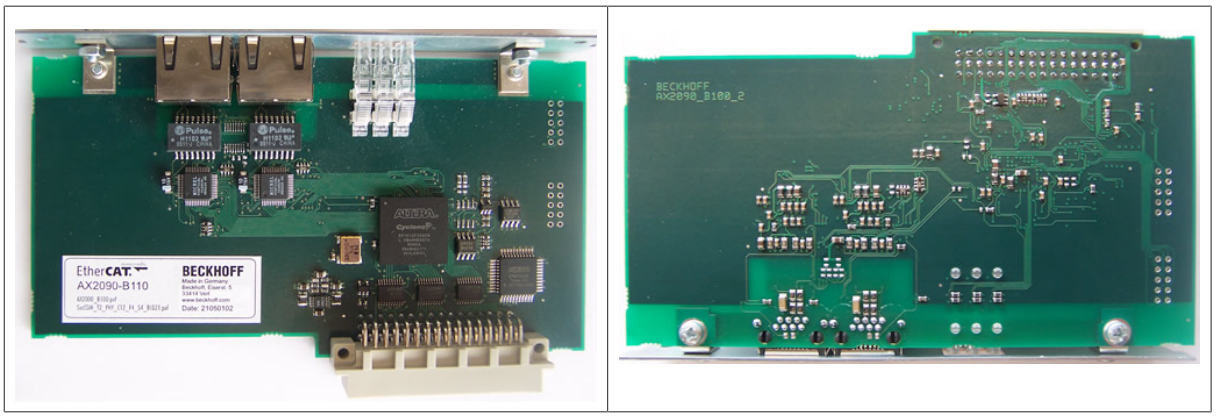
Fig. 1: In this example: 29.02 indicates the 29th calendar week in the year 2002.

The hardware status, firmware version and serial number can also be displayed by the Commissioning software [▶ 13] for the AX2000 (Drive.exe, "DriveTool").

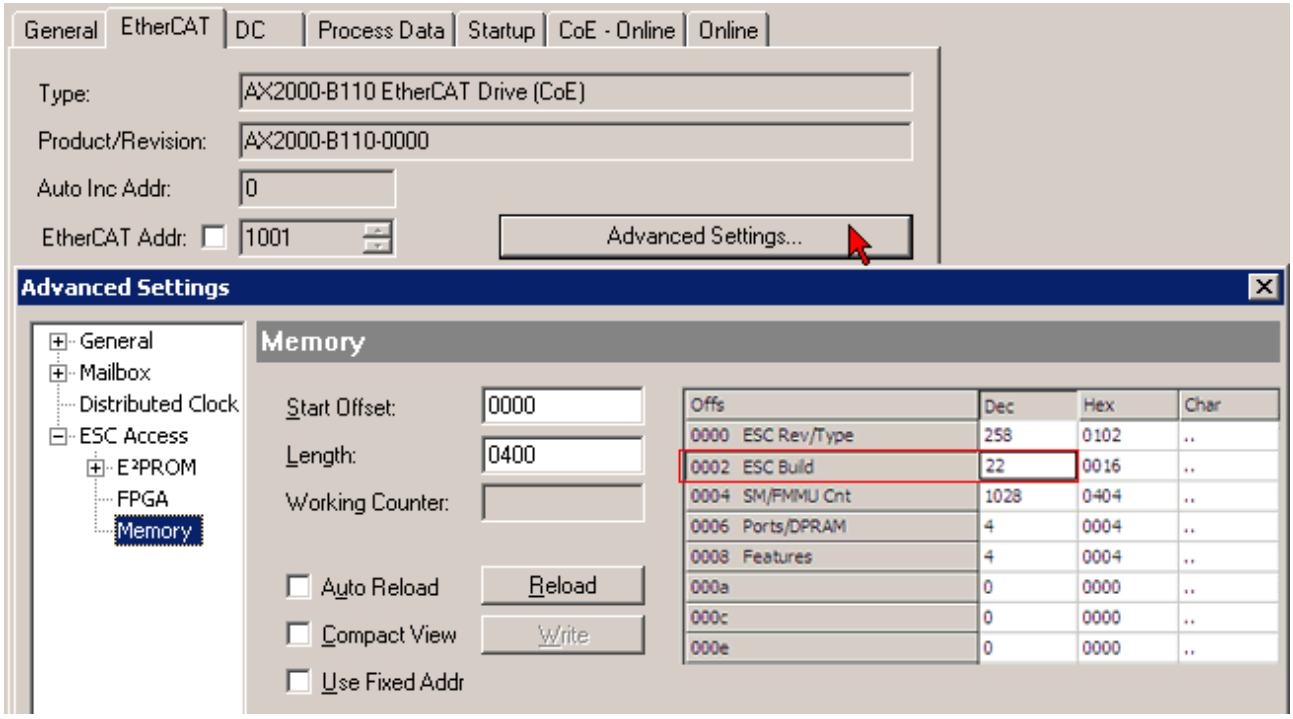


A firmware version of 6.78 or above must be installed on the servo drive!

EtherCAT AX2090-B110 interface card

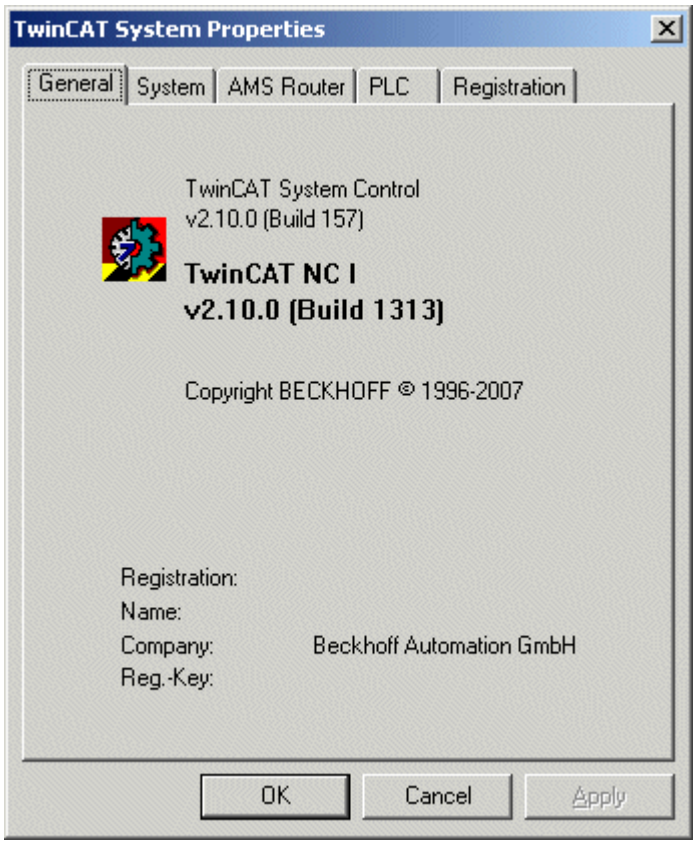


The FPGA fitted on the AX2090-B110 interface card must be of Build 22 or higher.
The interface card's FPGA version can be displayed by the TwinCAT System Manager:



TwinCAT

You require TwinCAT 2.10 (Build 1313 or above) to be able to communicate with the AX2090-B110 interface card.
You will find the current version on our web site at www.beckhoff.com in the area ">->software->TwinCAT".



Network card

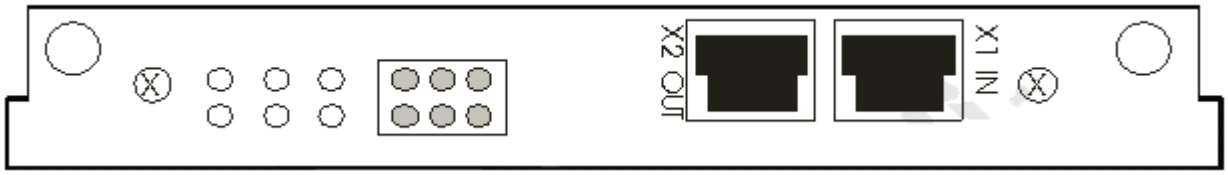
In addition, the TwinCAT EtherCAT driver in your PC requires an Ethernet card with an Intel chipset.

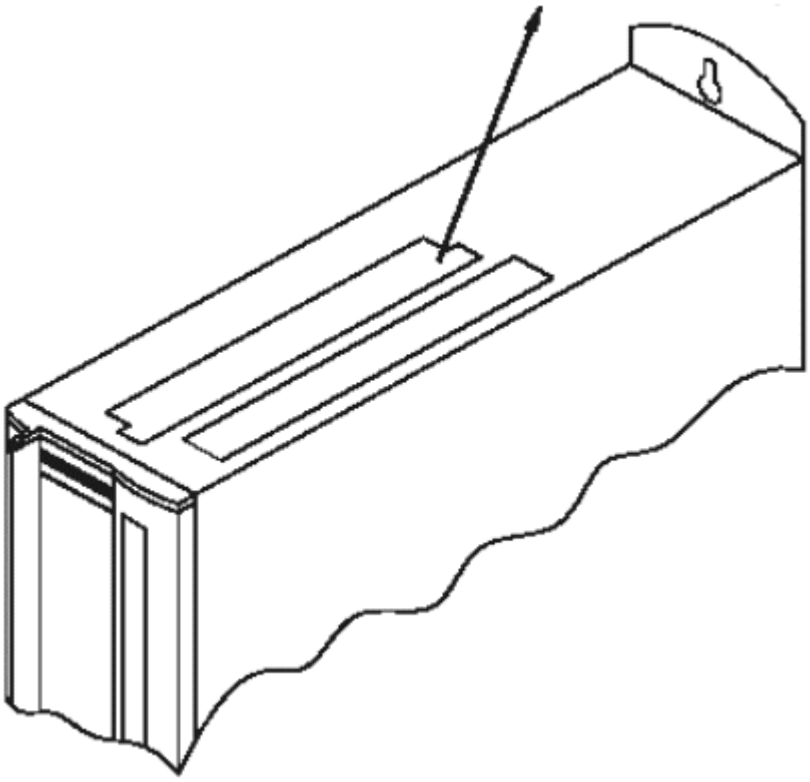
3.2 Position of the extension card

EtherCAT AX2090-B110 extension card

The AX2090-B110 extension card is plugged and screwed into the servo drive's extension slot when the AX2000 is shipped.

Position of the plug





The AGND and DGND terminal points on plug X3 must be bridged!

NOTICE

Please note that the plug of the EtherCAT cable from the PC is plugged into socket X1 “IN” and that the signal from socket X2 “OUT” must be fed to socket X1 “IN” on the next AX2000 and so forth up to the last AX2000. If the sockets are mixed up, indefinable states and errors may occur.

Assembly

If the EtherCAT AX2090-B110 interface card has not yet been plugged into your servo drive, install it as follows:

- Lever out the cover of the option slot using a suitable screwdriver.
  Make sure that no small parts (such as screws) fall into the open option slot!
- Push the extension card carefully into the guide rails, making sure that it is not misaligned.
- Push the extension card firmly down into the slot, until the front cover is level with the fixing plates.
  This ensures that proper contact is made with the connectors.
- Turn the screws in the front cover to tighten them in the threads of the fixing plates.

