Documentation

EL6688

IEEE 1588 PTP External Synchronization Interface

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BECKHOFF

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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, DE102004044764, DE102007017835 with corresponding applications or registrations in various other countries.

The TwinCAT Technology is covered, including but not limited to the following patent applications and patents: EP0851348, US6167425 with corresponding applications or registrations in various other countries.

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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
2.3	- Chapter "Commissioning" updated - Update revision status - Update structure
2.2	- Chapter "EL6688 – Technical data" updated - Update revision status - Update structure
2.1	- Chapter "LEDs and connection" updated - Update revision status
2.0	- Migration - Chapter "Notes to Commissioning" updated
1.5	- Chapter "Basics IEEE1588" updated
1.4	- Chapter "Commissioning" updated
1.3	- Technical notes added
1.2	- Technical notes added
1.1	- Technical notes added
1.0	- Minor corrections, 1st public issue
0.3	- Addenda
0.1	- Provisional documentation for EL6688

1.4 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. 1: EL5021 EL terminal, standard IP20 IO device with serial/ batch number and revision ID (since 2014/01)

Fig. 2: EK1100 EtherCAT coupler, standard IP20 IO device with serial/ batch number

Fig. 3: CU2016 switch with serial/ batch number

Fig. 4: EL3202-0020 with serial/ batch number 26131006 and unique ID-number 204418

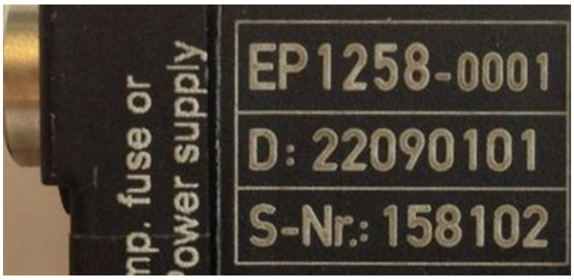


Fig. 5: EP1258-00001 IP67 EtherCAT Box with batch number/ date code 22090101 and unique serial number 158102

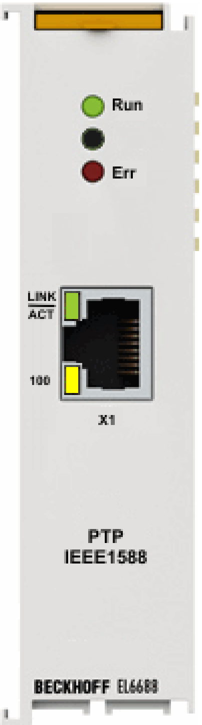
Fig. 6: EP1908-0002 IP67 EtherCAT Safety Box with batch number/ date code 071201FF and unique serial number 00346070

Fig. 7: EL2904 IP20 safety terminal with batch number/ date code 50110302 and unique serial number 00331701

Fig. 8: ELM3604-0002 terminal with unique ID number (QR code) 100001051 and serial/ batch number 44160201

2 Product overview

2.1 EL6688 - Introduction



IEEE 1588 external synchronization interface

The EL6688 EtherCAT Terminal is a device in the IEEE-1588 synchronization system that supports the Ethernet-based precision time protocols PTPv1 (IEEE 1588-2002) and PTPv2 (IEEE 1588-2008).

On the one hand the EL6688 is an IEEE-1588 clock (master or slave) that is synchronized based on the protocol precision. On the other hand it is synchronized as an EtherCAT Terminal by the distributed clock system.

The following operating modes can be selected via the TwinCAT System Manager: "SlaveOnly", "MasterOnly" and "Best Master Clock" for the PTP side. In this way a consistent timebase can be created across applications for any number of spatially separated EtherCAT systems and machine sections, e.g. for application with axes or measurement technology. The compact EtherCAT Terminal enables flexible deployment depending on the application requirements.

2.2 EL6688 - Technical data

Prerequisites

Technical data	EL6688
Supported TwinCAT version	from 2.11
IEEE1588 physics	Ethernet (IEEE 802.3), 10/100 Mbit/s
IEEE1588 operating modes	PTPv1 Master/Slave, PTPv2 Master/Slave
Number of Ethernet ports	1
Ethernet interface	10BASE-T/100BASE-TX Ethernet with 1 x RJ45 10/100 Mbit/s, IEEE 802.3u Auto negotiation, half or full duplex at 10 and 100 Mbit/s possible, automatic settings
Cable length	up to 100 m acc. EN50173
Diagnosis	Status LEDs
Power supply	via the E-bus
Current consumption via E-bus	typ. 310 mA
Electrical isolation	500 V (E-Bus/Ethernet)
Configuration	TwinCAT System Manager/CAN-over-EtherCAT (CoE)
Weight	approx. 75 g
permissible ambient temperature range during operation	0°C ... + 55°C
permissible ambient temperature range during storage	-25°C ... + 85°C
permissible relative humidity	95 %, no condensation
Dimensions (W x H x D)	approx. 26 mm x 100 mm x 52 mm (width aligned: 23 mm)
Mounting [▶ 32]	on 35 mm mounting rail conforms to EN 50022
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	IP 20
Installation position	variable
Approval	CE ATEX [▶ 38] UL [▶ 39]

2.3 Basics IEEE1588

Definition

The PTP (Precision Time Protocol) defined in IEEE1588 is a protocol standard for synchronization of distributed clocks in networks. Each PTP clock cyclically runs the “Best Master Clock Algorithm” (BMCA) to determine the clock with the best precision. The clock with the best precision is referred to as grandmaster and is used as synchronization source for all other PTP clocks in the network. Current 2 standards are defined, PTPv1 and PTPv2. The PTP can be based on Ethernet as transport medium, for example.

If PTP devices are not directly connected and Ethernet traffic takes place via switches/routers instead, it is highly advisable to use PTP-capable switches/routers. If a switch supports PTP, it behaves like a slave clock vis-à-vis a connected master clock, i.e. it is synchronized by the master clock. Vis-à-vis other connected slave clocks it behaves like a master clock. The switch becomes a PTPv1/v2 boundary clock.

In addition, PTPv2 offers a transparent clock option, in which case each switch enters a time correction value in a correction field in the PTP telegram. This enables downstream slaves to calculate the influence of the switch on the transmission link.

Different implementation types are available in the switch/router:

- No PTP support in the switch/router: This is likely to result in extremely reduced synchronization precision [ms range], and the application of such switches should therefore be avoided. Load-dependent instability in the control characteristics may occur.
- Software-based PTP support in the switch: This is likely to result in significantly reduced synchronization precision [ms range], and we would therefore advise against using this type of switch.
- Hardware-based PTP support in the switch: The application of this type of switch is recommended.

The architectural differences between the two stages are as follows:

- **IEEE-1588-2002 V1**
  V1 was developed in principle for testing & measurement and industrial automation. The Multicast protocol is conceived for LAN use and achieves better accuracy than NTP.
  From a technical point of view higher-priced boundary clocks have to be used with V1 in order to achieve optimum results. The use of V1 is less widespread in practice.
- **IEEE-1588-2008 V2**
  V2 is an improvement on V1. It is only possible to use either V1 or V2 in a network. V2 was extended by many features, for which reason it has been well accepted by the market. The selection of devices on the market is greater than for V1. From a technical point of view simpler switches with the clock type “Transparent clock” can be used with V2.

V1 and V2 barely differ in terms of the theoretically attainable accuracy; an accuracy of < 1 µs is attainable with both versions in the ideal case, i.e. with an optimum infrastructure. The maximally attainable accuracy depends alone on the type of time stamping that can be implemented in hardware or software.

Functioning

Time determination, 2-step procedure

A basic function in all PTP protocols is the option of allocating exact timestamps for sending and receiving of Ethernet telegrams in the Ethernet hardware. This enables the delay times between the grandmaster and the slaves to be calculated.

1. At time t_1 the grandmaster sends a *SyncMessage* containing the estimated send time to the slaves. It arrives at the slave at time t_2.
2. Shortly afterwards the grandmaster sends a *FollowUp* containing the actual send time t_1 of the previous telegram.
3. This process is cyclically repeated at the *SyncInterval*, e.g. every 2 seconds. Defined/supported Sync Intervals are 1 s, 2 s, 4 s, 8 s, 16 s, 32 s (PTPv1) and 0.5 s, 1 s, 2 s, 4 s (PTPv2).

At longer intervals the slave examines the return path:

1. The slave sends a *DelayRequest* to the master, which receives it at time t_4.
2. It responds with a *DelayResponse* message containing the time of arrival t_4.

This can be used to calculate the latency periods on both sides and correct any drift.

In Fig. "PTPv1 traffic in 2-step mode" the grandmaster "192.168.200.2" triggers a *Sync* every 2 seconds. The slave "192.168.200.1" responds with a *DelayRequest* every 8 seconds.

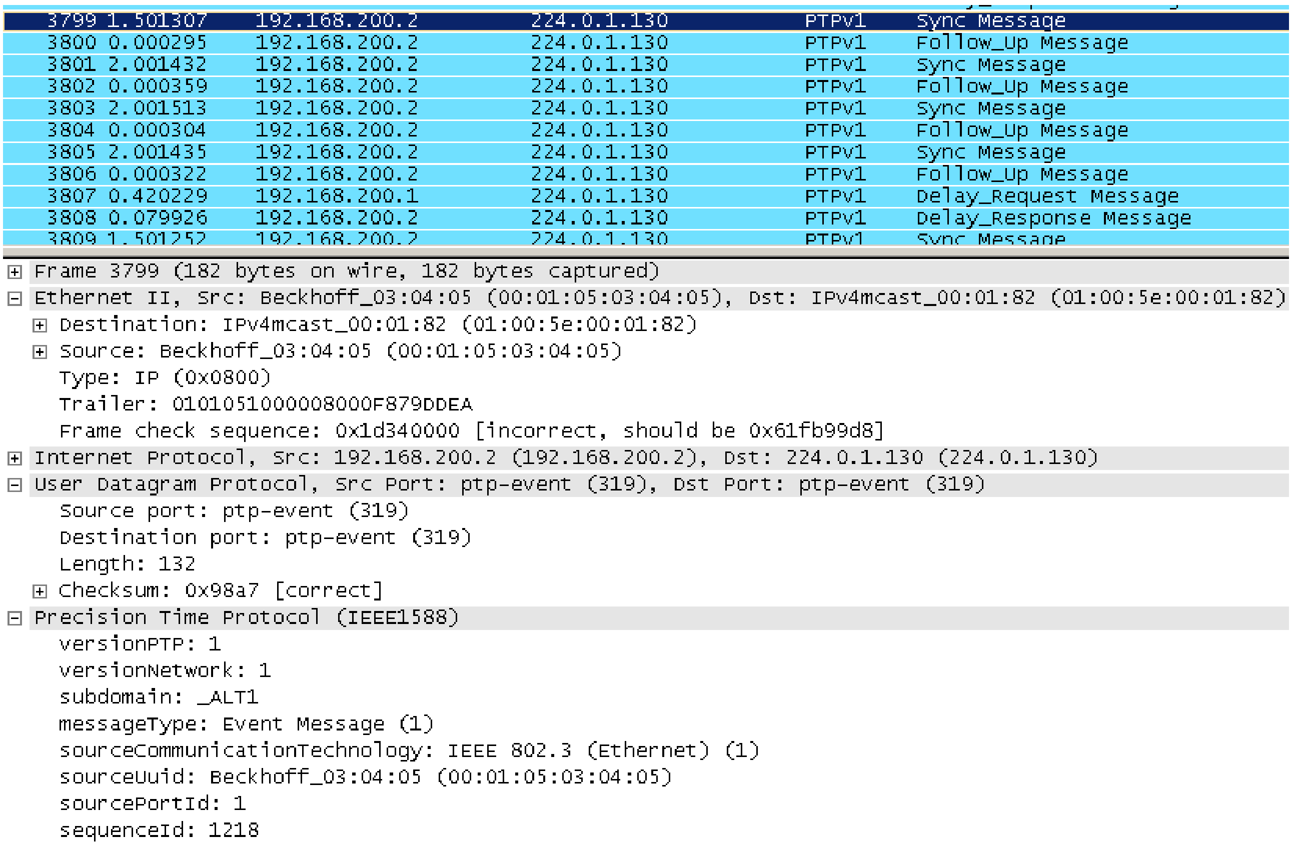


Fig. 9: PTPv1 traffic in 2-step mode

Routing

The telegrams are usually routed via IP/UDP through multicast via ports 319 (event messages: SyncMsg, DeleyReq) and 320 (general messages: FollowUp, Announce, DelayResp, Management). These ports should be prioritized, if possible.

4 multicast domains are defined, so that up to 4 independent time networks can be established within a network:

- _DFLT: 224.0.1.129
- _ALT1: 224.0.1.130
- _ALT2: 224.0.1.131
- _ALT3: 224.0.1.132

The domains in the grandmaster and slave clocks must match. A dedicated IP address for the slave is only required if the PTP master requires this.

Terminology

Stratum: measure for the quality of a clock. Stratum-1 is the highest level.

Grandmaster Clock selection

A balanced PTP system according to IEEE1588 only has a single time source, the Grandmaster Clock. Each PTP clock can start off as a Master or Slave Clock. A PTP clock uses different criteria (Stratum, Preferred flag) to indicate the quality of the time it supplies, depending on whether it is based on GPS, quartz, atomic clock or similar, for example. If more than one PTP clock exists in a network, the PTP clocks select the best clock within the network as timer (Grandmaster Clock), based on the standardized BMCA, which should be integrated in the same way in all PTP clocks. The remaining clocks switch to the passive mode, as long as the selected Grandmaster Clock sends out Sync messages.
Through its parameters a PTP clock can enforce Grandmaster Clock status within a network (by setting its

parameter optimally) or Slave Clock status (by setting its parameter in the worst possible way).
All devices automatically run the BMCA in each cycle (generally every few seconds). This ensures that the system can respond to changes in topology and always selects the best Grandmaster Clock.

Infrastructure

If more than 2 directly connected PTP clocks are used, FastEthernet switches have to be used for 100 Mbit. Since the synchronization mechanism takes into account the signal run times for compensation of network delays, irregular latency periods along the signal route have a negative effect on the synchronization precision.

Normal switches based on the store and forward concept are therefore not very suitable. The synchronization precision of special IEEE1588 switches with "boundary clocks" depends on the protocol.

PTPv1

The boundary clock switches appear as Slave Clocks relative to the Grandmaster Clock, although at their outgoing ports they appear as Grandmaster Clock relative to the connected slaves. The switches insert their own send time into the telegram and therefore act as "transparent clocks".