3.3 Commissioning software

The commissioning software for the AX2000 (Drive.exe, "DriveTool ") is described in the *Commissioning software documentation for the AX2x00 Servo Drive*, which you will find on our website (www.beckhoff.com) under *Motion*.

Default data record

The commissioning software for the AX2000 (Drive.exe, "DriveTool ") does not require any special settings to be made in order to use the EtherCAT AX2090-B110 interface card, provided your AX2000 was supplied with firmware version 6.48 (or higher).

Default data record for older firmware versions

For operation of the AX2090-B110 EtherCAT interface card, if you operate your AX2000 with an older firmware version, you must

- first update the firmware of the AX2000
- manually adapt the following parameters of the default data record

The following parameter settings are a basic precondition for proper function of the AX2000 with EtherCAT. You should only deviate from them in exceptional cases.
These parameters should already be loaded if an AX2000 is delivered with firmware version 6.48 or higher; please check for reasons of safety!

NOTICE

If the bus system is converted to EtherCAT or for older devices that are converted to EtherCAT, you must adapt these parameters manually.

Parameters	Default	Description
ANCNFG	-1	Deactivates analog inputs 1 and 2
ANOUT1	0	Deactivates analog output 1
ANOUT2	0	Deactivates analog output 2
AENA	0	Deactivates 'Auto Enable'
WMASK	8	Assesses the communication monitoring ("TimeOut") with reference to the error
ACTFAULT	1	An emergency halt procedure is initiated in the event of an error
VCOMM	3600	Speed threshold for monitoring the commutation error in rpm
BOOT	0	Internal controller setting is compiled every time the system boots
UID	1	Returns the customer identifier (1: Beckhoff)
DRVCNFG2	|=6	Bits 1 and 2 are set as the default data record (=> latch activation by the controller)
EXTWD	100	No longer a special Beckhoff parameter, as has been adopted as standard
DRVCNFG	Bit 20	Only for EtherCAT: bit 20 is set due to CAN compatibility with DS402 V2.0
FPGA	3	Only for EtherCAT: EtherCAT/CAN FPGA version
OPMODE	0	Digital speed (depending on “operation mode”)
POSCNFG	0	Axis type (0 = linear, 1 = rotary, 2 = modular)
PRBASE	20	Internal position resolution of the drive (EtherCAT = 20-bit, Lightbus = 16-bit)
SERCSET	0	Fieldbus specific settings: 0x00010000 = TRUE - generates an error reset if shifted up from INIT/ BOOT 0x00020000 = TRUE - synchronisation error monitoring (F28) is deactivated 0x00080000 = FALSE - generates an error reset via Bit 7 "Fault Reset"

The selection of operating mode (position, speed) is executed automatically by the TwinCAT system manager depending on the choice of process image.

3.4 EtherCAT Wiring

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

Cables and connectors

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

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

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

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

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

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

E-Bus supply

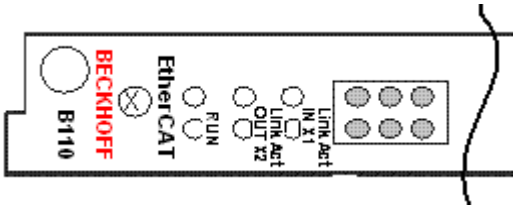
NOTICE

Malfunction possible!

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

4 Diagnostics

4.1 Diagnostic LEDs



Light-emitting diodes

- Link / Act IN X1: Indicates activity (Ethernet frame) at the incoming port.
- Link / Act OUT X2: Indicates activity (Ethernet frame) at the outgoing port.
- Run: see table

Run LED	EtherCAT state
Off	Init
Flashes at 1 Hz	Pre-Operational
Flashes at 0.5 Hz	Safe-Operational
Lit	Operational

4.2 Warning messages

Faults that occur that do not cause the servo drive's output stage to be switched off (ready for operation contact remains open), are encoded and shown in the form of a warning number on the LED display on the front panel.

Requirements

Number	Designation	Explanation
n01	I²t	I²t monitoring threshold exceeded
n02	Ballast power	Configured ballast power reached
n03*	S_error	Configured following error window exceeded
n04*	Communication monitoring	Communication monitoring (fieldbus) activated
n05	Mains phase	Mains phase missing
n06*	Sw limit switch 1	Software limit switch 1 passed
n07*	Sw limit switch 2	Software limit switch 2 passed
n08	Travel command error	A faulty travel command has been started
n09	No reference point	No reference point had been set at the start of the travel command
n10*	PSTOP	PSTOP limit switch triggered
n11*	NSTOP	NSTOP limit switch triggered
n12	Motor default values loaded	Only ENDAT or HIPERFACE® : Different motor numbers are stored in the encoder and the servo drive; default motor values have been loaded
n13*	Extension card	Extension card is not operating properly
n14	SinCos feedback	SinCos commutation (wake & shake) not complete; is cleared when the servo drive is enabled and wake & shake is executed
n15	Table Errors	Fault in the INXMODE 35 speed-current table
n16	Collective warning	Collective warning for warnings n17..n32

Number	Designation	Explanation
n17	Synchronisation error	=1: Synchronization is generated when the drive is set for synchronization (SYNCSRC) but has not yet synchronized (e.g. CAN Sync). Obvious reasons for this can, for instance, be that TwinCAT is stopped, or that the drive is only in the “INIT” EtherCAT state. Other, more serious reasons, could be that the real-time jitter in the controller (IPC with TwinCAT) is too large, as a result of which the drive cannot synchronize to the EtherCAT Master (this may be caused by, e.g. an internal graphic card, a USB device, to little main buffer, or interrupt blocking times).
n18	Multi-turn overflow	An overflow exceeding the maximum number of rotations (+/-2048) has been detected in the multi-turn encoder feedback.
n19-n31	Reserve	
n32	Firmware is a beta version	=1: The firmware version has not been released
A	Reset	A reset is being asserted at the DIGITAL INx input

*) These warning messages result in the drive being halted (braking with emergency ramp)

4.3 Error Messages

The LED display on the servo drive's front panel displays errors that occur as an error number.
All error messages cause the ready for operation contact to be opened and the servo drive's output stage to be switched off. The motor generates no torque, and the motor's holding brake is applied.

Error number	Designation	Explanation
F01*	Heatsink temperature	Heatsink temperature too high. Limit value set by the manufacturer to 80° C.
F02*	Overvoltage	Overvoltage in DC link. Limit value depends on the mains voltage.
F03*	Following error	Message from position controller
F04	Feedback	Broken cable, short-circuit, earth short
F05*	Undervoltage	Undervoltage in DC link. Limit value set by the manufacturer to 100V.
F06	Motor temperature	Temperature sensor faulty or motor temperature too high. Limit value set by the manufacturer to 145°C.
F07	Auxiliary voltage	Internal auxiliary voltage not correct
F08*	Overspeed	Motor out of control, rotation speed unacceptably high
F09	EEPROM	The "F09" fault occurs if the checksum for the data and parameters in the EEPROM is not correct (can be caused, for instance, if power is removed from the drive while the parameters are being saved). This error can result either from a faulty EEPROM or from a faulty data checksum. In the second case, the fault can be rectified by saving the data (SAVE) again.
F10	Flash-EPROM	Checksum error
F11	Brake	Broken cable, short-circuit, earth short
F12	Motor phase	A motor phase is missing (broken connection or similar)
F13*	Internal temperature	Internal temperature too high
F14	Output stage	Fault in the power output stage
F15	I²t max.	I²t maximum value exceeded
F16*	Mains BTB	Two or three phases are missing from the supply
F17	A/D converter	Fault in the analog/digital conversion, usually caused by exceptional electromagnetic interference

Error number	Designation	Explanation
F18	Ballast	Ballast circuit faulty, or setting not correct
F19*	Mains phase	Absence of a phase from the supply (can be switched off for operation with two phases)
F20	Slot error	Slot error
F21	Handling error	Software error in the extension card
F22	Earth short	Only for 40/70 amp devices: Earth short
F23	CAN Bus off	Serious CAN Bus communication error
F24	Warning	Warning indication is interpreted as an error
F25	Commutation error	Commutation error
F26	Limit switch	Reference transit error (hardware limit switch reached)
F27	AS option	Fault in the operation of the AS option (control of the AS option and the ENABLE signal are present at the same time)
F28	EtherCAT synchronization error	EtherCAT synchronization error (e.g. jitter, double MDT error)
F29	EtherCAT configuration error	EtherCAT configuration error (e.g. Sync Manager parameterization)
F30	Emergency stop timeout	The "F30" error ("Emergency stop timeout") occurs when, in the case of a Stop or of an Emergency stop, the axis cannot physically be brought to a halt within a parameterized time window (default: 5000 ms, see <EMRGTO>) (halt limit <VEL0>: 5 RPM). This error can be triggered if very soft ramps are parameterized in the drive (see <DEC>, <DECSTOP>, <DECDIS>).
F31	Macro error	Error in the macro programming
F32	System error	The "F32" error ("System error") indicates an internal error. This error is generated when the servo drive is switched on if it has not been possible to successfully complete the system check during the initialization phase (see the output from the RS232 serial interface for the exact cause of the error). The error can also occur if the servo drive is too heavily loaded when cycle times a very short (see Runtime optimization).

*) These error messages can be cleared with the CLRFAULT ASCII command without carrying out a reset. If only one of these faults is present, and the Reset button is pressed or the Reset I/O function is used, then again only the CLRFAULT command will be executed.

5 EtherCAT

5.1 EtherCAT operating principle

This supplementary manual describes the extended functional capabilities of the AX2000 with the AX2090-B110 EtherCAT interface. The basic functions, together with general advice on installation and commissioning, are described in the AX2000 manual.