PTPv2

PTPv2 has a further clock type in addition to boundary clocks, the transparent clock. Transparent clock switches insert their own cycle time into the telegram. (Cycle times are added up in a CorrectionField). Transparent clocks are invisible for other PTP clocks.

PTPv1 vs. PTPv2

- PTPv1:
  - PTPv1 according to IEEE 1588-2002
  - PTPv1 via UDP (ISO/OSI layer 3, Ethertype: UDP x0800)
  - shortest Sync (synchronization) interval: 1 second
  - compensation of network delays (assumption: the path and return path are time-symmetric)
- PTPv2:
  - PTPv2 according to IEEE 1588-2008
  - PTPv2 via UDP (ISO/OSI layer 3, Ethertype: UDP x0800) or via Ethernet (layer 2, Ethertype x88F7)
  - shorter Sync intervals: e.g. 500 ms
  - CorrectionField: each switch component can use this field for adding up its cycle time for analysis by the slaves
  - compensation of network delays (assumption: path and return patch time-asymmetric --> more realistic)
  - “transparent” switches, “transparent clocks”: insert their own send time into the telegram when forwarding Sync telegrams

PTP modes

1. “SlaveOnly”:
The terminal is permanently configured as synchronization slave through lower settings and cannot become grandmaster.
The BMCA is run cyclically to determine the best available synchronization source in the network.

2. “Grandmaster”:
The terminal is configured as grandmaster through high settings and is available as synchronization source for other clocks in the network. The BMCA is also run in this mode, although it is only used to check whether another grandmaster with higher quality is available. If this is the case, terminal switches to passive mode.

3. “Best Master Clock”:
The terminal can act as master clock or slave clock.
The BMCA is run cyclically to determine the best available clock.
If no better clock is found, the terminal becomes grandmaster.

3 Basics communication

3.1 EtherCAT basics

Please refer to the chapter EtherCAT System Documentation for the EtherCAT fieldbus basics.

3.2 Internal and external EtherCAT synchronization

In a machine control with distributed components (I/O, drives, several masters) it may be useful for the components to operate with a close time link to each other. The components must therefore have a local “time”, to which the component (e.g. an I/O terminal) has access at all times.

Associated requirements may include:

1. several outputs in a control system have to be set simultaneously, irrespective of when the respective station receives the output data

2. drives/axes in a control system must read their axis positions synchronized, irrespective of the topology or cycle time

Both requirements necessitate a synchronization mechanism between the local times of the components of a control system.

3. if inputs affect the control system, the (absolute) time must be recorded. This can be helpful for subsequent analysis, if such an analysis is required for determining the sequence of events in functional chains.
This means that time running in the components must be coupled to a globally valid time, e.g. Greenwich world time or a network clock.

4. tasks on different controllers should run synchronous and without phase shift.

The terms “close temporal reference” or “simultaneous” can be interpreted depending on requirements: for a “simultaneity” in the 10 ms range a serial communication structure may be adequate, while in other ranges 100 ns or less are required.

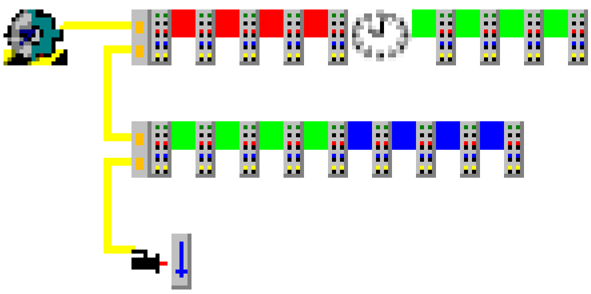


Fig. 10: Simple I/O topology

Fig. "Simple I/O topology" shows a simple EtherCAT topology consisting of a master, several I/Os and an axis. A local time is to be applied in different components. The tasks:

- synchronization of local clocks
- coupling to a higher-level reference time
- task synchronization

are discussed below.

Requirement 1 + 2: synchronization

In an EtherCAT system the distributed clocks concept (DC) is used for synchronization of local clocks in the EtherCAT components. Further information can be found in the separate documentation.

Synchronization of local EtherCAT devices

General:

- 1 ns time resolution corresponds to 1 digit, scope of 64 bits corresponds to approx. 584 years
- the EtherCAT master must keep the distributed clocks synchronous within the system accuracy (EtherCAT: <100 ns) using synchronization datagrams.
- not all EtherCAT devices have to support this feature. If a slave does not support this concept, the master will not include it in the synchronization. If the EtherCAT master does not support this feature, DC is also ineffective in all slaves.
- such a clock also runs in the EtherCAT master, in this case software-based.
- in the system *one* of the existing clocks is selected as reference clock and used for synchronizing all other clocks. This reference clock is usually one of the EtherCAT slave clocks, not the EtherCAT master clock. The clock of the first EtherCAT slave in the topology that supports distributed clocks is usually automatically selected as reference clock.
- a distinction is made between
  - the EtherCAT master (the software that “manages” the EtherCAT slaves with Ethernet frames) and the EtherCAT slaves managed by it
  - the reference clock, which is usually located in the first DC slave, and the slave clocks whose time is based on it, including the clock in the EtherCAT master

Master:

- during the system start phase the EtherCAT master must set the local time of the reference clock and the other slave clocks to the current time and subsequently minimize deviations between the clocks through cyclic synchronization datagrams
- in the event of topology changes the EtherCAT master must re-synchronize the clocks accordingly
- not all EtherCAT masters support this procedure
- the EtherCAT master in the Beckhoff TwinCAT automation suite fully supports distributed clocks.

Slave:

- due to the high precision required this local clock is implemented in hardware (ASIC, FPGA)
- distributed clocks are managed in the EtherCAT slave controller (ESC) in registers x0900 - x09FF. Specifically, the local synchronized time runs in the 8 byte from x0910.

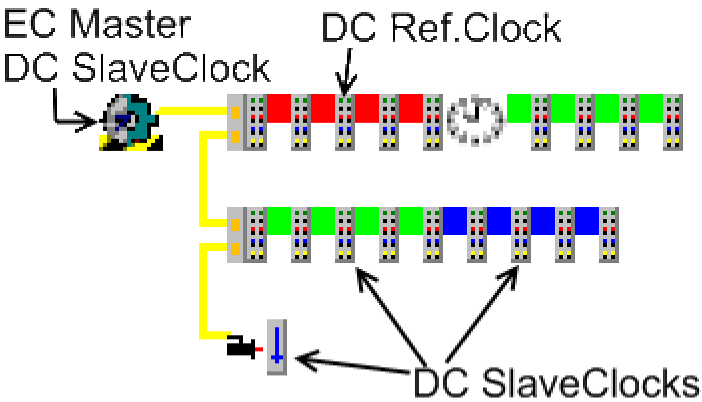


Fig. 11: Mapping of DC to the topology

In Fig. "Mapping of DC to the topology" the 3rd EtherCAT slave was selected as DC reference clock as an example. The local time of this slave is now used to adjust all other distributed clocks, i.e. all other EtherCAT slaves and the clock of the EtherCAT master. This is achieved through synchronization datagrams, which the EtherCAT master sends cyclically.

This procedure ensures that all devices supporting DC always have local access to a time that is identical (within the DC synchronization precision) in all devices.

The system now operates based on the timebase of the selected DC reference clock and its local clock generator/quartz with T_{DC}. Due to production tolerances this timebase is rarely the same as the official sidereal time/coordinated world time UTC T_{UTC} or another reference time. This means that 1 ms_{UTC} is never exactly 1 $ms_{DC,}$ $T_{DC} \neq T_{UTC}$. Over longer periods also drift processes may also change the ratio. As long as DC is used for relative processes within the EtherCAT system, the deviation from the UTC is irrelevant. However, if the DC time is to be used for data logging with a global timebase, for example, the $_{DC}$ timebase must be synchronized with the $_{UTC}$ timebase. This is described in section Requirement 3.

Requirement 3: higher-level global time, absolute time

If the timebase T_{DC} is to be adjusted based on a higher-level timebase, the timebase and the associated procedure must be selected. Generally common synchronization protocols are used for the synchronization. Examples for time sources and synchronization procedures are listed below.

- Sources: UTC world time, network time, adjacent control system, radio clocks (in Central Europe: DCF77)
- Procedures: GPS, radio clocks, NTP (NetworkTimeProtocol), SNTP (Simple NTP), PTP (IEEE1588), distributed clocks DC

The following synchronization precisions can be achieved (depending on the hardware)

- NTP/SNTP: ms range
- PTP: < 1 µs
- DC: < 100 ns

The following two control aims must be achieved:

- The frequency of the subordinate timebase must be adjusted to the higher-level timebase
- Any offset between two absolute times does not have necessarily to be controlled to 0. It is sufficient for it to be announced and kept constant. The maximum offset adjustment is ±½ cycle time.

External EtherCAT synchronization

External synchronization sources (e.g. EL6688, EL6692) can only be used from TwinCAT 2.11 used. In older versions of TwinCAT such EtherCAT slaves have no meaningful function.

If a higher-level master clock is integrated in an EtherCAT system, a special EtherCAT device is generally used for the physical connection. The device monitors both timebases and is therefore able to determine the time difference.

Please refer to www.beckhoff.de for suitable products currently available for this purpose.

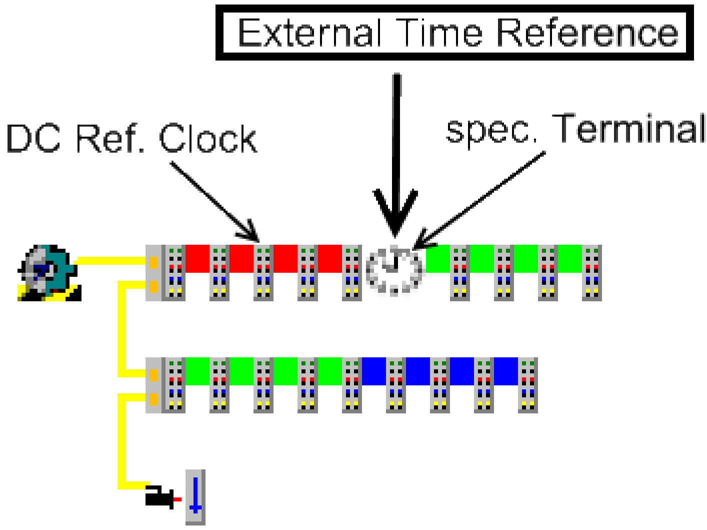


Fig. 12: EtherCAT topology with external reference clock:

The different timebases can be arranged hierarchically, so that at the start of the respective system the current absolute time is taken from the subordinate system. If necessary top-down synchronization is used, if external timebases or DC components are present in the system.

Readjustment of local time vs. higher-level absolute time

For the purpose of synchronization the local DC time is not adjusted based on the higher-level absolute time, but only to a constant offset. This offset is made available to the user as a process data. The offset is corrected by ±½ cycle time to ensure both tasks run in phase.

- When TwinCAT starts the EtherCAT master, the local DC system in the slaves is started and synchronized immediately.
- However, an external reference slave such as EL6688 (IEEE1588 PTP) takes a few seconds before it can supply a reference time that is synchronized with the higher-level clock.
- As soon as the external reference time is available, the offset to the local time is calculated and corrected by ±½ cycle time to ensure that both tasks run in phase, and the EtherCAT master Info Data are made available to the user for reconciliation with the local time values.
- From this time the offset is kept constant, depending on the selected control direction.

TwinCAT system behavior

External reference clock outage

If the external reference clock signal fails, both timebases will naturally drift apart again. Once the signal is available again, the system will once again be controlled based on the previous offset values.

TwinCAT can start without external clock signal. In this case the offset is calculated and maintained as described above, as soon as a stable external reference clock signal is received.

Settings in TwinCAT 2.11

External synchronization via EtherCAT is supported from TwinCAT 2.11. The synchronization direction can be set in the associated dialog.

Distributed clock timing settings

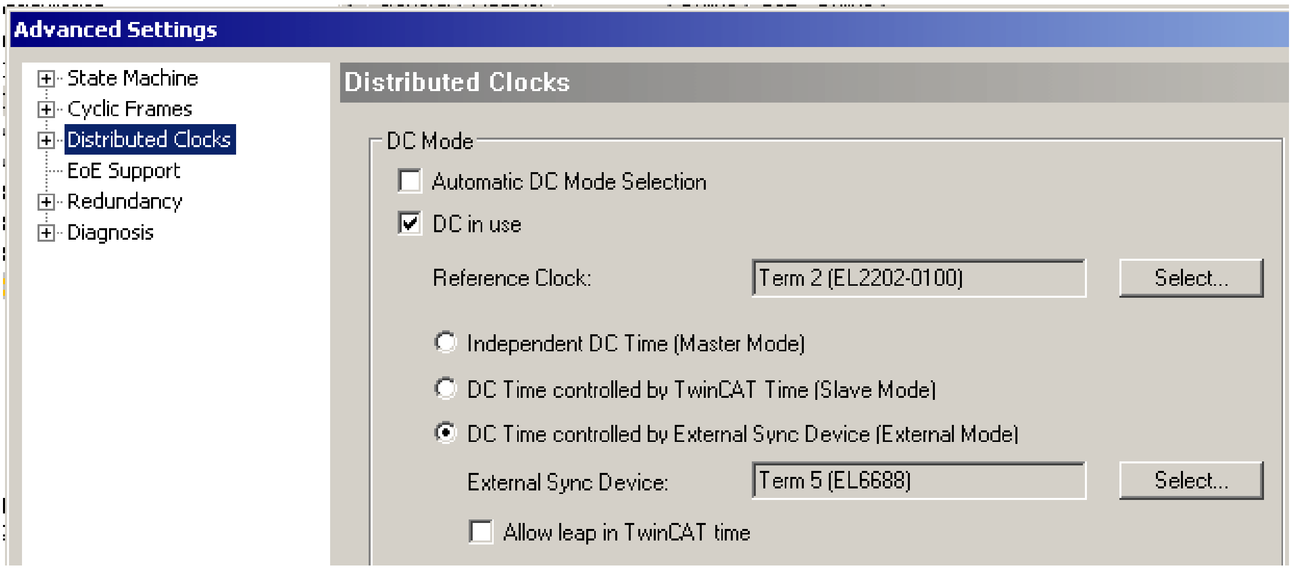


Fig. 13: TwinCAT 2.11 distributed clock settings - Example for EL6688 in PTP slave mode as time reference for the local EtherCAT system

- **Independent DC Time:** one of the EL terminals (generally the first terminal supporting DC) is the reference clock to which all other DC terminals are adjusted. Selection of the reference clock in the dialog above.
- **DC Time controlled by TwinCAT:** the DC reference clock is adjusted to the local TwinCAT time.
- **DC Time controlled by External Sync Device**: if the EtherCAT system is to be adjusted to a higher-level clock, the external sync device can be selected here.

Process data settings

TwinCAT 2.11 can display the current offsets in [ns] in the EtherCAT master info data.

- These offsets are calculated once after EtherCAT has started.
- The synchronization control keeps these offsets constant.
- If local DC time values in the synchronized EtherCAT system are to be related to the absolute reference from the higher-level EtherCAT system (e.g. from EL1252 timestamp terminals), the user must adjust this offset with each local timestamp.

Example: $t_{\text{EL1252 timestamp channel 1, absolute time}} = t_{\text{EL1252 timestamp channel 1, local DC time}} + t_{\text{ExtToDcOffset}}$

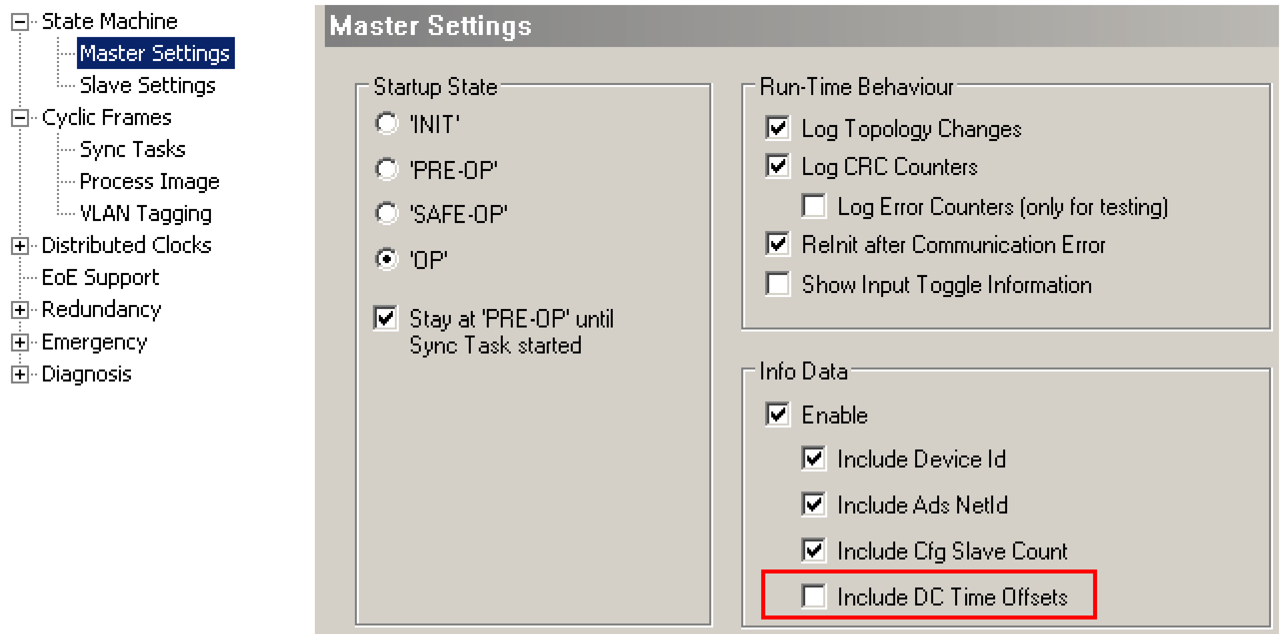


Fig. 14: display current offsets

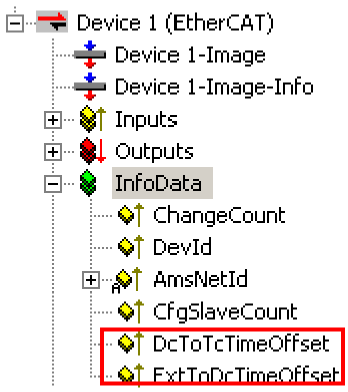


Fig. 15: *Current offsets*

3.3 General notes for setting the watchdog

ELxxxx terminals are equipped with a safety feature (watchdog) that switches off the outputs after a specifiable time e.g. in the event of an interruption of the process data traffic, depending on the device and settings, e.g. in OFF state.

The EtherCAT slave controller (ESC) in the EL2xxx terminals features 2 watchdogs:

- SM watchdog (default: 100 ms)
- PDI watchdog (default: 100 ms)

SM watchdog (SyncManager Watchdog)

The SyncManager watchdog is reset after each successful EtherCAT process data communication with the terminal. If no EtherCAT process data communication takes place with the terminal for longer than the set and activated SM watchdog time, e.g. in the event of a line interruption, the watchdog is triggered and the outputs are set to FALSE. The OP state of the terminal is unaffected. The watchdog is only reset after a successful EtherCAT process data access. Set the monitoring time as described below.

The SyncManager watchdog monitors correct and timely process data communication with the ESC from the EtherCAT side.

PDI watchdog (Process Data Watchdog)

If no PDI communication with the EtherCAT slave controller (ESC) takes place for longer than the set and activated PDI watchdog time, this watchdog is triggered.
PDI (Process Data Interface) is the internal interface between the ESC and local processors in the EtherCAT slave, for example. The PDI watchdog can be used to monitor this communication for failure.

The PDI watchdog monitors correct and timely process data communication with the ESC from the application side.

The settings of the SM- and PDI-watchdog must be done for each slave separately in the TwinCAT System Manager.

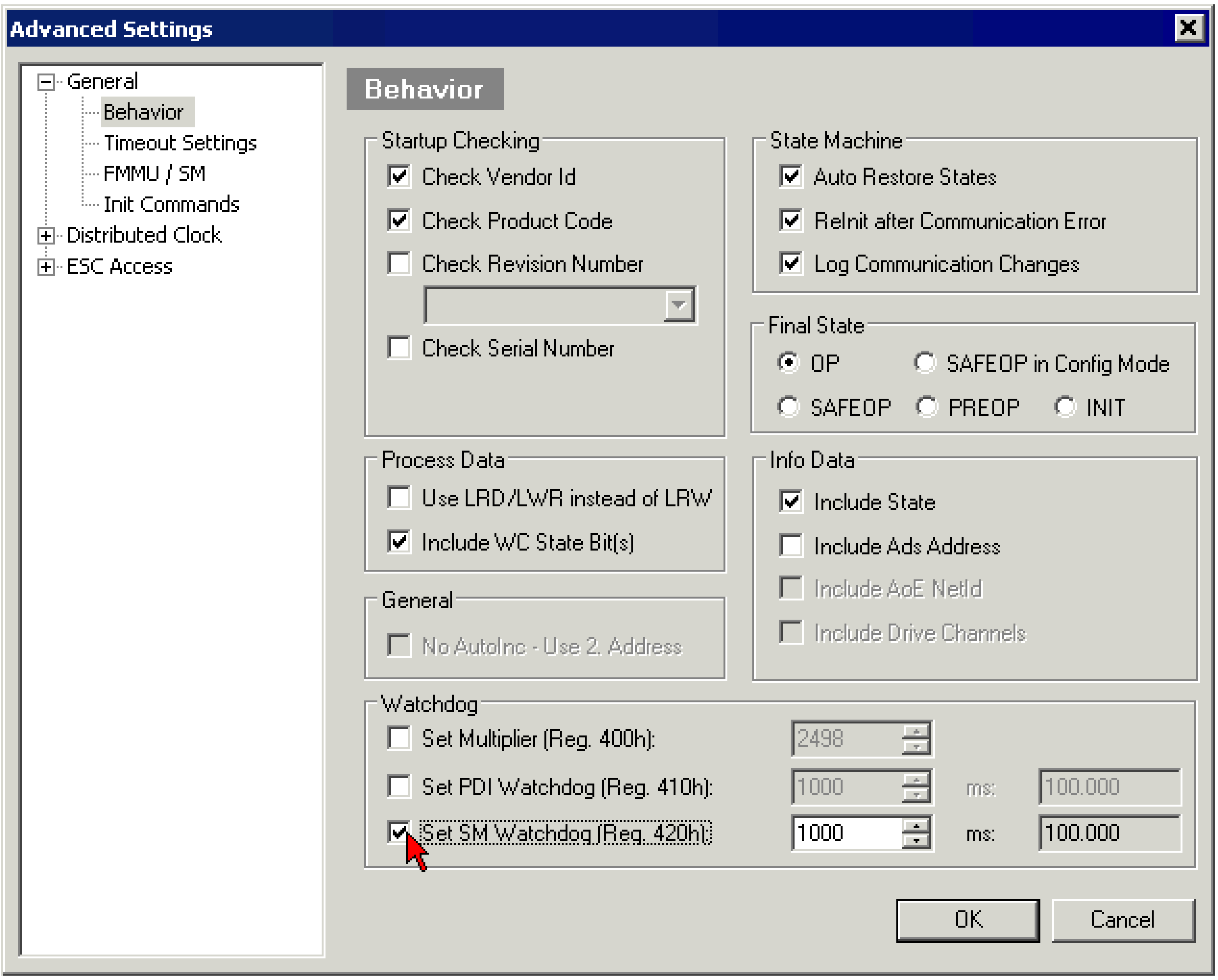


Fig. 16: *EtherCAT tab -> Advanced Settings -> Behavior -> Watchdog*

Notes:

- the multiplier is valid for both watchdogs.
- each watchdog has its own timer setting, the outcome of this in summary with the multiplier is a resulting time.
- Important: the multiplier/timer setting is only loaded into the slave at the start up, if the checkbox is activated.
  If the checkbox is not activated, nothing is downloaded and the ESC settings remain unchanged.

Multiplier

Multiplier

Both watchdogs receive their pulses from the local terminal cycle, divided by the watchdog multiplier:

1/25 MHz * (watchdog multiplier + 2) = 100 µs (for default setting of 2498 for the multiplier)

The standard setting of 1000 for the SM watchdog corresponds to a release time of 100 ms.

The value in multiplier + 2 corresponds to the number of basic 40 ns ticks representing a watchdog tick. The multiplier can be modified in order to adjust the watchdog time over a larger range.

Example "Set SM watchdog"

This checkbox enables manual setting of the watchdog times. If the outputs are set and the EtherCAT communication is interrupted, the SM watchdog is triggered after the set time and the outputs are erased. This setting can be used for adapting a terminal to a slower EtherCAT master or long cycle times. The default SM watchdog setting is 100 ms. The setting range is 0..65535. Together with a multiplier with a range of 1..65535 this covers a watchdog period between 0..~170 seconds.

Calculation

Multiplier = 2498 → watchdog base time = 1 / 25 MHz * (2498 + 2) = 0.0001 seconds = 100 µs
SM watchdog = 10000 → 10000 * 100 µs = 1 second watchdog monitoring time

⚠ CAUTION

Undefined state possible!

The function for switching off of the SM watchdog via SM watchdog = 0 is only implemented in terminals from version -0016. In previous versions this operating mode should not be used.

⚠ CAUTION

Damage of devices and undefined state possible!

If the SM watchdog is activated and a value of 0 is entered the watchdog switches off completely. This is the deactivation of the watchdog! Set outputs are NOT set in a safe state, if the communication is interrupted.

3.4 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.

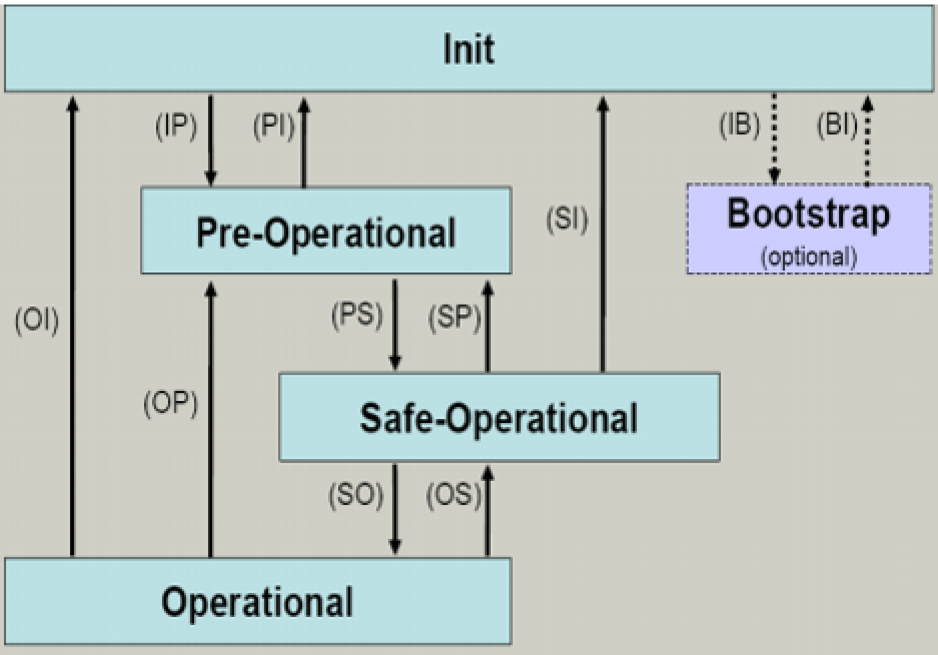


Fig. 17: *States of the EtherCAT State Machine*

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 [▶ 22] 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.

3.5 CoE Interface

General description

The CoE interface (CANopen over EtherCAT) is used for parameter management of EtherCAT devices. EtherCAT slaves or the EtherCAT master manage fixed (read only) or variable parameters which they require for operation, diagnostics or commissioning.

CoE parameters are arranged in a table hierarchy. In principle, the user has read access via the fieldbus. The EtherCAT master (TwinCAT System Manager) can access the local CoE lists of the slaves via EtherCAT in read or write mode, depending on the attributes.

Different CoE parameter types are possible, including string (text), integer numbers, Boolean values or larger byte fields. They can be used to describe a wide range of features. Examples of such parameters include manufacturer ID, serial number, process data settings, device name, calibration values for analog measurement or passwords.

The order is specified in 2 levels via hexadecimal numbering: (main)index, followed by subindex. The value ranges are

- Index: 0x0000 …0xFFFF (0...65535$_{dez}$)
- SubIndex: 0x00…0xFF (0...255$_{dez}$)

A parameter localized in this way is normally written as 0x8010:07, with preceding "x" to identify the hexadecimal numerical range and a colon between index and subindex.

The relevant ranges for EtherCAT fieldbus users are:

- 0x1000: This is where fixed identity information for the device is stored, including name, manufacturer, serial number etc., plus information about the current and available process data configurations.
- 0x8000: This is where the operational and functional parameters for all channels are stored, such as filter settings or output frequency.