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

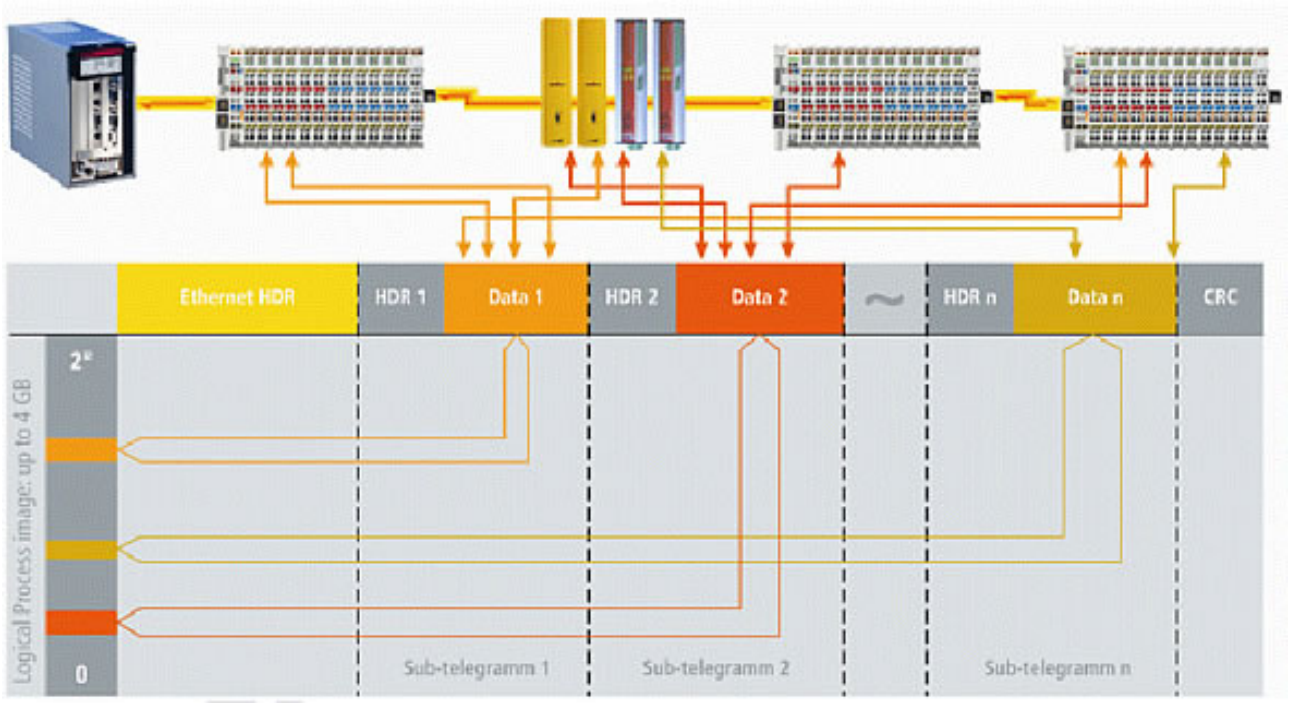


Fig. 2: Process data are inserted in telegrams

5.2 EtherCAT as drive bus

The option of being able to use EtherCAT both for drive applications and for fast I/O signals was one of its main developments aims right from the start. In former systems it has only been possible to implement short cycle times offering high synchronicity, as are required for control loops that are closed by the bus, with the aid of special "drive buses" such as CANopen.

Special drive technology requirements

- Cycle time
- Synchronicity
- Simultaneity

Typical values for the necessary cycle times lie between 1 and 4 milliseconds when position is specified cyclically, with position control in the drive. Drive technology frequently specifies a microsecond as an adequate requirement for synchronicity. Whereas the synchronicity specifies the temporal jitter in the processing of functions by the devices involved (drive and controller), simultaneity defines the size of the

temporal delay involved with these functions. Synchronicity is important for the individual devices, so that their own subordinate control loops can synchronize with the cyclic signal with the required precision. Simultaneity moreover enables distributed devices to work on a common task with identical timebase.

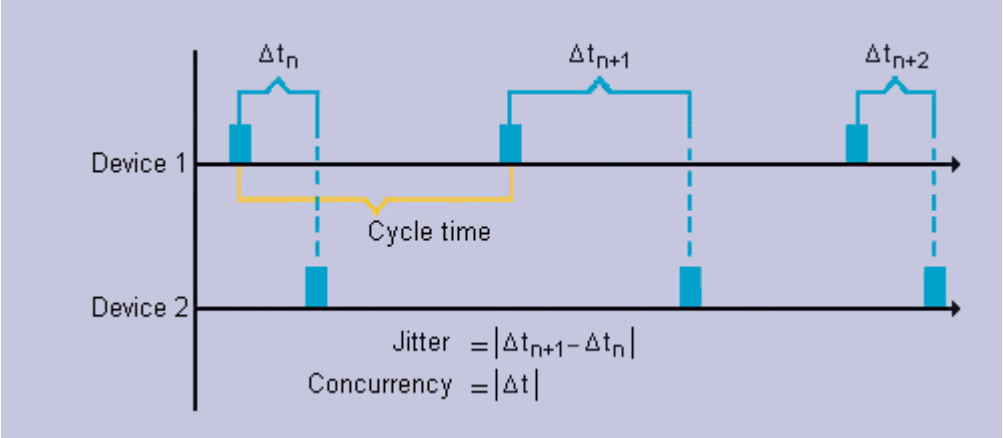


Fig. 3: Cycle time, synchronicity, and simultaneity

Distributed clocks - Properties of the EtherCAT slave controller

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

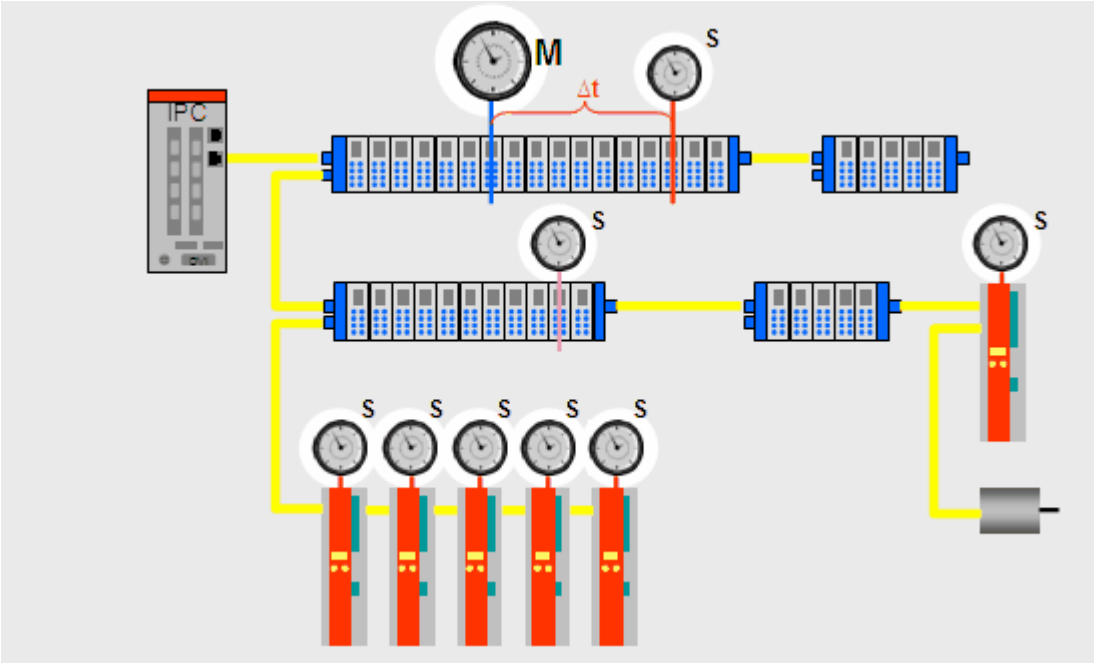


Fig. 4: Distributed clocks

Topology

Line, tree, or star: EtherCAT supports almost any topology (see figure). The bus or line structure known from the field busses thus also becomes available for Ethernet. Particularly useful for system wiring is the combination of line and branches or stubs: the required interfaces exist on the couplers; no additional switches are required. Naturally, the classic switch-based Ethernet star topology can also be used. Wiring flexibility is further maximized through the choice of different cables. Flexible and inexpensive standard Ethernet patch cables transfer the signals optionally in Ethernet mode (100Base-TX) or in E-bus signal representation. Plastic optical fibers (POF) complement the system for special applications. The complete bandwidth of the Ethernet network - such as different optical fibers and copper cables - can be used in combination with switches or media converters. The Fast Ethernet physics enables a cable length of

100 m between two devices, the E-bus line is intended for distances of up to 10m. For each cable distance, the signal variant can be selected individually. Since up to 65535 devices can be connected, the size of the network is almost unlimited.

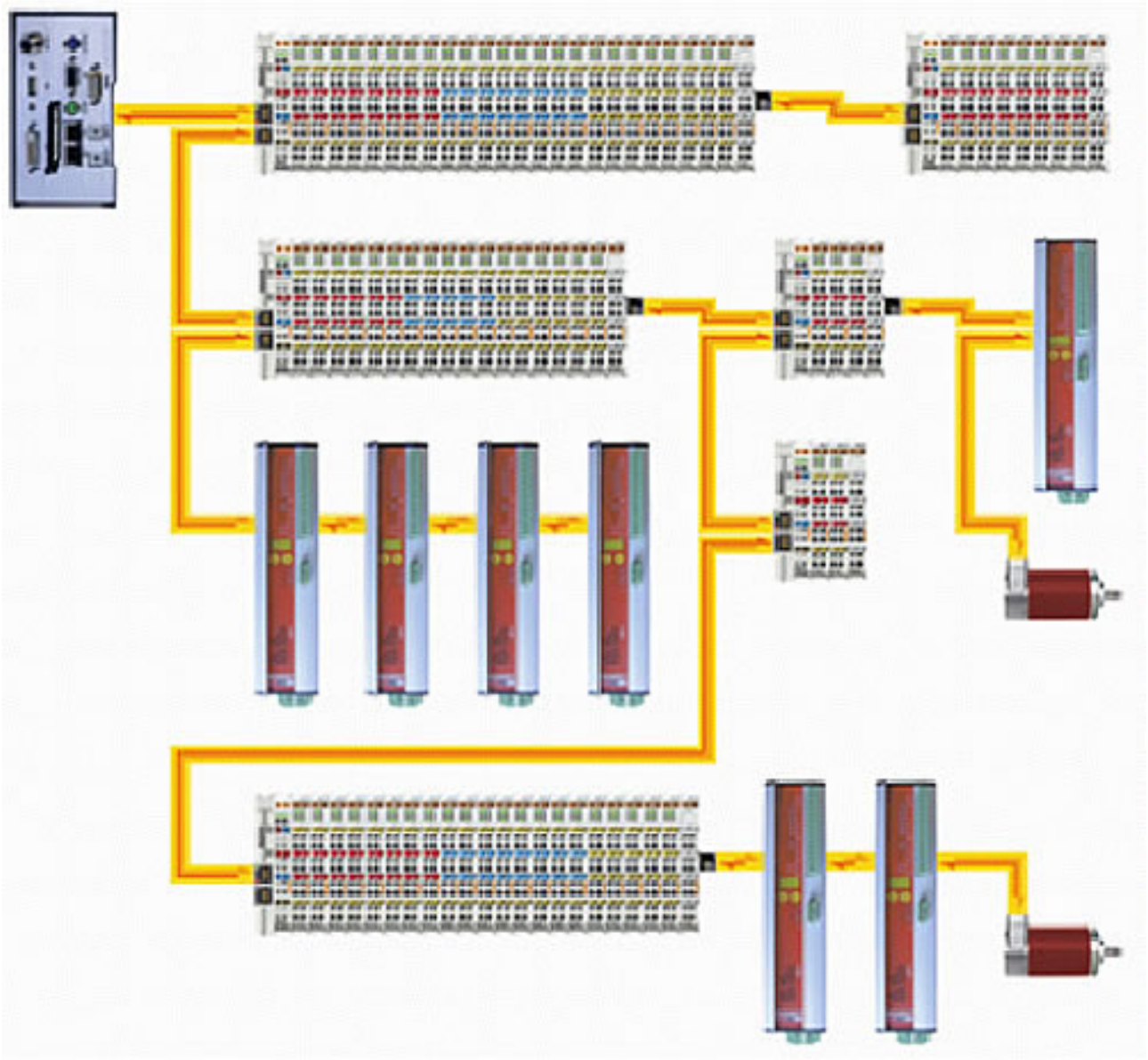


Fig. 5: Flexible topology: line, tree, or star

5.3 Multi-protocol capability

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

None of the available protocols on their own support all communication requirements of modern field busses (process data, parameter data, parallel TCP/IP, firmware updates, routing to subordinate bus systems, etc.). EtherCAT therefore introduces multi-protocol capability, consolidating the different protocols in a standardized mailbox. This enables quick and full conversion of existing devices to EtherCAT.