Other important ranges are:

- 0x4000: In some EtherCAT devices the channel parameters are stored here (as an alternative to the 0x8000 range).
- 0x6000: Input PDOs ("input" from the perspective of the EtherCAT master)
- 0x7000: Output PDOs ("output" from the perspective of the EtherCAT master)

Availability

Not every EtherCAT device must have a CoE list. Simple I/O modules without dedicated processor usually have no variable parameters and therefore no CoE list.

If a device has a CoE list, it is shown in the TwinCAT System Manager as a separate tab with a listing of the elements:

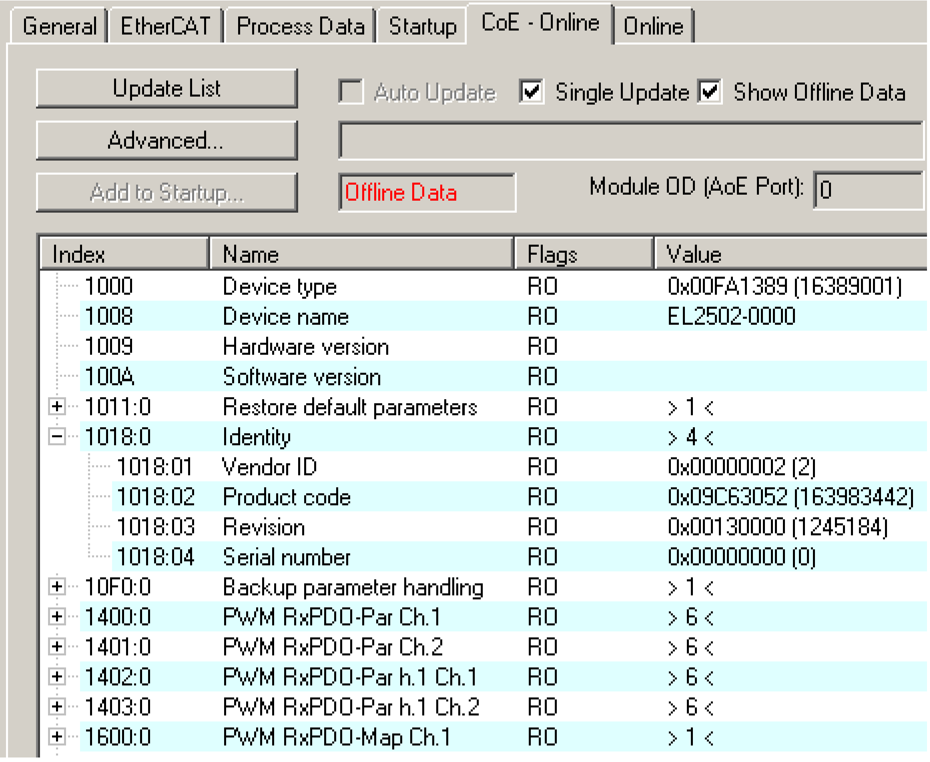


Fig. 18: *"CoE Online " tab*

The figure above shows the CoE objects available in device "EL2502", ranging from 0x1000 to 0x1600. The subindices for 0x1018 are expanded.

Data management and function "NoCoeStorage"

Some parameters, particularly the setting parameters of the slave, are configurable and writeable. This can be done in write or read mode

- via the System Manager (Fig. *"CoE Online " tab*) by clicking
  This is useful for commissioning of the system/slaves. Click on the row of the index to be parameterised and enter a value in the "SetValue" dialog.
- from the control system/PLC via ADS, e.g. through blocks from the TcEtherCAT.lib library
  This is recommended for modifications while the system is running or if no System Manager or operating staff are available.

Data management

If slave CoE parameters are modified online, Beckhoff devices store any changes in a fail-safe manner in the EEPROM, i.e. the modified CoE parameters are still available after a restart.
The situation may be different with other manufacturers.

An EEPROM is subject to a limited lifetime with respect to write operations. From typically 100,000 write operations onwards it can no longer be guaranteed that new (changed) data are reliably saved or are still readable. This is irrelevant for normal commissioning. However, if CoE parameters are continuously changed via ADS at machine runtime, it is quite possible for the lifetime limit to be reached. Support for the NoCoeStorage function, which suppresses the saving of changed CoE values, depends on the firmware version.
Please refer to the technical data in this documentation as to whether this applies to the respective device.

- If the function is supported: the function is activated by entering the code word 0x12345678 once in CoE 0xF008 and remains active as long as the code word is not changed. After switching the device on it is then inactive. Changed CoE values are not saved in the EEPROM and can thus be changed any number of times.
- Function is not supported: continuous changing of CoE values is not permissible in view of the lifetime limit.

Startup list

Changes in the local CoE list of the terminal are lost if the terminal is replaced. If a terminal is replaced with a new Beckhoff terminal, it will have the default settings. It is therefore advisable to link all changes in the CoE list of an EtherCAT slave with the Startup list of the slave, which is processed whenever the EtherCAT fieldbus is started. In this way a replacement EtherCAT slave can automatically be parameterized with the specifications of the user.

If EtherCAT slaves are used which are unable to store local CoE values permanently, the Startup list must be used.

Recommended approach for manual modification of CoE parameters

- Make the required change in the System Manager
  The values are stored locally in the EtherCAT slave
- If the value is to be stored permanently, enter it in the Startup list.
  The order of the Startup entries is usually irrelevant.

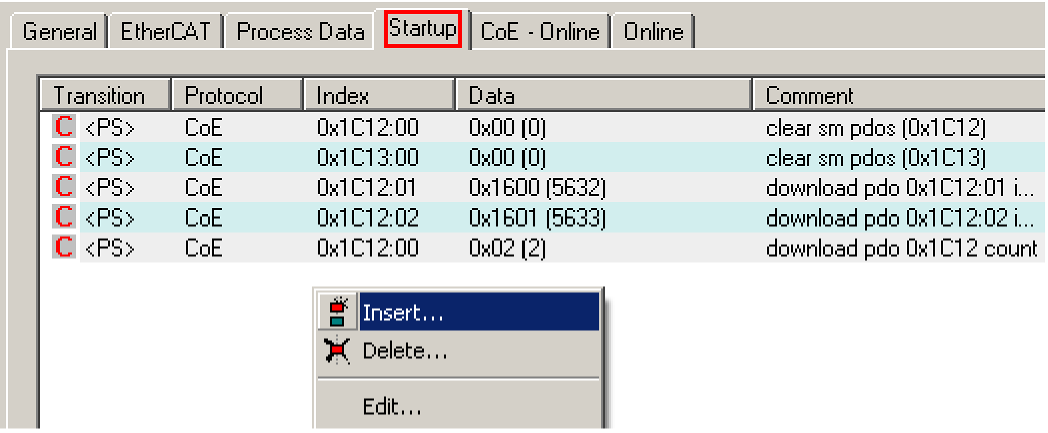


Fig. 19: *Startup list in the TwinCAT System Manager*

The Startup list may already contain values that were configured by the System Manager based on the ESI specifications. Additional application-specific entries can be created.

Online/offline list

While working with the TwinCAT System Manager, a distinction has to be made whether the EtherCAT device is "available", i.e. switched on and linked via EtherCAT and therefore **online**, or whether a configuration is created **offline** without connected slaves.

In both cases a CoE list as shown in Fig. *"'CoE online' tab"* is displayed. The connectivity is shown as offline/online.

- If the slave is offline
  - The offline list from the ESI file is displayed. In this case modifications are not meaningful or possible.
  - The configured status is shown under Identity.
  - No firmware or hardware version is displayed, since these are features of the physical device.
  - **Offline** is shown in red.

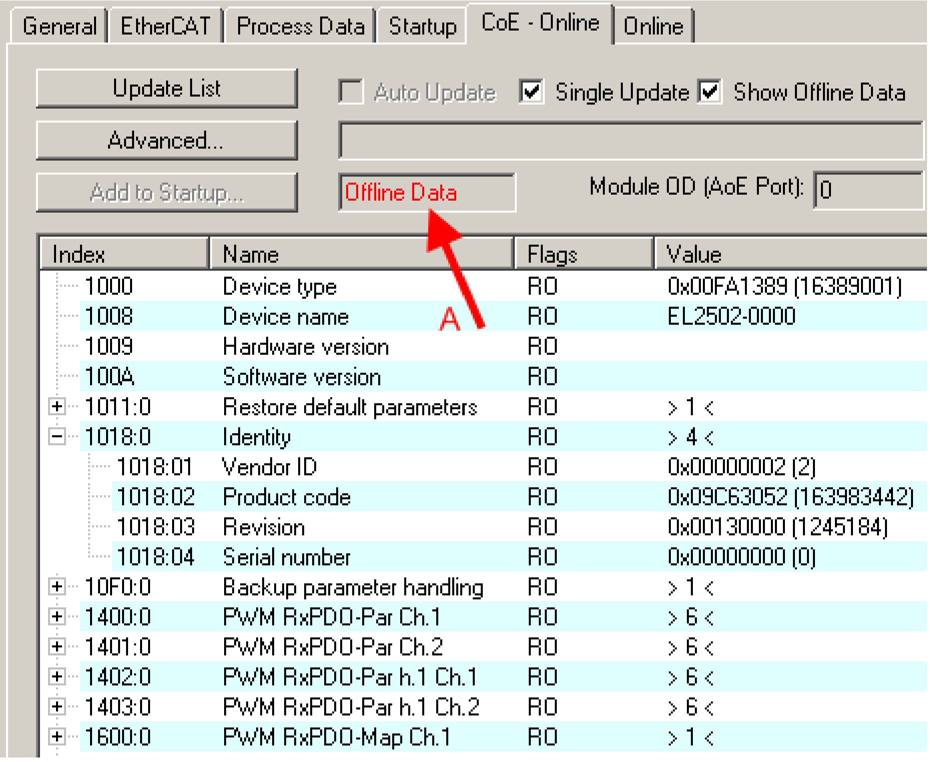


Fig. 20: *Offline list*

- If the slave is online
    - The actual current slave list is read. This may take several seconds, depending on the size and cycle time.
    - The actual identity is displayed
    - The firmware and hardware version of the equipment according to the electronic information is displayed
    - **Online** is shown in green.

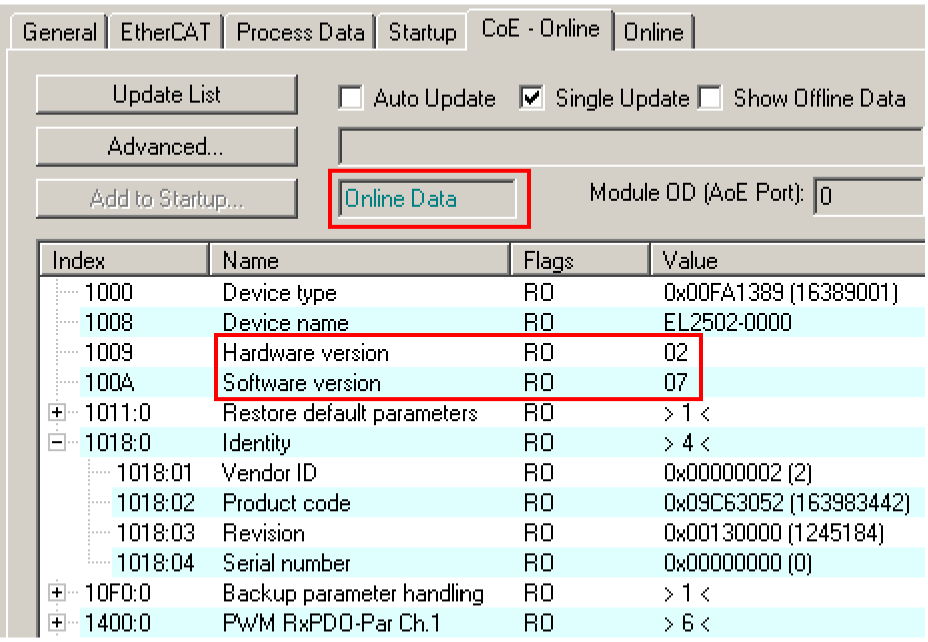


Fig. 21: *Online list*

Channel-based order

The CoE list is available in EtherCAT devices that usually feature several functionally equivalent channels. For example, a 4-channel analog 0..10 V input terminal also has 4 logical channels and therefore 4 identical sets of parameter data for the channels. In order to avoid having to list each channel in the documentation, the placeholder "n" tends to be used for the individual channel numbers.

In the CoE system 16 indices, each with 255 subindices, are generally sufficient for representing all channel parameters. The channel-based order is therefore arranged in $16_{dec}/10_{hex}$ steps. The parameter range 0x8000 exemplifies this:

- Channel 0: parameter range 0x8000:00 ... 0x800F:255
- Channel 1: parameter range 0x8010:00 ... 0x801F:255
- Channel 2: parameter range 0x8020:00 ... 0x802F:255
- ...

This is generally written as 0x80n0.

Detailed information on the CoE interface can be found in the EtherCAT system documentation on the Beckhoff website.

3.6 Distributed Clock

The distributed clock represents a local clock in the EtherCAT slave controller (ESC) with the following characteristics:

- Unit *1 ns*
- Zero point *1.1.2000 00:00*
- Size *64 bit* (sufficient for the next 584 years; however, some EtherCAT slaves only offer 32-bit support, i.e. the variable overflows after approx. 4.2 seconds)
- The EtherCAT master automatically synchronizes the local clock with the master clock in the EtherCAT bus with a precision of < 100 ns.

For detailed information please refer to the EtherCAT system description.

4 Mounting and wiring

4.1 Mounting and demounting - terminals with front unlocking

The terminal modules are fastened to the assembly surface with the aid of a 35 mm mounting rail (e.g. mounting rail TH 35-15).

Fixing of mounting rails

The locking mechanism of the terminals and couplers extends to the profile of the mounting rail. At the installation, the locking mechanism of the components must not come into conflict with the fixing bolts of the mounting rail. To mount the recommended mounting rails under the terminals and couplers, you should use flat mounting connections (e.g. countersunk screws or blind rivets).

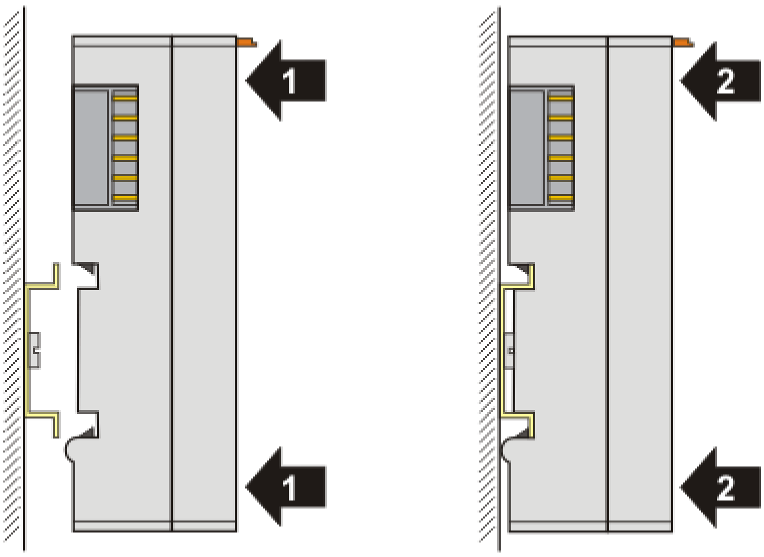
⚠ WARNING

Risk of electric shock and damage of device!

Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the Bus Terminals!

Mounting

- Fit the mounting rail to the planned assembly location.

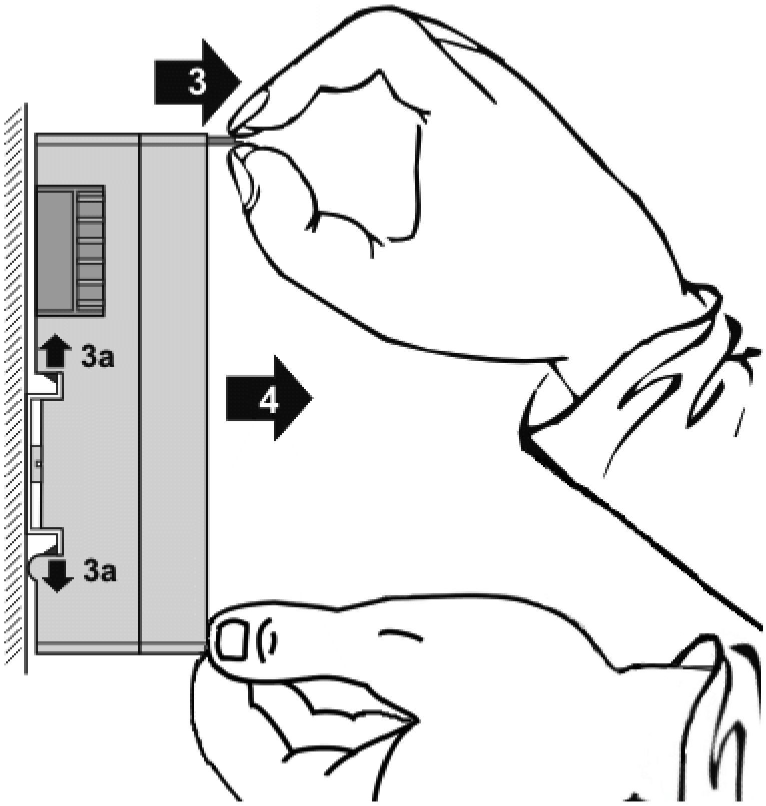


and press (1) the terminal module against the mounting rail until it latches in place on the mounting rail (2).

- Attach the cables.

Demounting

- Remove all the cables.
- Lever the unlatching hook back with thumb and forefinger (3). An internal mechanism pulls the two latching lugs (3a) from the top hat rail back into the terminal module.



- Pull (4) the terminal module away from the mounting surface.
  Avoid canting of the module; you should stabilize the module with the other hand, if required.

4.2 Mounting and demounting - terminals with traction lever unlocking

The terminal modules are fastened to the assembly surface with the aid of a 35 mm mounting rail (e.g. mounting rail TH 35-15).

Fixing of mounting rails

The locking mechanism of the terminals and couplers extends to the profile of the mounting rail. At the installation, the locking mechanism of the components must not come into conflict with the fixing bolts of the mounting rail. To mount the recommended mounting rails under the terminals and couplers, you should use flat mounting connections (e.g. countersunk screws or blind rivets).

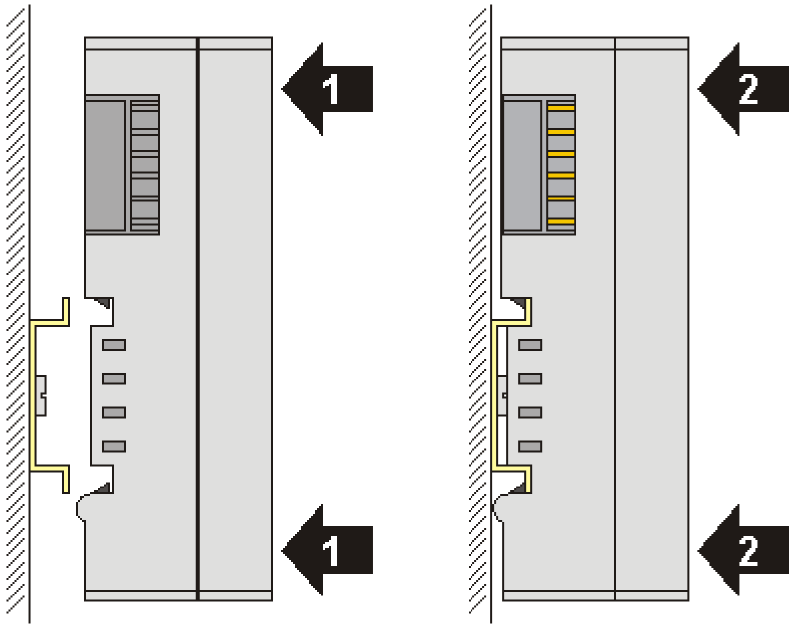
⚠ WARNING

Risk of electric shock and damage of device!

Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the Bus Terminals!

Mounting

- Fit the mounting rail to the planned assembly location.

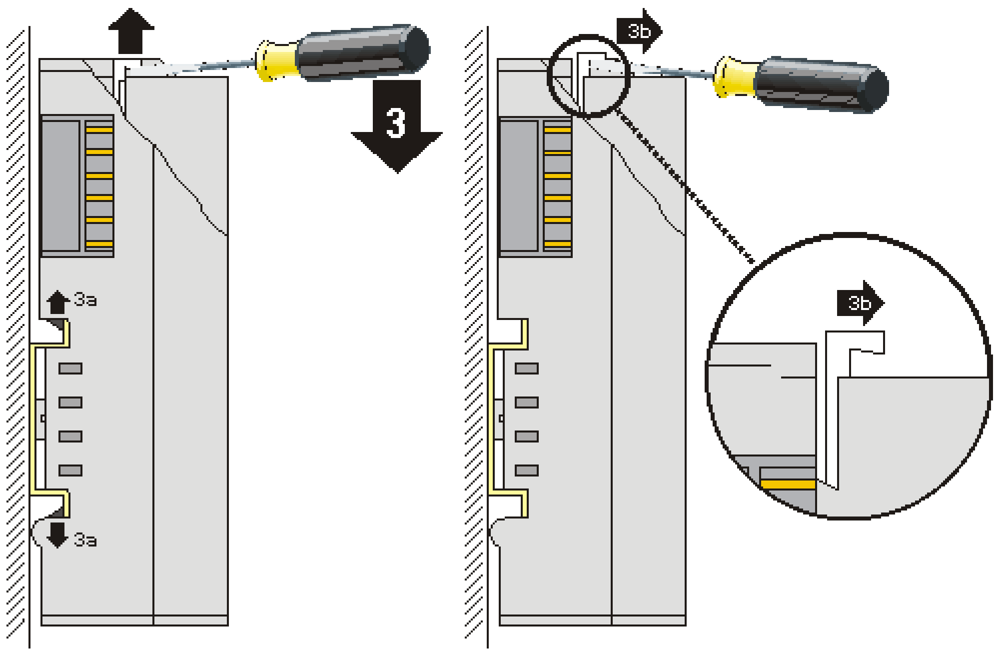


and press (1) the terminal module against the mounting rail until it latches in place on the mounting rail (2).

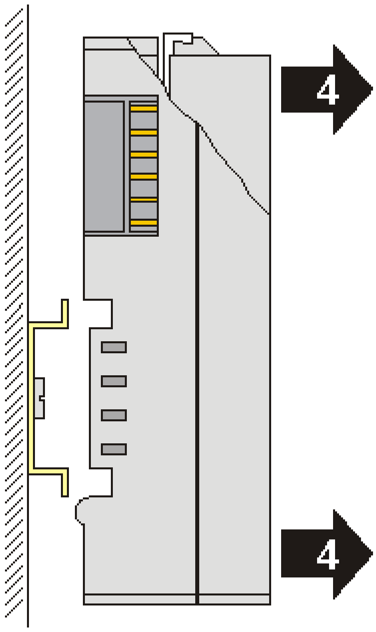
- Attach the cables.

Demounting

- Remove all the cables. Thanks to the KM/EM connector, it is not necessary to remove all the cables separately for this, but for each KM/EM connector simply undo 2 screws so that you can pull them off (fixed wiring)!
- Lever the unlatching hook on the left-hand side of the terminal module upwards with a screwdriver (3). As you do this
    - an internal mechanism pulls the two latching lugs (3a) from the top hat rail back into the terminal module,
    - the unlatching hook moves forwards (3b) and engages



- In the case 32 and 64 channel terminal modules (KMxxx4 and KMxxx8 or EMxxx4 and EMxxx8) you now lever the second unlatching hook on the right-hand side of the terminal module upwards in the same way.
- Pull (4) the terminal module away from the mounting surface.



4.3 Recommended mounting rails

Terminal Modules und EtherCAT Modules of KMxxxx and EMxxxx series, same as the terminals of the EL66xx and EL67xx series can be snapped onto the following recommended mounting rails:

- DIN Rail TH 35-7.5 with 1 mm material thickness (according to EN 60715)
- DIN Rail TH 35-15 with 1,5 mm material thickness

Pay attention to the material thickness of the DIN Rail

Terminal Modules und EtherCAT Modules of KMxxxx and EMxxxx series, same as the terminals of the EL66xx and EL67xx series does not fit to the DIN Rail TH 35-15 with 2,2 to 2,5 mm material thickness (according to EN 60715)!

4.4 Positioning of passive Terminals

Hint for positioning of passive terminals in the bus terminal block

EtherCAT Terminals (ELxxxx / ESxxxx), which do not take an active part in data transfer within the bus terminal block are so called passive terminals. The passive terminals have no current consumption out of the E-Bus.
To ensure an optimal data transfer, you must not directly string together more than 2 passive terminals!

Examples for positioning of passive terminals (highlighted)

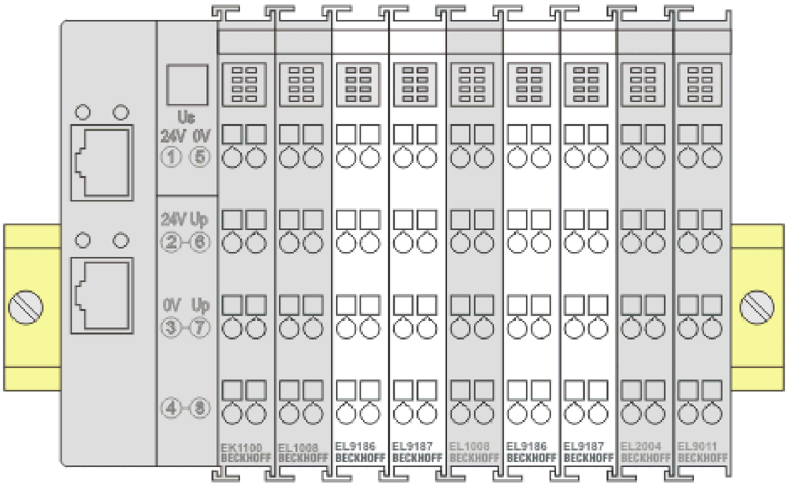


Fig. 22: Correct positioning

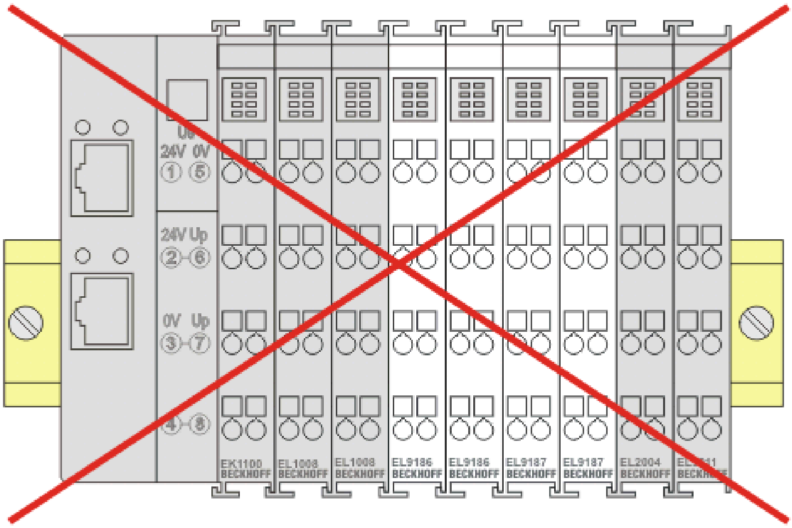


Fig. 23: Incorrect positioning

4.5 Installation positions

NOTE

Constraints regarding installation position and operating temperature range

Please refer to the technical data for a terminal to ascertain whether any restrictions regarding the installation position and/or the operating temperature range have been specified. When installing high power dissipation terminals ensure that an adequate spacing is maintained between other components above and below the terminal in order to guarantee adequate ventilation!

Optimum installation position (standard)

The optimum installation position requires the mounting rail to be installed horizontally and the connection surfaces of the EL/KL terminals to face forward (see Fig. *"Recommended distances for standard installation position"*). The terminals are ventilated from below, which enables optimum cooling of the electronics through convection. "From below" is relative to the acceleration of gravity.