The *CANopen over EtherCAT* (CoE) and *Servo Profile over EtherCAT* (SoE) protocols are relevant for drive technology; they make it possible to combine the advantageous transmission properties of EtherCAT with proven, profile-specific drive functions.

The *Ethernet over EtherCAT* (EoE) and *File Access over EtherCAT* (FoE) protocols provide options for integrating a web server in the drive, for example, or for efficiently exchanging firmware or cam plate tables via the bus.

5.4 CANopen over EtherCAT

The *CANopen over EtherCAT* (CoE) protocol enables the complete CANopen profile family to be utilized via EtherCAT. The SDO protocol is used directly, so that existing CANopen stacks can be used practically unchanged. Optional extensions are defined that lift the 8-byte limit and enable complete readability of the object list.

The process data are organized in process data objects (PDO), which are transferred using the efficient means of EtherCAT - naturally without 8-byte limit. All CANopen profiles - including the drive profile (DS 402) - are fully usable, and devices based on it can be transferred to EtherCAT very easily.

Apart from a few details, the EtherCAT state machine of the slave corresponds to the CANopen state machine, so that only a limited number of changes are required. To enable less ambiguous start-up behavior, a further state called "safe operational" is defined, to which inputs that are already valid are transferred, while the outputs remain in safe state.

The AX2000 contains the CANopen profile, to implement the technical drive functions:

1. There are 8 fixed PDO configurations. No other information can be configured in the cyclic data exchange. The PDO configurations are to be considered as "constant configurations".
2. If other information is required, this can only be read and written asynchronously via ADS (entirely normal CAN objects). Almost every item of information is available as a CAN object (SDO): see examples in the appendix, e.g., the drive's error codes or warnings etc.).
3. Resolver: one motor rotation has a fixed 20 bit resolution
   (see ASCII parameter <PRBASE> equal to 20).

State machine

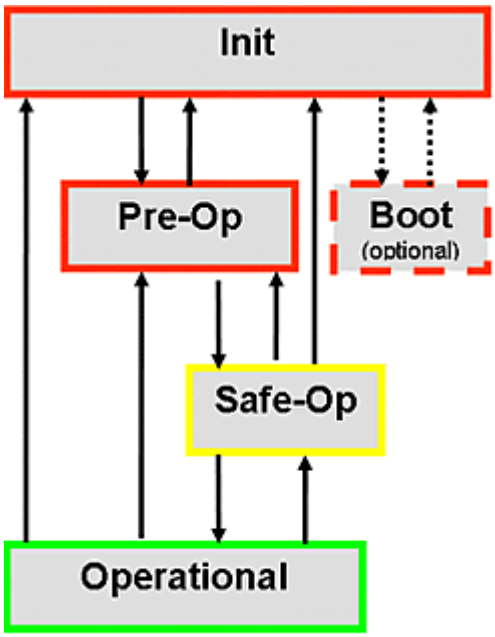


Fig. 6: EtherCAT State-machine

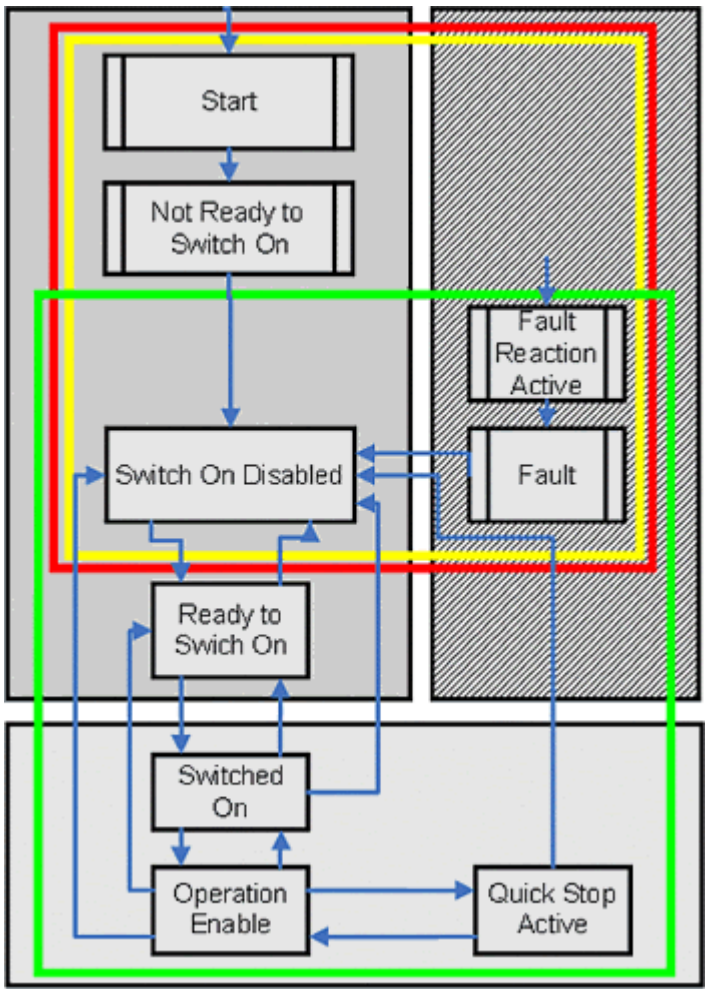
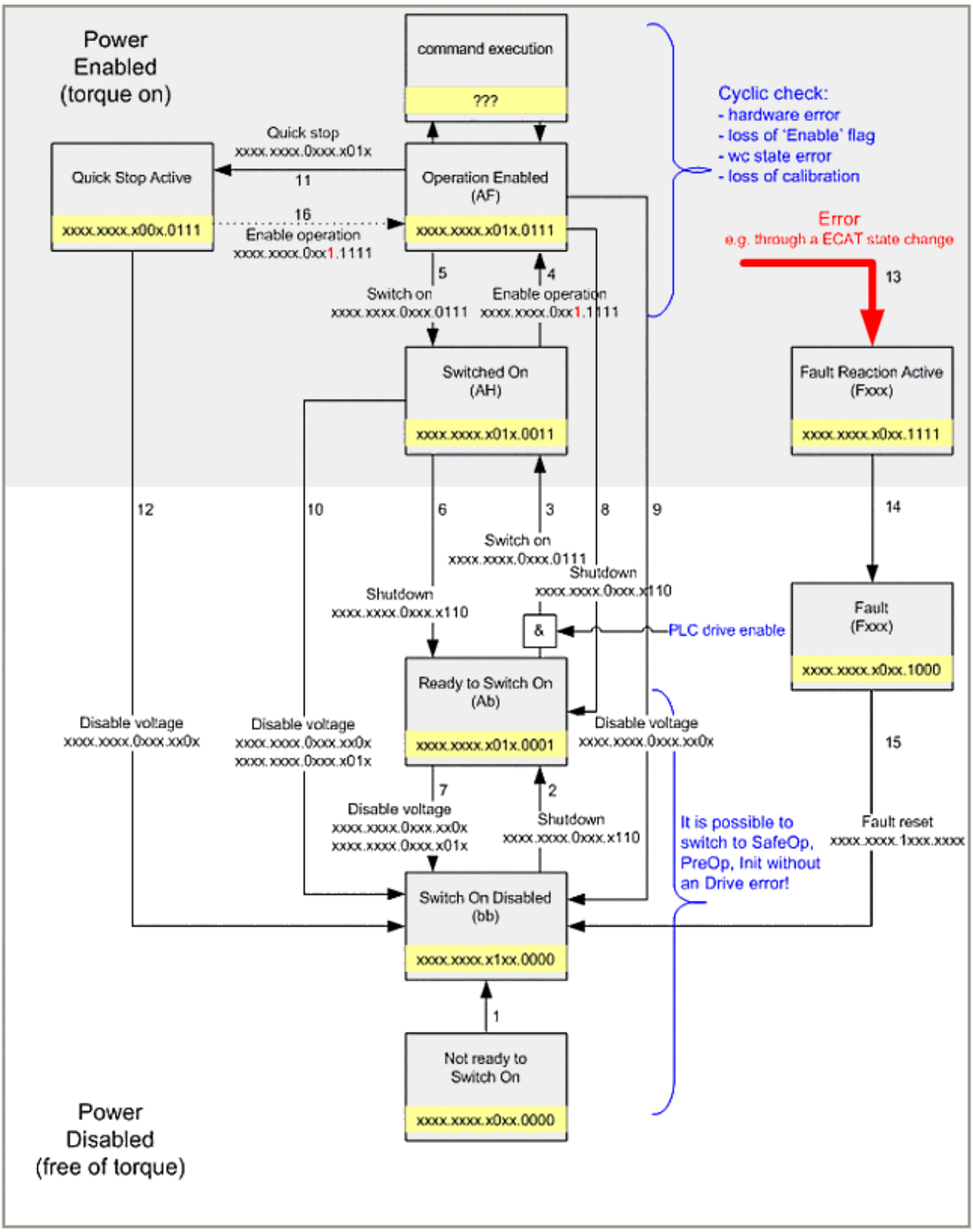


Fig. 7: Drive State-machine based on CANopen (DS402)


Power Enabled (torque on)
command execution
???
Cyclic check:
- hardware error
- loss of 'Enable' flag
- wc state error
- loss of calibration
Quick stop
xxxx.xxxx.0xxx.x01x
11
Quick Stop Active
xxxx.xxxx.x00x.0111
16
Enable operation
xxxx.xxxx.0xx1.1111
Operation Enabled
(AF)
xxxx.xxxx.x01x.0111
Error
e.g. through a ECAT state change
13
5
Switch on
xxxx.xxxx.0xxx.0111
4
Enable operation
xxxx.xxxx.0xx1.1111
Switched On
(AH)
xxxx.xxxx.x01x.0011
Fault Reaction Active
(Fxxx)
xxxx.xxxx.x0xx.1111
12
10
6
3
8
9
14
Switch on
xxxx.xxxx.0xxx.0111
Shutdown
xxxx.xxxx.0xxx.x110
Shutdown
xxxx.xxxx.0xxx.x110
&
PLC drive enable
Fault
(Fxxx)
xxxx.xxxx.x0xx.1000
Ready to Switch On
(Ab)
xxxx.xxxx.x01x.0001
Disable voltage
xxxx.xxxx.0xxx.xx0x
Disable voltage
xxxx.xxxx.0xxx.xx0x
xxxx.xxxx.0xxx.x01x
Disable voltage
xxxx.xxxx.0xxx.xx0x
15
7
2
Disable voltage
xxxx.xxxx.0xxx.xx0x
xxxx.xxxx.0xxx.x01x
Shutdown
xxxx.xxxx.0xxx.x110
It is possible to switch to SafeOp, PreOp, Init without an Drive error!
Fault reset
xxxx.xxxx.1xxx.xxxx
Switch On Disabled
(bb)
xxxx.xxxx.x1xx.0000
1
Not ready to Switch On
xxxx.xxxx.x0xx.0000
Power Disabled (free of torque)

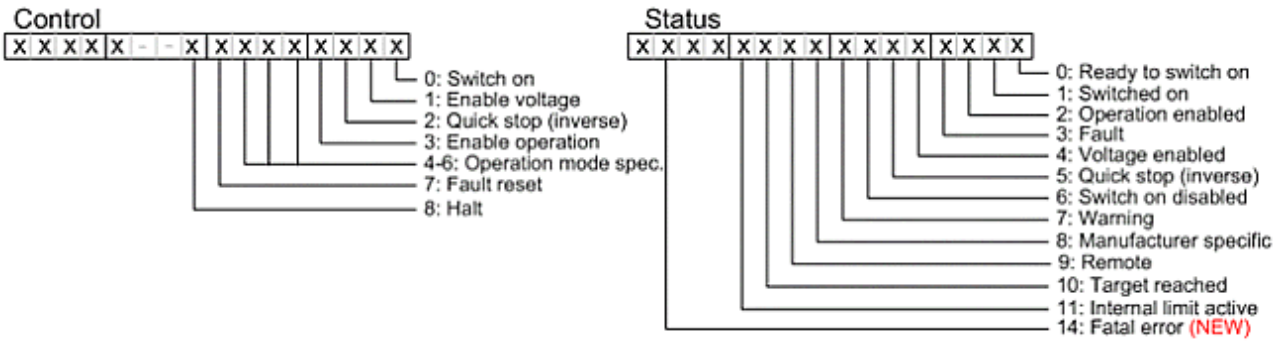


Fig. 8: Drive State-machine based on CANopen (DS402)

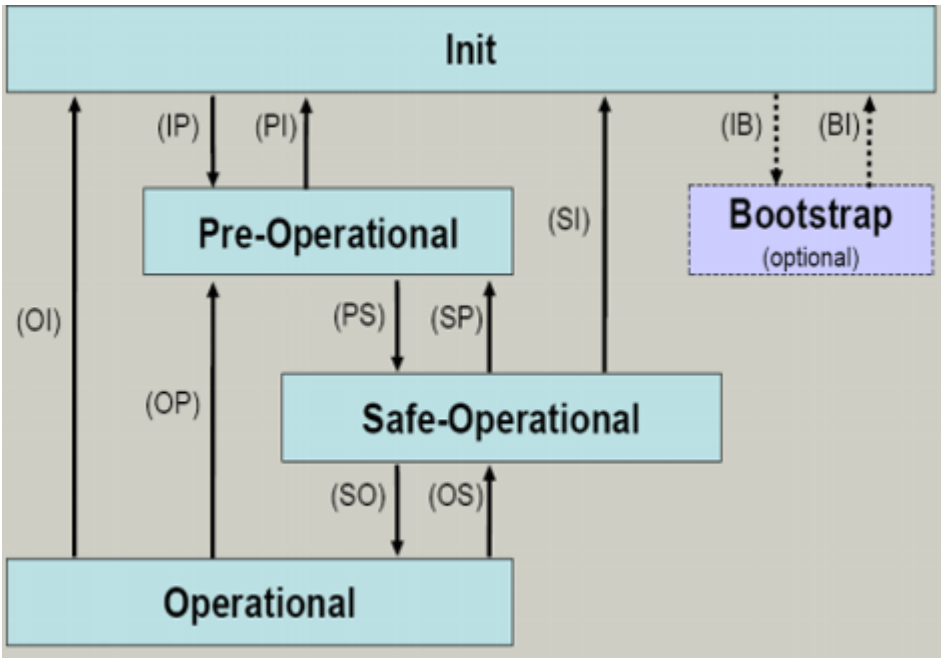
5.5 EtherCAT State Machine

The state of the EtherCAT slave is controlled via the EtherCAT State Machine (ESM). Depending upon the state, different functions are accessible or executable in the EtherCAT slave. Specific commands must be sent by the EtherCAT master to the device in each state, particularly during the bootup of the slave.

A distinction is made between the following states:

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

The regular state of each EtherCAT slave after bootup is the OP state.



Init

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

Pre-Operational (Pre-Op)

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

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

Safe-Operational (Safe-Op)

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

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

Outputs in SAFEOP state

The default set watchdog monitoring sets the outputs of the module in a safe state - depending on the settings in SAFEOP and OP - e.g., in OFF state.
If this is prevented by deactivation of the watchdog monitoring in the module, the outputs can be switched or set also in the SAFEOP state.

Operational (Op)

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

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

Boot

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

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

5.6 Adaptation of the EtherCAT State Machine

The adaptation of the states of the EtherCAT Slaves is described in the following section. The general descriptions of the states in the chapter “EtherCAT State Machine” are still valid and have merely been added to.

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

Init

No addition.

Pre-Operational (Pre-Op)

A soft reset of *non*-fatal errors is executed by the drive device.

Safe-Operational (Safe-Op)

Switch-over from *Safe-Op* to *Operational* takes place on request; synchronization takes place beforehand. In the event of a synchronization error (e.g., double MDT error) operation reverts to *Safe-Op*.

Operational (Op)

No addition.

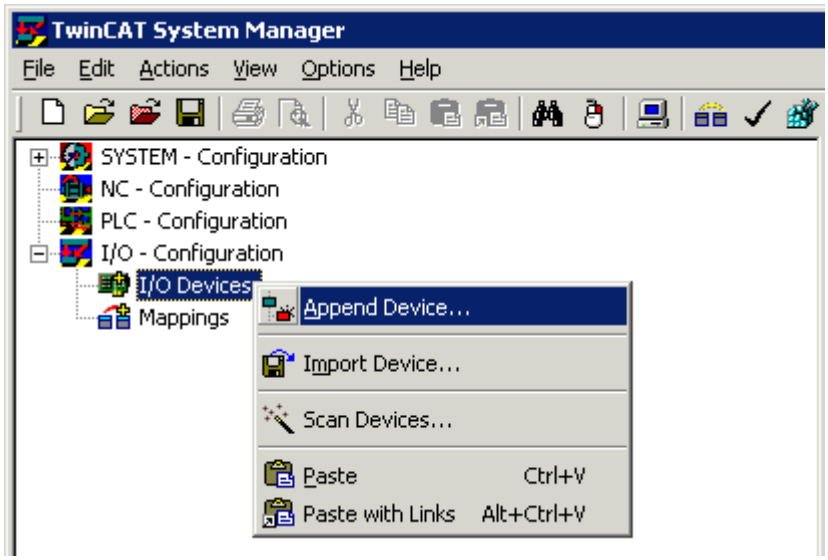
Boot

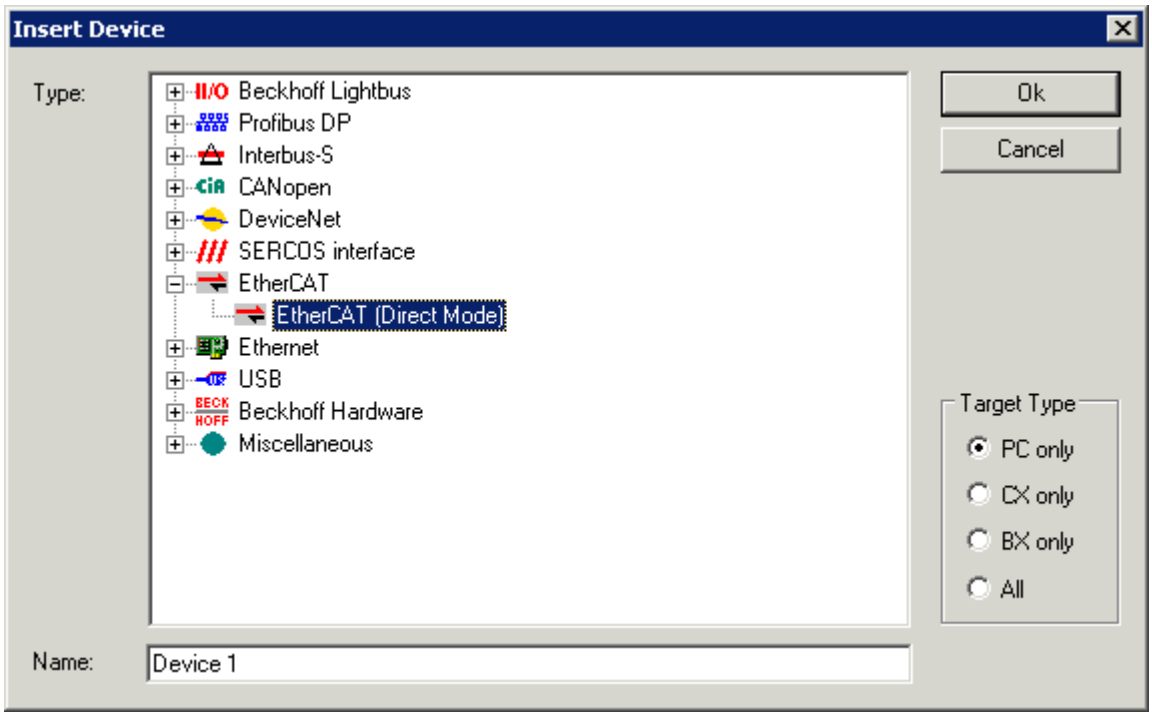
No addition.