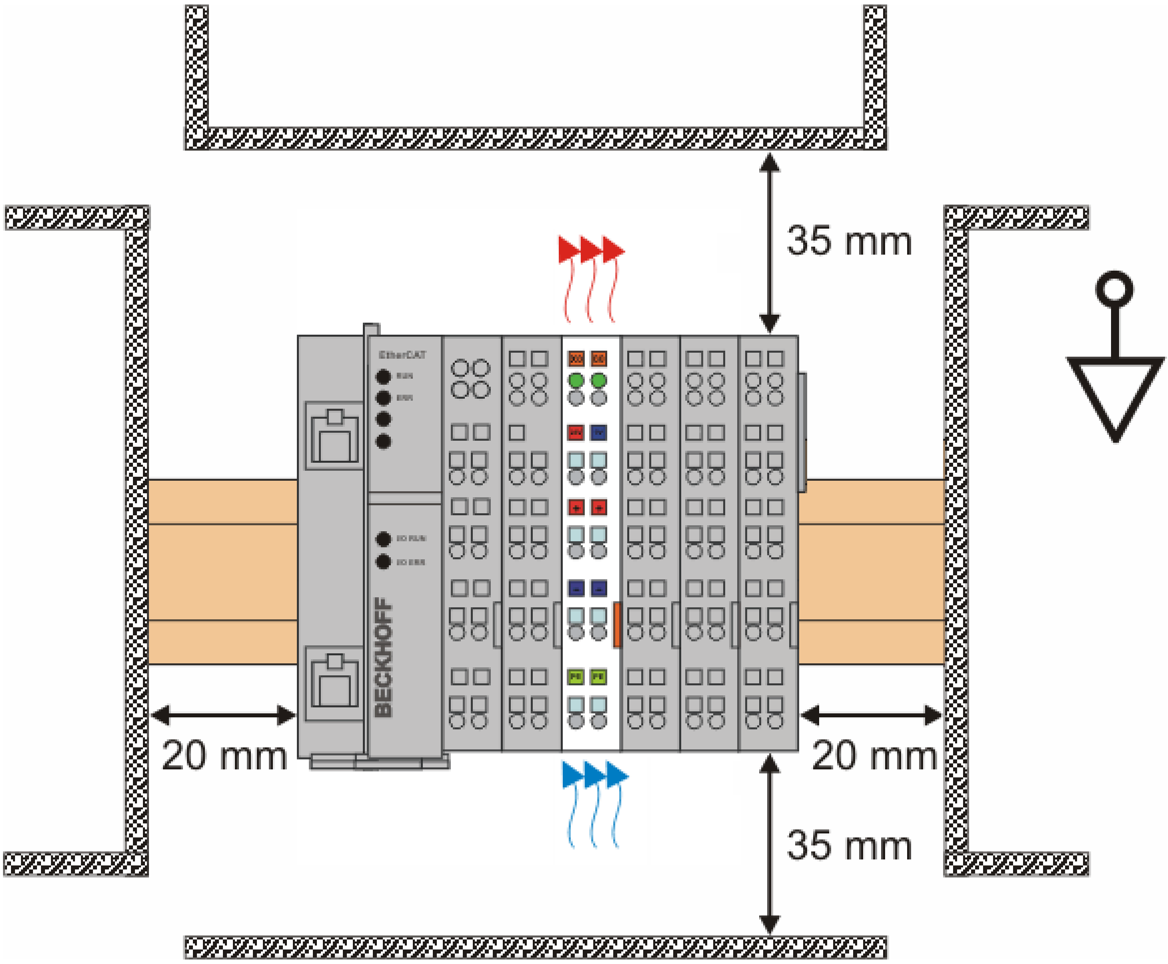


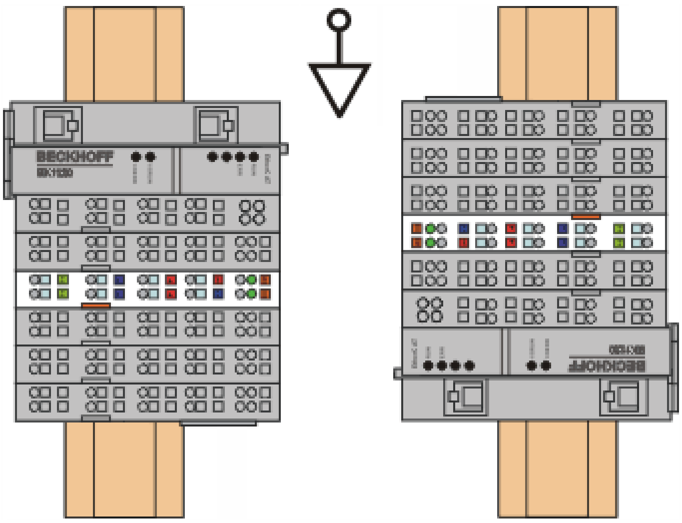
Fig. 24: *Recommended distances for standard installation position*

Compliance with the distances shown in Fig. *"Recommended distances for standard installation position"* is recommended.

Other installation positions

All other installation positions are characterized by different spatial arrangement of the mounting rail - see Fig *"Other installation positions".*

The minimum distances to ambient specified above also apply to these installation positions.



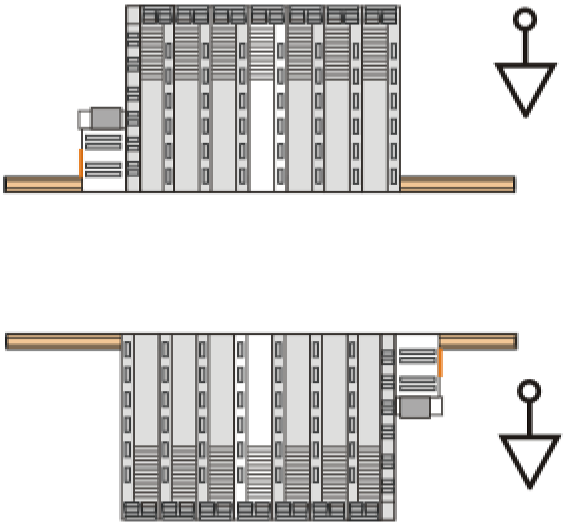


Fig. 25: *Other installation positions*

4.6 ATEX - Special conditions (standard temperature range)

⚠ WARNING

Observe the special conditions for the intended use of Beckhoff fieldbus components with standard temperature range in potentially explosive areas (directive 94/9/EU)!

- The certified components are to be installed in a suitable housing that guarantees a protection class of at least IP54 in accordance with EN 60529! The environmental conditions during use are thereby to be taken into account!
- If the temperatures during rated operation are higher than 70°C at the feed-in points of cables, lines or pipes, or higher than 80°C at the wire branching points, then cables must be selected whose temperature data correspond to the actual measured temperature values!
- Observe the permissible ambient temperature range of 0 to 55°C for the use of Beckhoff fieldbus components standard temperature range in potentially explosive areas!
- Measures must be taken to protect against the rated operating voltage being exceeded by more than 40% due to short-term interference voltages!
- The individual terminals may only be unplugged or removed from the Bus Terminal system if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
- The connections of the certified components may only be connected or disconnected if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
- The fuses of the KL92xx/EL92xx power feed terminals may only be exchanged if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!
- Address selectors and ID switches may only be adjusted if the supply voltage has been switched off or if a non-explosive atmosphere is ensured!

Standards

The fundamental health and safety requirements are fulfilled by compliance with the following standards:

- EN 60079-0:2012+A11:2013
- EN 60079-15:2010

Marking

The Beckhoff fieldbus components with standard temperature range certified for potentially explosive areas bear one of the following markings:

II 3G KEMA 10ATEX0075 X Ex nA IIC T4 Gc Ta: 0 … 55°C

or

II 3G KEMA 10ATEX0075 X Ex nC IIC T4 Gc Ta: 0 … 55°C

4.7 ATEX Documentation

Notes about operation of the Beckhoff terminal systems in potentially explosive areas (ATEX)

Pay also attention to the continuative documentation

Notes about operation of the Beckhoff terminal systems in potentially explosive areas (ATEX)

that is available in the download area of the Beckhoff homepage http:\\www.beckhoff.com!

4.8 UL notice

	Application Beckhoff EtherCAT modules are intended for use with Beckhoff's UL Listed EtherCAT System only.
	Examination For cULus examination, the Beckhoff I/O System has only been investigated for risk of fire and electrical shock (in accordance with UL508 and CSA C22.2 No. 142).
	For devices with Ethernet connectors Not for connection to telecommunication circuits.

Basic principles

Two UL certificates are met in the Beckhoff EtherCAT product range, depending upon the components:

1. UL certification according to UL508. Devices with this kind of certification are marked by this sign:

2. UL certification according to UL508 with limited power consumption. The current consumed by the device is limited to a max. possible current consumption of 4 A. Devices with this kind of certification are marked by this sign:

US LISTED
Ind. Cont. Eq.: 24TB

Use 4 Amp. fuse or
Class 2 power supply.
See instructions.

Almost all current EtherCAT products (as at 2010/05) are UL certified without restrictions.

Application

If terminals certified *with restrictions* are used, then the current consumption at 24 V_{DC} must be limited accordingly by means of supply

- from an isolated source protected by a fuse of max. 4 A (according to UL248) or
- from a voltage supply complying with *NEC class 2*.
  A voltage source complying with *NEC class 2* may not be connected in series or parallel with another *NEC class 2*compliant voltage supply!

These requirements apply to the supply of all EtherCAT bus couplers, power adaptor terminals, Bus Terminals and their power contacts.

4.9 EL6688 - LEDs and connection

LEDs

LED	Color	Meaning	
Run	green	These LEDs indicate the terminal's operating state:	
		off	State of the EtherCAT State Machine [▶ 66]: **INIT** = initialization of the terminal or **BOOTSTRAP** = function for firmware updates [▶ 99] of the terminal
		flashing	State of the EtherCAT State Machine: **PREOP** = function for mailbox communication and different standard-settings set
		single flash	State of the EtherCAT State Machine: **SAFEOP** = verification of the Sync Manager [▶ 66] channels and the distributed clocks. Outputs remain in safe state
		on	State of the EtherCAT State Machine: **OP** = normal operating state; mailbox and process data communication is possible
Err	red	Fault indication EtherCAT	
Lnk/Act	green	This LED shows the connection state of the Ethernet port:	
		off	no Link signal
		on	Link signal present, Ethernet connection established
		flashing	Data traffic
100	yellow	off	Data transmission with 10 Mbit/s
		on	Data transmission with 100 Mbit/s

Connections

1 x RJ45 with 10BASE-T/100BASE-TX Ethernet

5 Commissioning

5.1 TwinCAT Development Environment

The Software for automation TwinCAT (The Windows Control and Automation Technology) will be distinguished into:

- TwinCAT 2: System Manager (Configuration) & PLC Control (Programming)
- TwinCAT 3: Enhancement of TwinCAT 2 (Programming and Configuration takes place via a common Development Environment)

Details:

- **TwinCAT 2:**
    - Connects I/O devices to tasks in a variable-oriented manner
    - Connects tasks to tasks in a variable-oriented manner
    - Supports units at the bit level
    - Supports synchronous or asynchronous relationships
    - Exchange of consistent data areas and process images
    - Datalink on NT - Programs by open Microsoft Standards (OLE, OCX, ActiveX, DCOM+, etc.)
    - Integration of IEC 61131-3-Software-SPS, Software- NC and Software-CNC within Windows NT/2000/XP/Vista, Windows 7, NT/XP Embedded, CE
    - Interconnection to all common fieldbusses
    - More...

Additional features:

- **TwinCAT 3** (eXtended Automation)**:**
    - Visual-Studio®-Integration
    - Choice of the programming language
    - Supports object orientated extension of IEC 61131-3
    - Usage of C/C++ as programming language for real time applications
    - Connection to MATLAB®/Simulink®
    - Open interface for expandability
    - Flexible run-time environment
    - Active support of Multi-Core- und 64-Bit-Operatingsystem
    - Automatic code generation and project creation with the TwinCAT Automation Interface
    - More...

Within the following sections commissioning of the TwinCAT Development Environment on a PC System for the control and also the basically functions of unique control elements will be explained.

Please see further information to TwinCAT 2 and TwinCAT 3 at http://infosys.beckhoff.com.

5.1.1 Installation of the TwinCAT real-time driver

In order to assign real-time capability to a standard Ethernet port of an IPC controller, the Beckhoff real-time driver has to be installed on this port under Windows.

This can be done in several ways. One option is described here.

In the System Manager call up the TwinCAT overview of the local network interfaces via Options → Show Real Time Ethernet Compatible Devices.

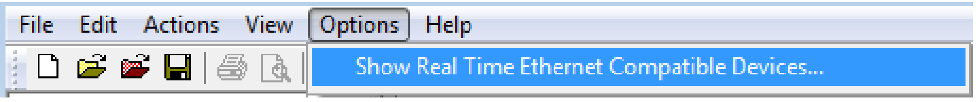


Fig. 26: *System Manager “Options” (TwinCAT 2)*

This have to be called up by the Menü “TwinCAT” within the TwinCAT 3 environment:

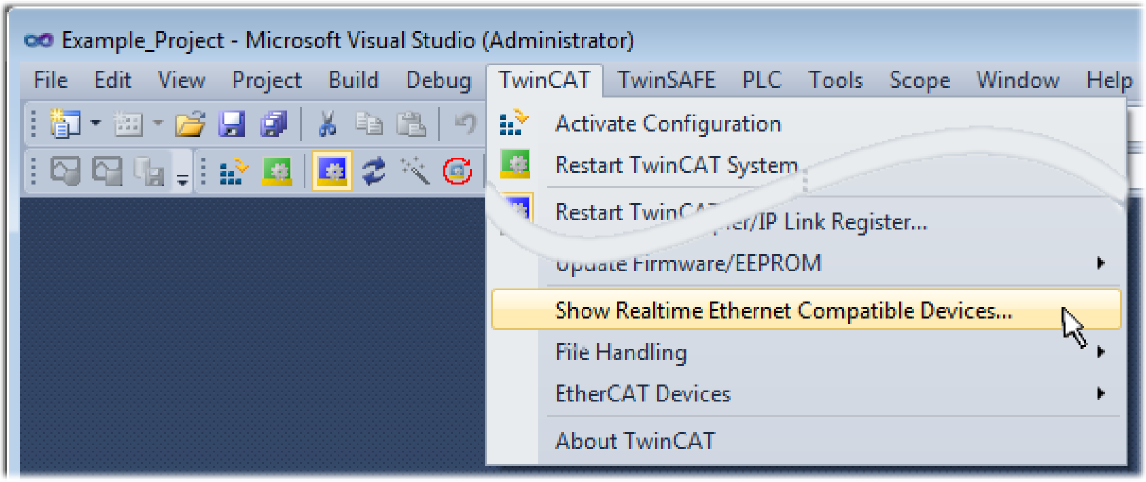


Fig. 27: *Call up under VS Shell (TwinCAT 3)*

The following dialog appears:

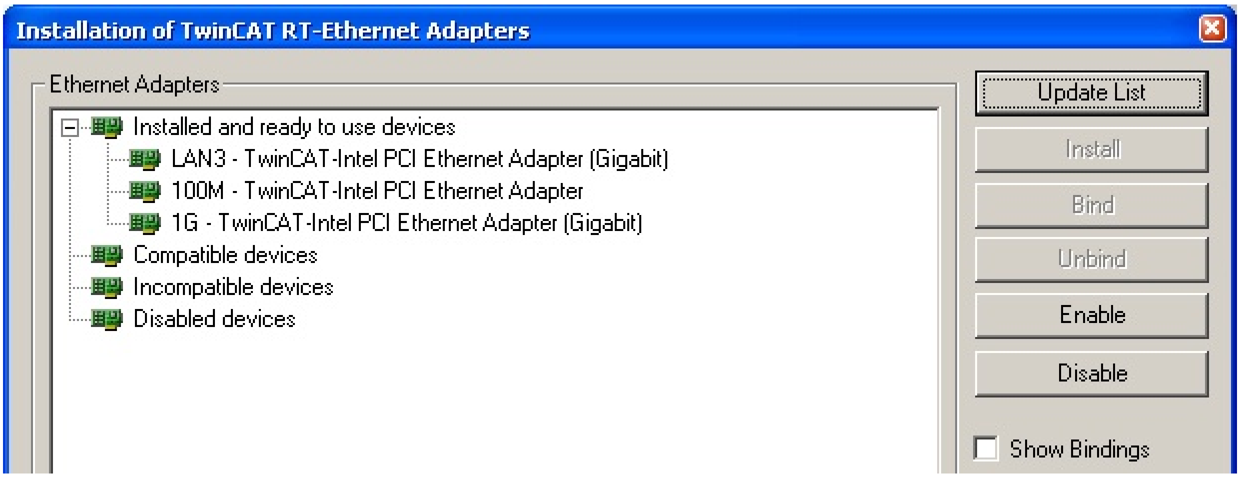


Fig. 28: *Overview of network interfaces*

Interfaces listed under “Compatible devices” can be assigned a driver via the “Install” button. A driver should only be installed on compatible devices.