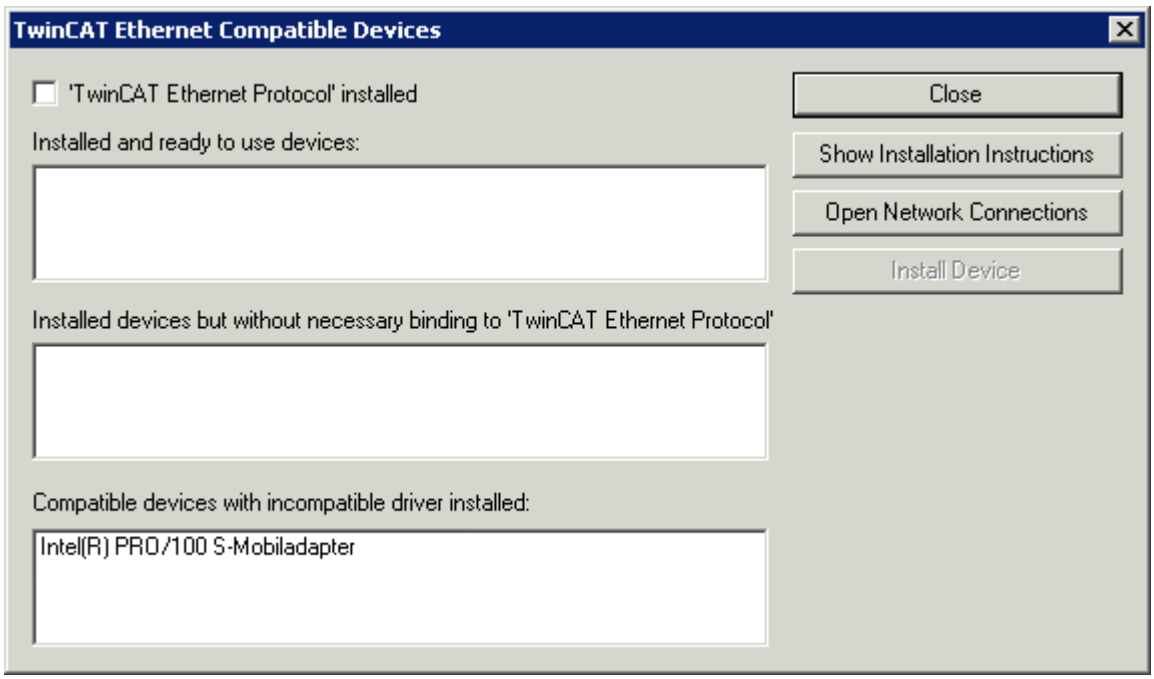
6 TwinCAT

6.1 Linking into the System Manager

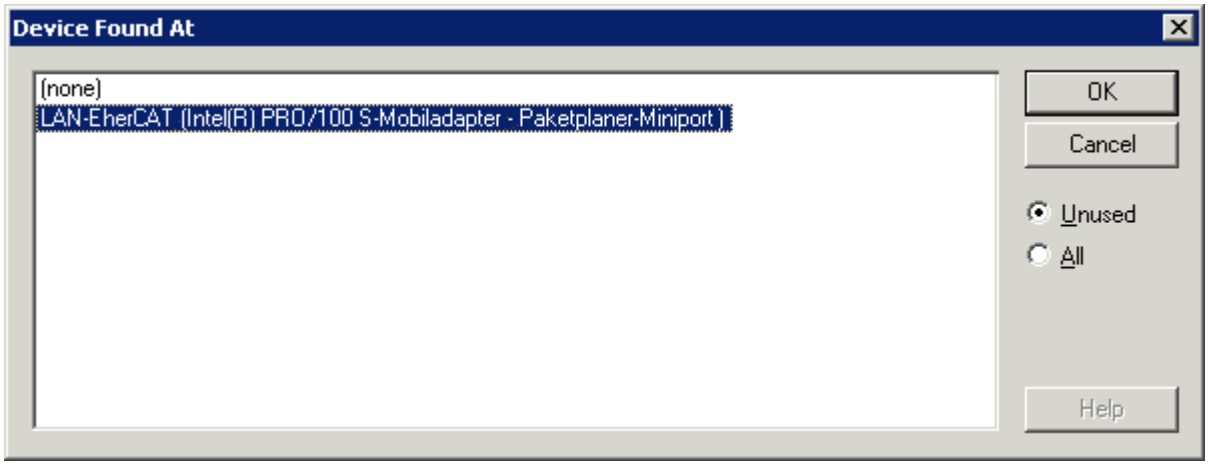
Because of the automatic mechanisms that are present, it is advisable to begin the configuration by inserting the I/O devices.







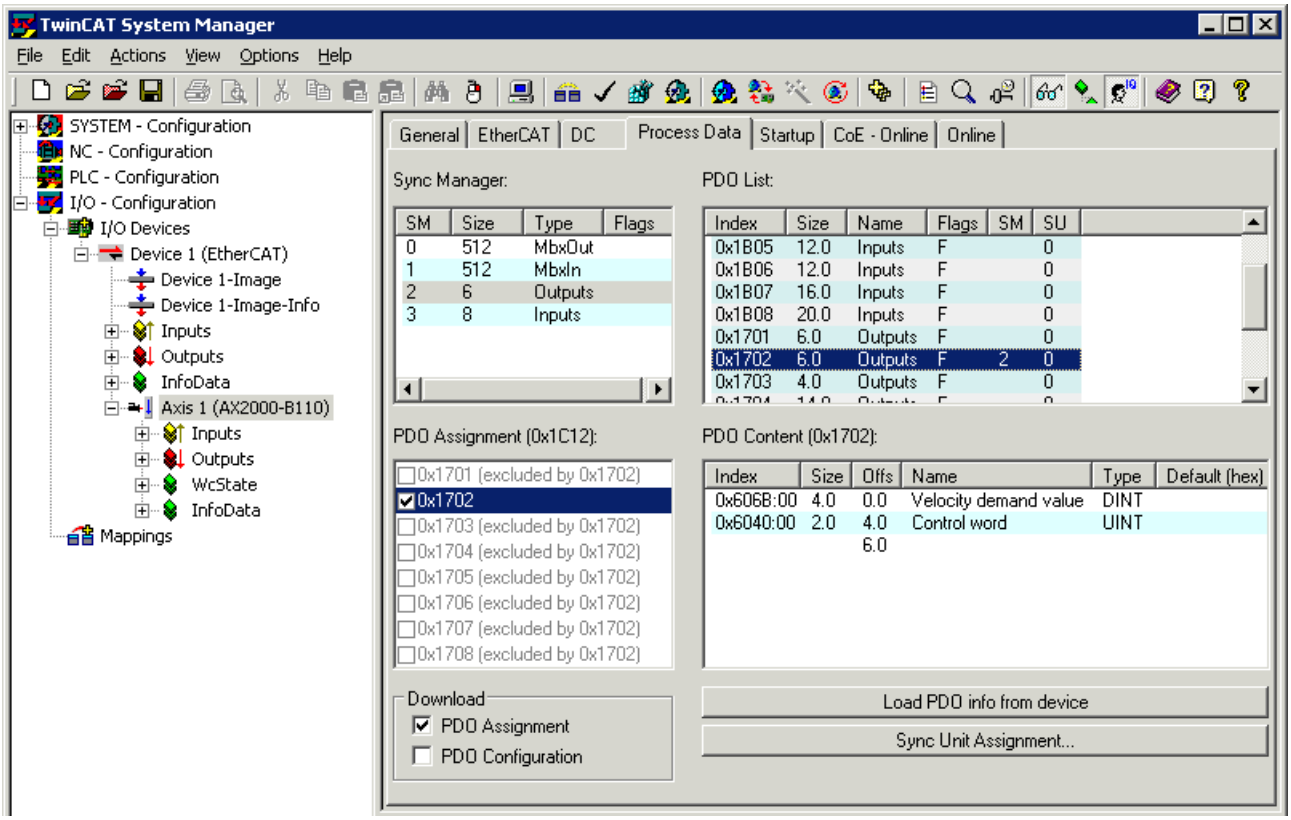
Reference to Information System -> System Manager -> Appendix C
If the master has been properly installed, it appears as a usable device.



The configuration that has been created is then switched into config mode, and a scan is made for connected boxes. Those devices that are connected are addressed by the master in accordance with their sequence in the ring. If an axis is detected, the System Manager offers the option of adding an NC axis and creating the corresponding link.

I/O level: Selecting the process image

Setpoint contents (outputs from the point of view of the master) can be selected as follows: AX2000-B110 Process Data tab under Sync Manager Outputs. The selected PDO can be seen in the PDO assignment window. A new selection is not possible until the configuration that had previously been established is deselected. Both inputs and outputs can be selected in the PDO list window. The content of the PDOs is then displayed in the PDO Content window.



In the default state, the PDO assignment is linked to object number 0x1702 (set values) and object number 0x1B03 (actual values).

Interfaces

Position interface

Address	Description	
0x1701	Position setpoint, control word (6 bytes)	DINT 32 bit position (20 bits/ rotation)
0x1B01	Actual position value, status word (6 bytes)	DINT 32 bit position (20 bits/ rotation)

Speed Interface (default mapping)

Address	Description	
0x1702	Speed setpoint, control word (6 bytes)	DINT 32 bit speed (rotation/139Inc)
0x1B01	Actual position value, status word (6 bytes)	DINT 32 bit position (20 bits/ rotation)

Torque interface

Address	Description	
0x1703	Torque setpoint, control word (4 bytes)	INT 16 bit torque setpoint (peak current -> 3280 Inc)
0x1B03	Actual position value, actual torque value, status word (8 bytes)	INT 16 bit torque setpoint (peak current -> 3280 Inc)

Position, speed, and torque interface with operating mode changeover

Address	Description	
0x1704	Position setpoint, speed setpoint, torque setpoint, operating mode request, control word (14 bytes)	Operating mode request object 0x6060

Address	Description	
0x1B04	Actual position value, actual torque value, operating mode feedback, status word (10 bytes)	Feedback of the selected operating mode 0x6061

Position and speed Interface with “Torque” extension package

Address	Description
0x1705	Position setpoint, speed setpoint, additive torque setpoint, torque limit, control word (14 bytes)
0x1B05	Actual position value, actual torque value, drive following error, status word (12 bytes)

Position and speed Interface with “Latching” extension package

Address	Description	
0x1706	Position setpoint, speed setpoint, control word, latch control word (12 bytes)	The latch control word is described in the Some important objects [▶ 34] section
0x1B06	Actual position value, status word, latch status word, latch position (12 bytes)	

Position, speed, and torque interface with operating mode changeover and with “Latching” extension package (not yet implemented!)

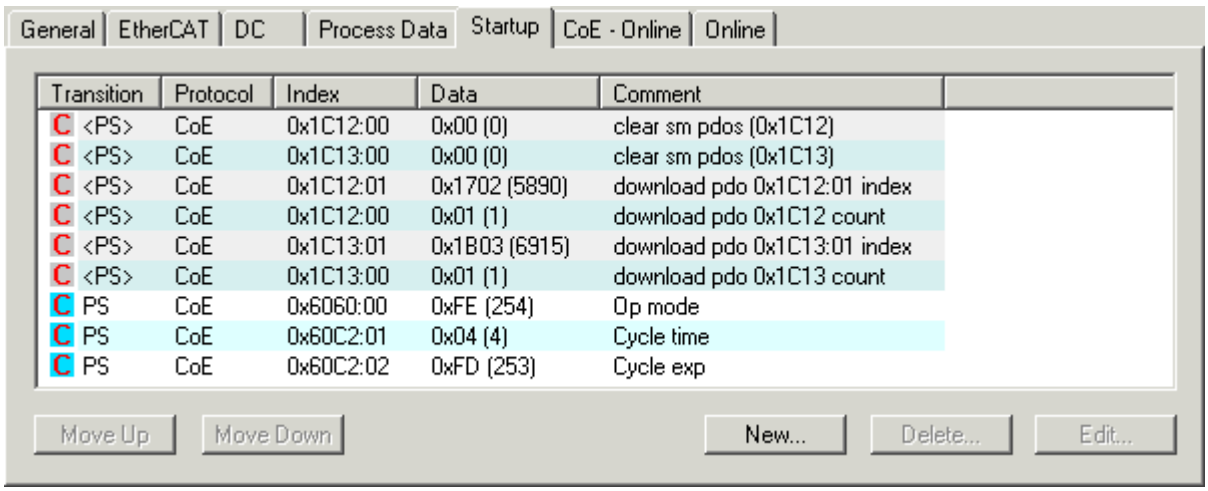
Address	Description
0x1707	Position setpoint, speed setpoint, torque setpoint, operating mode request, control word, latch control word (16 bytes)
0x1B07	Actual position value, actual torque value, operating mode feedback, status word, latch status word, latch position (16 bytes)

Position, speed, and torque interface with operating mode changeover and with the “Torque” and “Latching” extension packages

Address	Description
0x1708	Position setpoint, speed setpoint, torque setpoint, torque limit, operating mode request, control word, latch control word (18 bytes)
0x1B08	Actual position value, actual torque value, drive following error, operating mode feedback, status word, latch status word, latch position (20 bytes)

Start-up list

The user can save slave-related settings in this region of the configuration. This list is loaded into the servo drive every time there is a transition from the PREOP to the SAVEOP state.



These entries are generated by the System Manager. The first 6 entries save the process image in the Sync Manager. The seventh entry specifies the controller's operating mode:

Operation mode	Digital speed	Torque, digital	Ext. trajectory
Value	0xFE	0xFD	0xFA

The two last entries specify the cycle time. In this case it is $1*10^{-2}$ seconds.

NC level

No further settings need to be made after the inputs and outputs have been linked with the Box (AX2000-B110). The typical NC settings for the scaling factor, maximum speed, software limit switches and so forth are to be carried out according to the Information System.

6.2 Monitoring and operation

A PLC program must monitor the operating state of the drives and if necessary, put them in an error-free state, ready for operation. This state is attained if the following conditions are satisfied:

- The EtherCAT Master and all participating EtherCAT Slaves must be in the *OPERATIONAL (OP)* state.
- The drive devices must not be in an error state but must be ready for operation.

To satisfy the above-mentioned conditions, the PLC program must execute the following steps:

1. IO (fieldbus):
   Read the I/O device's hardware address associated with the NC axis.
   - Read the address of the I/O device such as NetId, Port, ChannelNo, etc. by means of FB_GetAxisAmsAddr (TcNc-Lib).
     (The data is required for EtherCAT function block).
2. IO (fieldbus):
   Check the EtherCAT communication.
   - Monitor the EtherCAT Master state by means of FB_EcGetMasterState (TcEtherCAT-Lib).
   - Monitor the EtherCAT Slave state by means of FB_EcGetSlaveState *(TcEtherCAT-Lib)*.
   - Change the EtherCAT Master state by means of FB_EcSetMasterState *(TcEtherCAT-Lib)*.
   - Change the EtherCAT Slave state by means of FB_EcSetSlaveState *(TcEtherCAT-Lib)*.
3. IO (fieldbus):
   Optional evaluation of the EtherCAT WorkingCounter
   - Evaluation of the EtherCAT WorkingCounter by additional mapping from the I/O device to the PLC (cyclic communication)
4. Drive:
   Check the drive status regarding errors, warnings, and notices (Drive State Machine)
   - Read the current drive error F01 to F32 (see ASCII command ERRCODE) by means of PDO 0x2070 (SubIndex: 0x16, Data: UINT32)
   - Read the current drive status, e.g., warnings n01 to n32 (see ASCII command STATCODE) by means of PDO 0x385E (SubIndex: 0x1, Data: UINT32)

7 Functions

7.1 Latching

The following steps must be carried out for the "flying measurement" function.

- Selection of the process image (0x1706 & 0x1B06) under the box (AX2000-B110) process data: The link is modified automatically.
- The latch function (IN1MODE 26) is activated at digital input 1 by means of the Drive Tool.
- The MC function block MC_TouchProbe is used in the PLC project (TcMC.lib)

Latch status word (2 bytes)

Bit	Value (bin)	Value (hex)	Description
0	00000000 00000001	xx01	External latch 1 valid (positive rise) through the Touch Probe block
1	00000000 00000010	xx02	External latch 1 valid (negative rise) through the Touch Probe block
2	00000000 00000100	xx04	External latch 2 valid (positive rise) - NOT IMPLEMENTED
3	00000000 00010000	xx08	External latch 2 valid (negative rise) - NOT IMPLEMENTED
4	00000000 00010000	xx10	Internal latch C valid (positive rise) through the MC_Home block
5-7	-	-	reserved
8-11	00000001 00000000	01xx	Acknowledge value external latch 1 (positive rise) through the Touch Probe block
	00000010 00000000	02xx	Acknowledge value external latch 1 (negative rise) through the Touch Probe block
	00000011 00000000	03xx	Acknowledge value external latch 2 (positive rise) - NOT IMPLEMENTED
	00000100 00000000	04xx	Acknowledge value external latch 2 (negative rise) - NOT IMPLEMENTED
	00000101 00000000	05xx	Acknowledge value internal latch C (positive rise) through the MC_Home block
12-15	00010000 00000000	1xxx	Digital input 4 *
	00100001 00000000	2xxx	Digital input 3 *
	01000001 00000000	4xxx	Digital input 2 *
	10000001 00000000	8xxx	Digital input 1 *

*) from AX2000 FW 6.68 and TwinCAT 2.10 Build 1308

Guide value, if the latch input is used for referencing: 1 % of the motor nominal speed.

Latch control word (2 bytes)

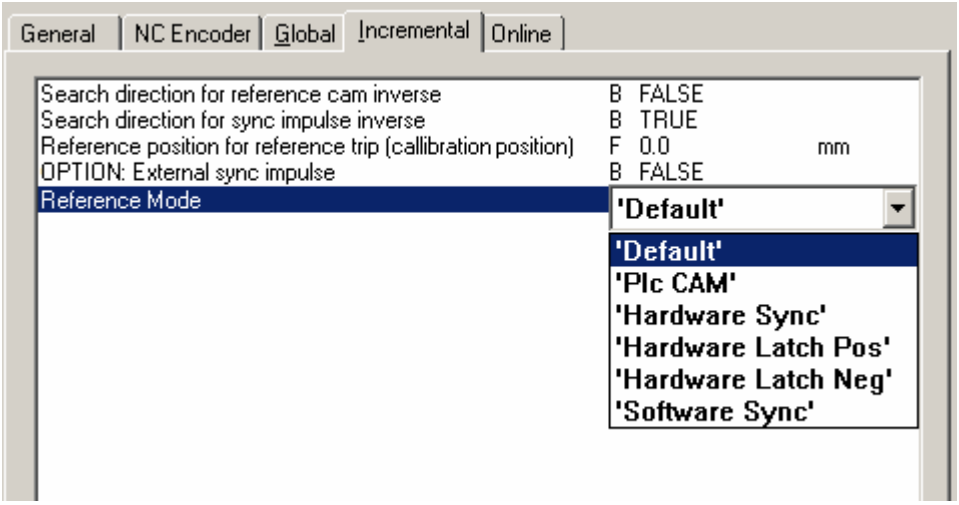
(Encoder->Outputs->nCtrl1 and Encoder->Outputs->nCtrl2):

Bit	Value (bin)	Value (hex)	Description
0	00000000 00000001	xx01	Enable external latch 1 (positive rise) through the Touch Probe block

Bit	Value (bin)	Value (hex)	Description
1	00000000 00000010	xx02	Enable external latch 1 (negative rise) through the Touch Probe block
2	00000000 00000100	xx04	Enable external latch 2 (positive rise) - NOT IMPLEMENTED
3	00000000 00001000	xx08	Enable external latch 2 (negative rise) - NOT IMPLEMENTED
4	00000000 00010000	xx10	Enable internal latch C (positive rise) through the MC_Home block
5-7	-	-	reserved
8-12	00000001 00000000	01xx	Read external latch 1 (positive rise) through the Touch Probe block
	00000010 00000000	02xx	Read external latch 1 (negative rise) through the Touch Probe block
	00000011 00000000	03xx	Read external latch 2 (positive rise) - NOT IMPLEMENTED
	00000100 00000000	04xx	Read external latch 2 (negative rise) - NOT IMPLEMENTED
	00000101 00000000	05xx	Read internal latch C (positive rise) through the MC_Home block
13-15	-	-	reserved

7.2 Hardware-oriented referencing

A choice can be made from the following reference modes in the NC when the "CANopen DS402" axis type is selected:



Type	Cam	Zero pulse
Default	Required	No zero pulse. Referencing is carried out at the negative edge of the cam.
PLC CAM	Required	No zero pulse. Referencing is carried out at the negative edge of the cam.
Hardware Sync	Required	In this procedure, the zero pulse of the measuring system is used for latching. The latched value is converted to the position in the NC. This procedure requires process image 0x1706 & 0x1B06. Suitable encoders: SinCos with a physical zero mark.
Hardware Latch Pos	Required	In this procedure, latching is carried out in response to digital input 1 (positive edge) of the controller. The latched value is converted to the position in the NC. This procedure requires process image 0x1706 & 0x1B06. Suitable encoders: Any

Type	Cam	Zero pulse
Hardware Latch Neg	Required	In this procedure, latching is carried out in response to digital input 1 (negative edge) of the controller. The latched value is converted to the position in the NC. This procedure requires process image 0x1706 & 0x1B06. Suitable encoders: Any
Software Sync	Required	In this procedure, it is assumed that an absolute single turn measuring system is being used. The zero pulse is generated in the NC when the encoder overruns. Suitable encoders: resolver, single turn.

7.3 Torque limiting

If the process requires positioning with a reduced torque, the following settings should be made.

- Selection of the process image (0x1705 & 0x1B05) under the box (AX2000-B110): The link is modified automatically.
- The parameter DILIM is set to 1 in the drive using the Drive Tool.
- In the PLC project, the variable MaxTorq from the controller's process image is limited to the maximum current. Scaling of the specification: the controller's peak current corresponds to 3280 increments.