A Windows warning regarding the unsigned driver can be ignored.

Alternatively an EtherCAT-device can be inserted first of all as described in chapter Offline configuration creation, section “Creating the EtherCAT device” [▸ 53] in order to view the compatible ethernet ports via its EtherCAT properties (tab „Adapter“, button „Compatible Devices…“):

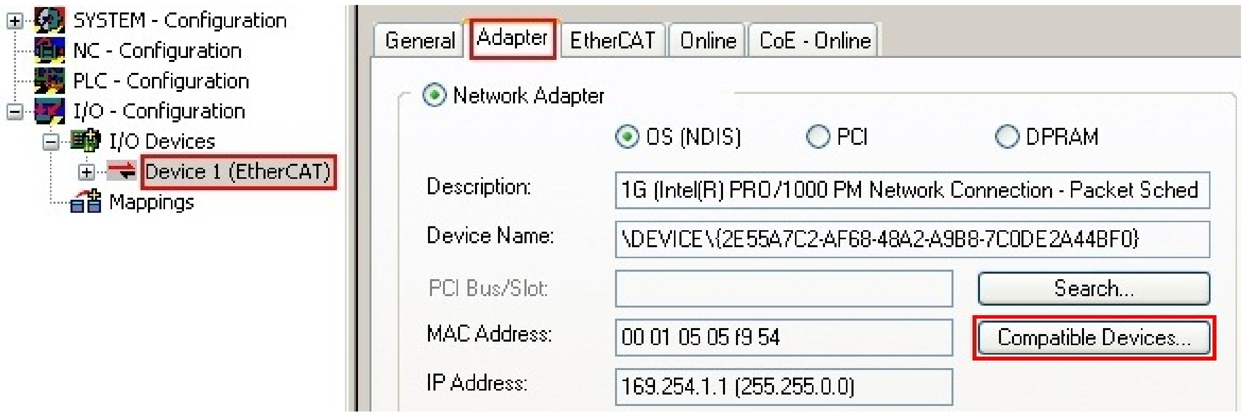


Fig. 29: *EtherCAT device properties(TwinCAT 2): click on „Compatible Devices…“ of tab “Adapter”*

TwinCAT 3: the properties of the EtherCAT device can be opened by double click on “Device .. (EtherCAT)” within the Solution Explorer under “I/O”:

After the installation the driver appears activated in the Windows overview for the network interface (Windows Start → System Properties → Network)

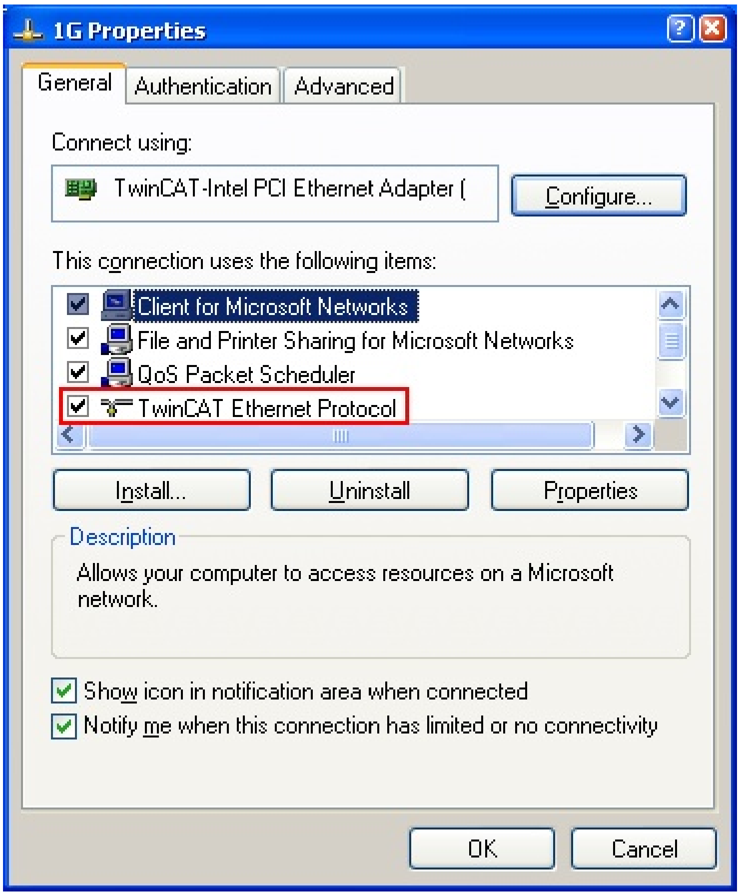


Fig. 30: *Windows properties of the network interface*

A correct setting of the driver could be:

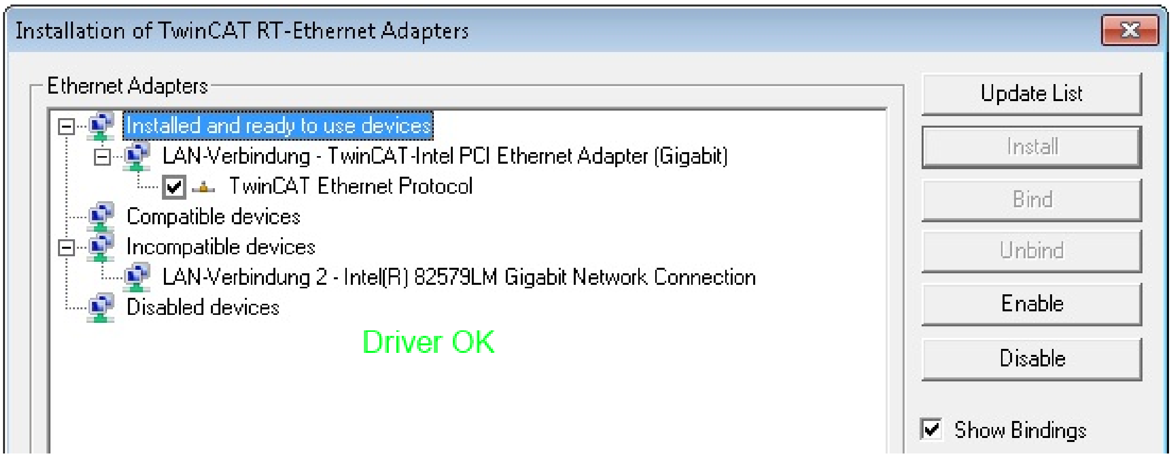


Fig. 31: *Exemplary correct driver setting for the Ethernet port*

Other possible settings have to be avoided:

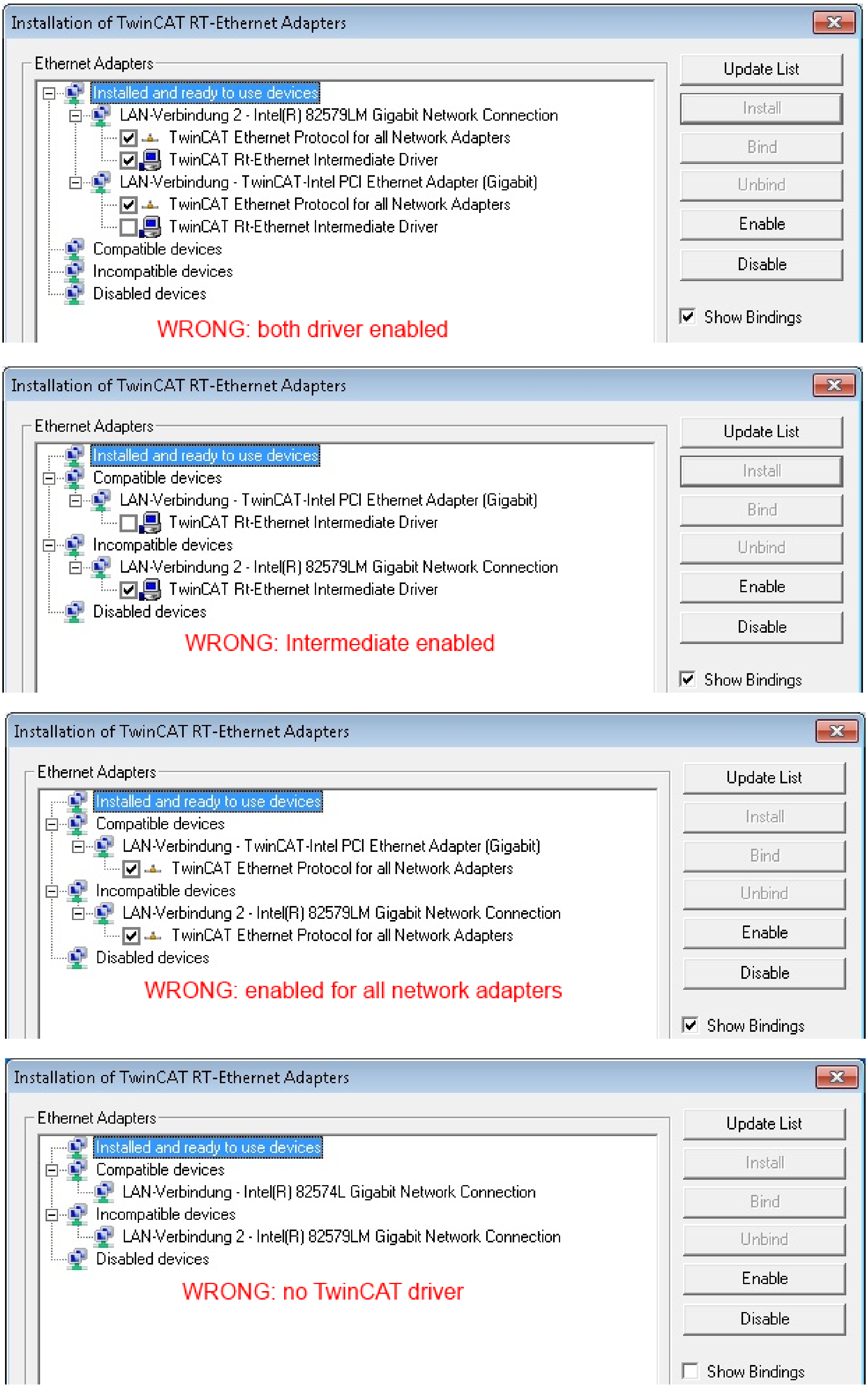


Fig. 32: *Incorrect driver settings for the Ethernet port*

IP address of the port used

IP address/DHCP

In most cases an Ethernet port that is configured as an EtherCAT device will not transport general IP packets. For this reason and in cases where an EL6601 or similar devices are used it is useful to specify a fixed IP address for this port via the “Internet Protocol TCP/IP” driver setting and to disable DHCP. In this way the delay associated with the DHCP client for the Ethernet port assigning itself a default IP address in the absence of a DHCP server is avoided. A suitable address space is 192.168.x.x, for example.

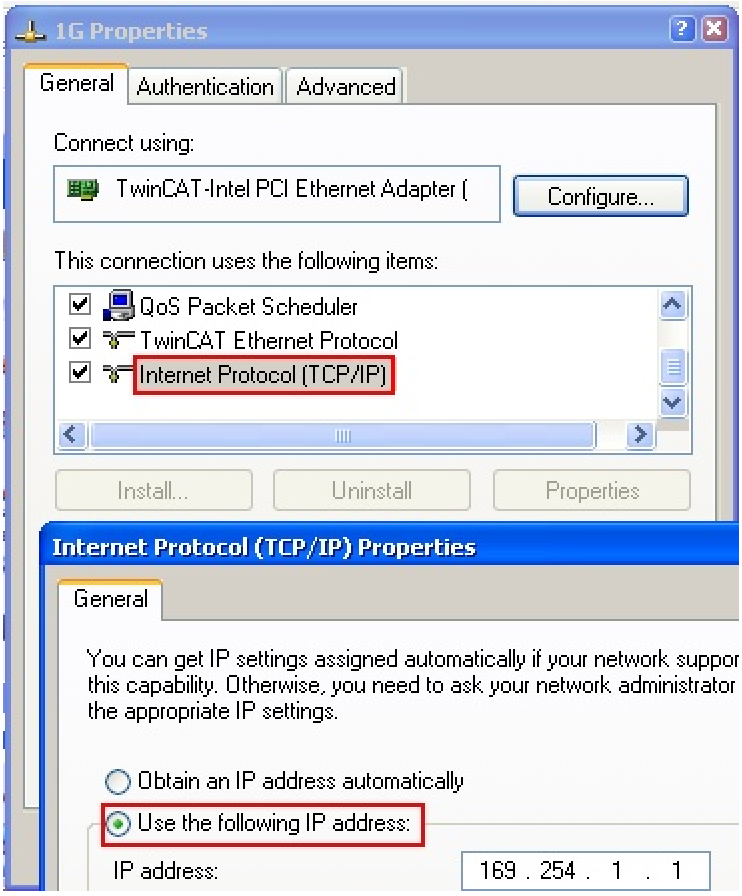


Fig. 33: *TCP/IP setting for the Ethernet port*

5.1.2 Notes regarding ESI device description

Installation of the latest ESI device description

The TwinCAT EtherCAT master/System Manager needs the device description files for the devices to be used in order to generate the configuration in online or offline mode. The device descriptions are contained in the so-called ESI files (EtherCAT Slave Information) in XML format. These files can be requested from the respective manufacturer and are made available for download. An *.xml file may contain several device descriptions.