7.4 Important objects

These can only be read acyclically (SDO)

Address	Description
1C12 (SI: 1)	"Sync Manager 2 PDO Communication Type" (Master Output, ARRAY OF UNSIGNED16)
1C13 (SI: 1)	"Sync Manager 3 PDO Communication Type" (Master Input, ARRAY OF UNSIGNED16)
1002 (SI: 0)	Current drive status ("Manufacturer Status Register", "DRVSTAT", SubIndex: 0h, UINT32) (equivalent to object 352D, SubIndex: 1h, UINT32)
385E (SI: 1)	Current drive warnings (“STATCODE”, SubIndex: 1h, UINT32) (from FW 6.68)
2070 (SI: 11)	Status of digital inputs ("Extended Status for TX-PDO 33", SubIndex: 11h, UINT32) bits 0..3: digital inputs 1..4; bit 4: "Hardware Enable"
2070 (SI: 16)	Current drive error ("ERRCODE", SubIndex: 16h, UINT32) (equivalent to object 385D, SubIndex: 1h, UINT32)
2080 (SI: 1)	Status of the digital outputs ("Input/Output/Latch", SubIndex: 1h, UINT8) bits 0..3: digital inputs 1..4; bits 4..5: digital outputs 1..2, bits 6..7: latch inputs 1..2
35D1 (SI: 1)	Internal position resolution of the Drive (e.g. 20 dec or 16 dec) ("PRBASE", SubIndex: 1h, UINT32)
35AE (SI: 1)	Write the digital output 1 ("O1", SubIndex: 1h, UINT8/UINT32), if "O1MODE" equals zero.
35B1 (SI: 1)	Write the digital output 2 ("O2", SubIndex: 1h, UINT8/UINT32), if "O2MODE" equals zero.
35EB (SI: 1)	"SAVE" saves the parameters in EEPROM (SubIndex: 1h, UINT32, value: 0).
363A (SI: 1)	"BCC" returns the checksum for the parameter region of the EEPROM (SubIndex: 1h, UINT16).
3632 (SI: 1)	"COLDSTART" causes a hardware reset in the drive (SubIndex: 1h, UINT32, value: 0).
36E4 (SI: 1)	Drive configuration for supplementary functions ("DRVCNFG2", SubIndex: 1h, UINT32)
-	"STATCODE" is not available as an SDO!

7.5 Priorities of the set values

	Description	Data type	PDO	DPR no.	NC assignment / remark
A	Position setpoint	UINT32	0x6062	1003	Drv->Out->nOutData1
B	Speed setpoint	INT32	0x606B	1007	Drv->Out->nOutData2
C	Current setpoint	INT16	0x6074	1002	Standardised to 3280 digits from DIPEAK

	Description	Data type	PDO	DPR no.	NC assignment / remark
D	Additive current setpoint	INT16	0x60F6[1]	1036	
E	Torque limit (2 ms*)	UINT16	0x6072	1039	
F	Operating mode request (2 ms*)	UINT16	0x6060	180	
G	Control word (2 ms*)	UINT16	0x6040	1000	Drv->Out->nCtrl1/nCtrl2
H	Latch control word (2 ms*)	UINT16	0x2802	1035	Enc->Out->nCtrl1/nCtrl2 (see below)

* Update times: PDO 1-5 with 2 ms, PDO 6 with 1 ms, PDO 7-8 with 4 ms

7.6 Priorities of the actual values

	Description	Data type	PDO	DPR no.	NC assignment / remark
A	Actual position value	UINT32	0x6064	200	Enc->In->nInData1
B	Actual position value 2	UINT32	0x35C9	201	Enc2->In->nInData1
C	Actual current value	INT16	0x6077	88	Standardised to 3280 digits from DIPEAK
D	Drive following error	INT32	0x60F4	197	Drv->In->nInData1
E	Operating mode (2 ms*)	UINT16	0x6061	1038	
F	Status word (2 ms*)	UINT16	0x6041	1004	Drv->In->nStatus1/nStatus2
G	Latch status word (2 ms*)	UINT16	0x2901	1037	Enc->In->nStatus1/nStatus2
H	Latch value (2 ms*)	UINT32	0x2902	1022	Enc->In->nInData2 (see below)
I	WorkingCounter (WcState)	BOOL			Drv/Enc->In->nStatus4

(*) Update times: PDO 1-5 with 2 ms, PDO 6 with 1 ms, PDO 7-8 with 4 ms

7.7 Recommended cycle times

(Depending on operating mode - runtime optimization)

The minimum cycle time depends heavily on the drive configuration (second encoder, latching). If possible, the following settings should be made to reduce the loading on the servo drive:

- The drive's analog output values should be deactivated wherever possible (ANOUT1=0, ANOUT2=0, ANCNFG=-1).
- If possible, the following parameters should be set to zero: (IN1MODE to IN4MODE, O1MODE, O2MODE, SWCNFG, POSCNFG, WPOS).

Interface	Recommended cycle time	Minimum cycle time
Position	2 ms (= 2000 µs)	1 ms
Speed	1 ms (= 1000 µs)	0.5 ms
Torque	0.5 ms (= 500 µs)	0.5 ms

8 Appendix

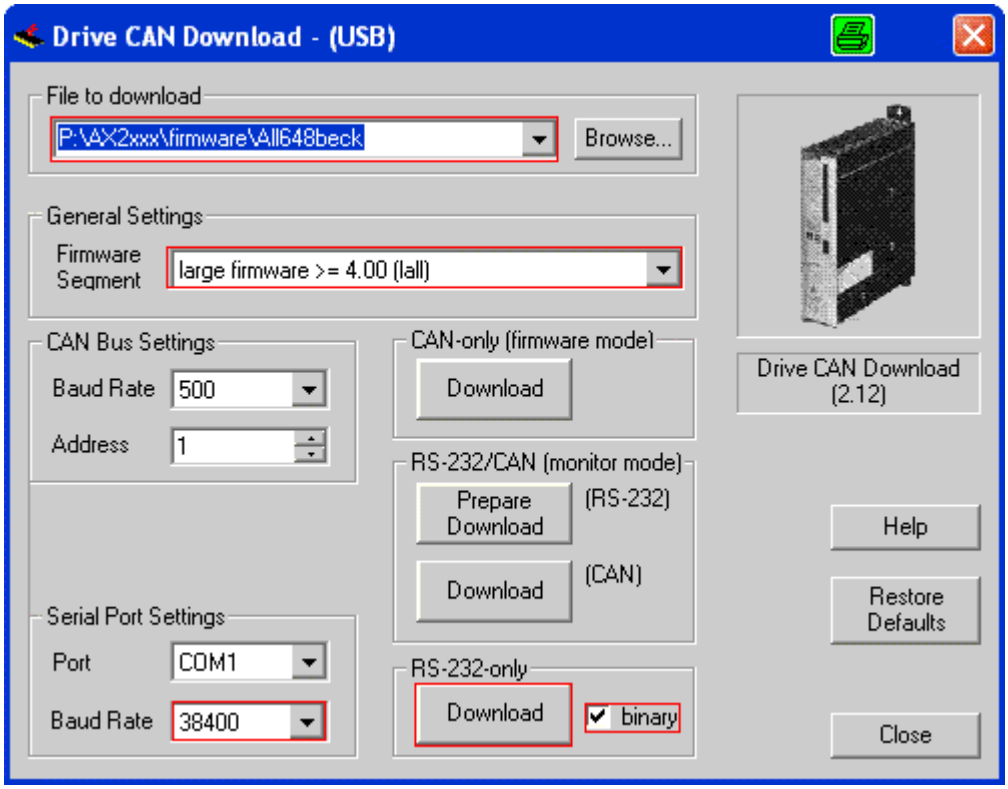
8.1 Firmware Update

NOTICE

The supply voltage must not be interrupted during a firmware update!

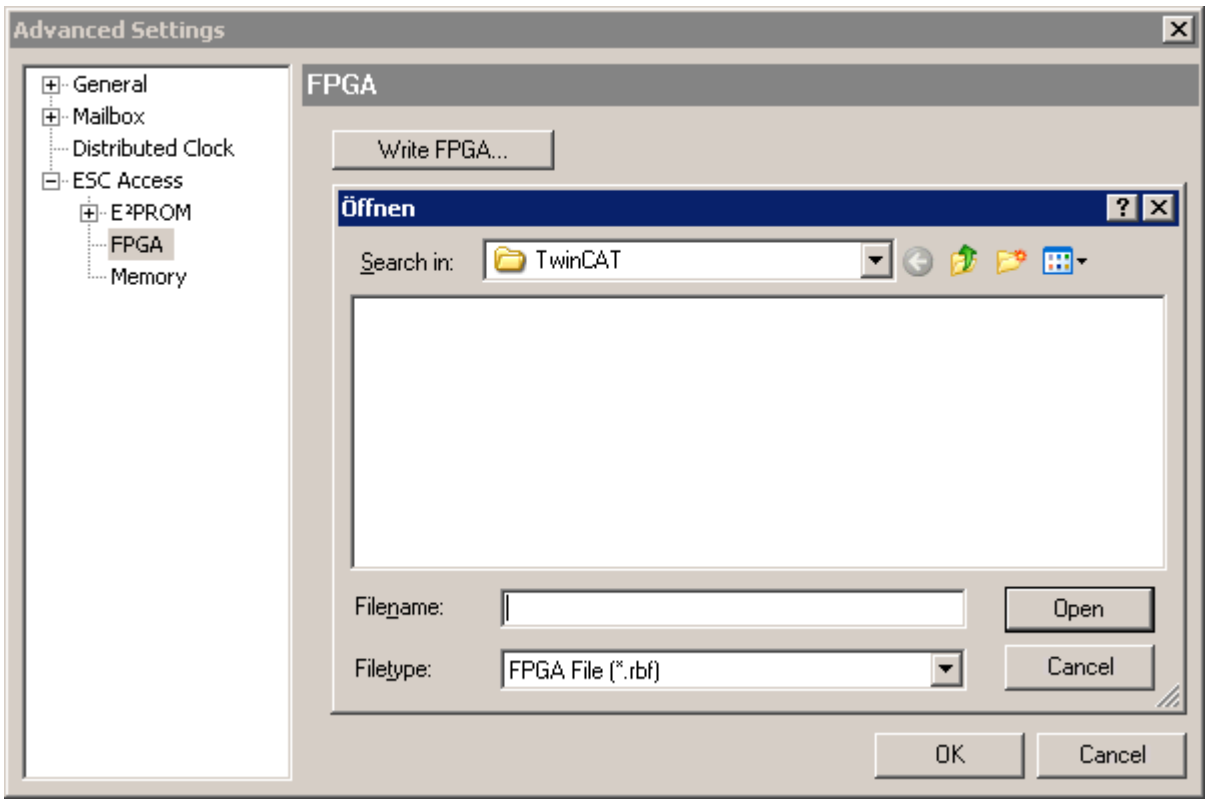
AX2000 Firmware

The firmware of the AX2000 can be updated with the Drive CAN Download Tool as follows:



AX2090-B110 Interface

For future updates, new firmware can be loaded as follows:



8.2 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.

Download finder

Our download finder contains all the files that we offer you for downloading. You will find application reports, technical documentation, technical drawings, configuration files and much more.

The downloads are available in various formats.

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 our internet page: 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
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

Hotline:	+49 5246 963-460
e-mail:	service@beckhoff.com

Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone:	+49 5246 963-0
e-mail:	info@beckhoff.com
web:	www.beckhoff.com

More Information:
www.beckhoff.com/en-en/products/motion/

Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany
Phone: +49 5246 9630
info@beckhoff.com
www.beckhoff.com