The ESI files for Beckhoff EtherCAT devices are available on the Beckhoff website.

The ESI files should be stored in the TwinCAT installation directory.

Default settings:

- **TwinCAT 2**: C:\TwinCAT\IO\EtherCAT
- **TwinCAT 3**: C:\TwinCAT\3.1\Config\Io\EtherCAT

The files are read (once) when a new System Manager window is opened, if they have changed since the last time the System Manager window was opened.

A TwinCAT installation includes the set of Beckhoff ESI files that was current at the time when the TwinCAT build was created.

For TwinCAT 2.11/TwinCAT 3 and higher, the ESI directory can be updated from the System Manager, if the programming PC is connected to the Internet; by

- **TwinCAT 2**: Option → “Update EtherCAT Device Descriptions”
- **TwinCAT 3**: TwinCAT → EtherCAT Devices → “Update Device Descriptions (via ETG Website)…”

The TwinCAT ESI Updater [▸ 52] is available for this purpose.

ESI

The *.xml files are associated with *.xsd files, which describe the structure of the ESI XML files. To update the ESI device descriptions, both file types should therefore be updated.

Device differentiation

EtherCAT devices/slaves are distinguished by four properties, which determine the full device identifier. For example, the device identifier EL2521-0025-1018 consists of:

- family key “EL”
- name “2521”
- type “0025”
- and revision “1018”

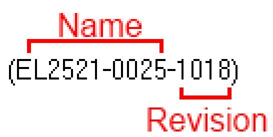


Fig. 34: *Identifier structure*

The order identifier consisting of name + type (here: EL2521-0010) describes the device function. The revision indicates the technical progress 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. Each revision has its own ESI description. See further notes [▸ 7].

Online description

If the EtherCAT configuration is created online through scanning of real devices (see section Online setup) and no ESI descriptions are available for a slave (specified by name and revision) that was found, the System Manager asks whether the description stored in the device should be used. In any case, the System Manager needs this information for setting up the cyclic and acyclic communication with the slave correctly.

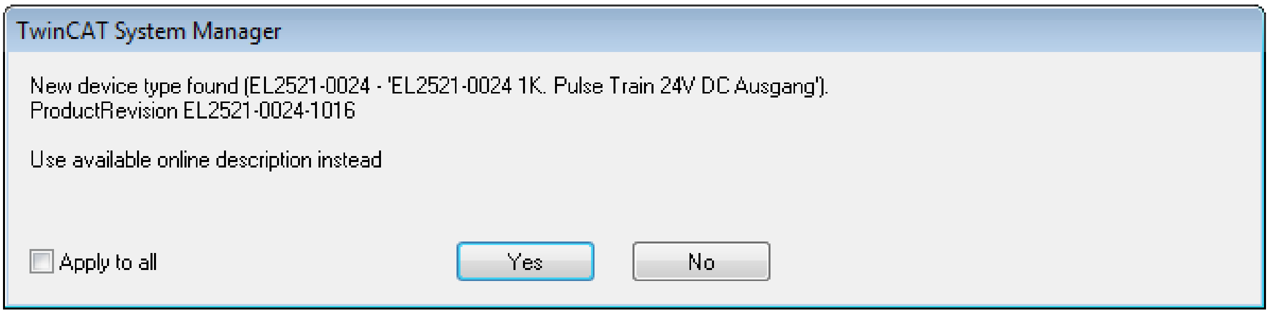


Fig. 35: *OnlineDescription information window (TwinCAT 2)*

In TwinCAT 3 a similar window appears, which also offers the Web update:

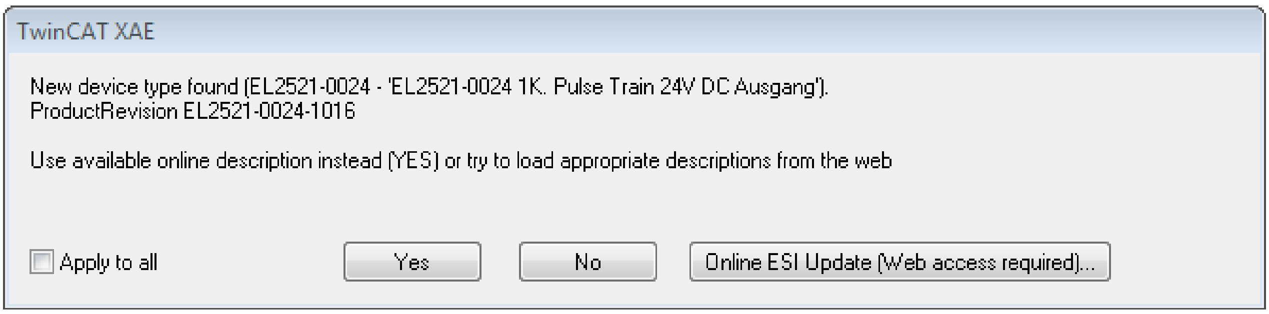


Fig. 36: *Information window OnlineDescription (TwinCAT 3)*

If possible, the *Yes* is to be rejected and the required ESI is to be requested from the device manufacturer. After installation of the XML/XSD file the configuration process should be repeated.

NOTE

Changing the 'usual' configuration through a scan

✓ If a scan discovers a device that is not yet known to TwinCAT, distinction has to be made between two cases. Taking the example here of the EL2521-0000 in the revision 1019

a) no ESI is present for the EL2521-0000 device at all, either for the revision 1019 or for an older revision. The ESI must then be requested from the manufacturer (in this case Beckhoff).

b) an ESI is present for the EL2521-0000 device, but only in an older revision, e.g. 1018 or 1017.
In this case an in-house check should first be performed to determine whether the spare parts stock allows the integration of the increased revision into the configuration at all. A new/higher revision usually also brings along new features. If these are not to be used, work can continue without reservations with the previous revision 1018 in the configuration. This is also stated by the Beckhoff compatibility rule.

Refer in particular to the chapter 'General notes on the use of Beckhoff EtherCAT IO components' and for manual configuration to the chapter 'Offline configuration creation' [▶ 53].

If the OnlineDescription is used regardless, the System Manager reads a copy of the device description from the EEPROM in the EtherCAT slave. In complex slaves the size of the EEPROM may not be sufficient for the complete ESI, in which case the ESI would be *incomplete* in the configurator. Therefore it's recommended using an offline ESI file with priority in such a case.

The System Manager creates for online recorded device descriptions a new file "OnlineDescription0000...xml" in its ESI directory, which contains all ESI descriptions that were read online.

Fig. 37: *File OnlineDescription.xml created by the System Manager*

Is a slave desired to be added manually to the configuration at a later stage, online created slaves are indicated by a prepended symbol “>” in the selection list (see Figure *“Indication of an online recorded ESI of EL2521 as an example”*).

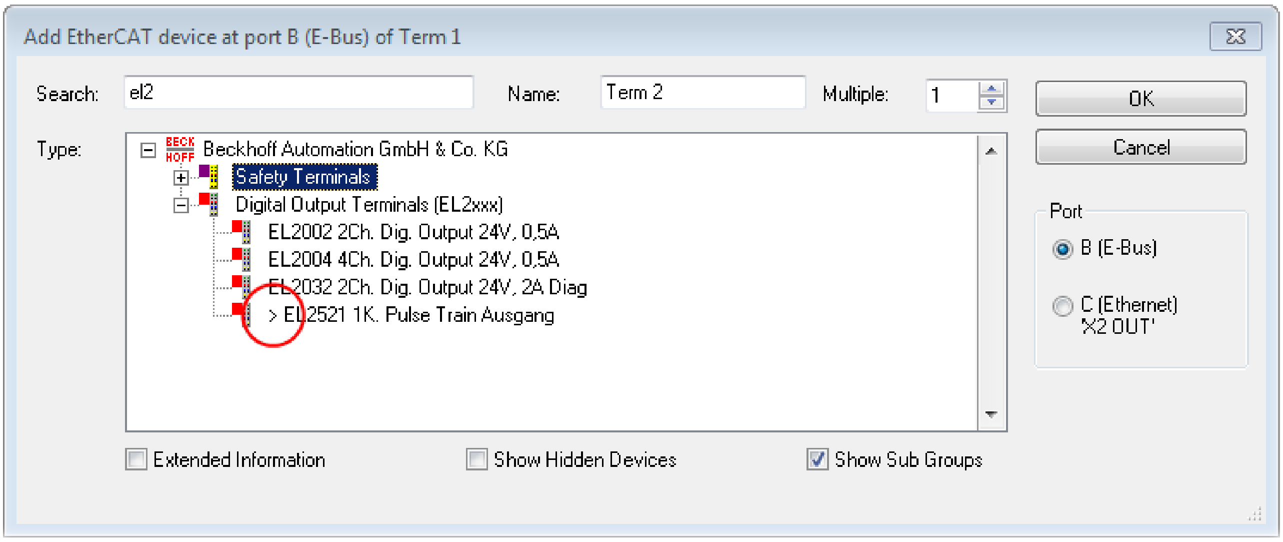


Fig. 38: *Indication of an online recorded ESI of EL2521 as an example*

If such ESI files are used and the manufacturer's files become available later, the file OnlineDescription.xml should be deleted as follows:

- close all System Manager windows
- restart TwinCAT in Config mode
- delete "OnlineDescription0000...xml"
- restart TwinCAT System Manager

This file should not be visible after this procedure, if necessary press <F5> to update

OnlineDescription for TwinCAT 3.x

In addition to the file described above "OnlineDescription0000...xml" , a so called EtherCAT cache with new discovered devices is created by TwinCAT 3.x, e.g. under Windows 7:

C:\User\[USERNAME]\AppData\Roaming\Beckhoff\TwinCAT3\Components\Base\EtherCATCache.xml

(Please note the language settings of the OS!)
You have to delete this file, too.

Faulty ESI file

If an ESI file is faulty and the System Manager is unable to read it, the System Manager brings up an information window.

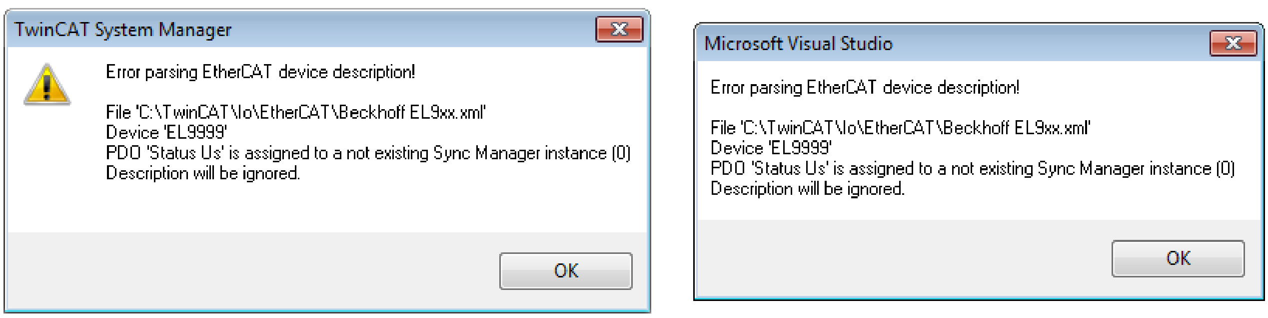


Fig. 39: *Information window for faulty ESI file (left: TwinCAT 2; right: TwinCAT 3)*

Reasons may include:

- Structure of the *.xml does not correspond to the associated *.xsd file → check your schematics
- Contents cannot be translated into a device description → contact the file manufacturer

5.1.3 TwinCAT ESI Updater

For TwinCAT 2.11 and higher, the System Manager can search for current Beckhoff ESI files automatically, if an online connection is available:

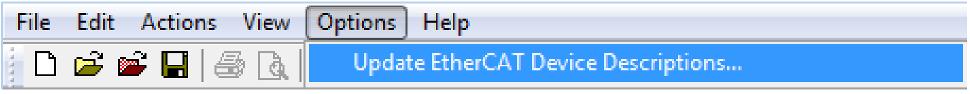


Fig. 40: *Using the ESI Updater (>= TwinCAT 2.11)*

The call up takes place under:
“Options” → "Update EtherCAT Device Descriptions"

Selection under TwinCAT 3:

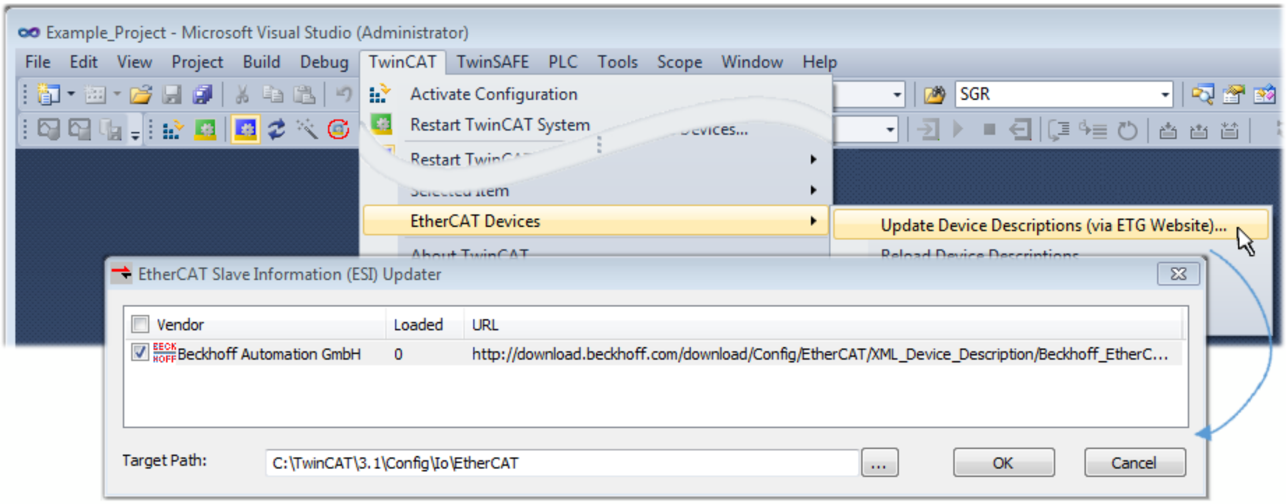


Fig. 41: *Using the ESI Updater (TwinCAT 3)*

The ESI Updater (TwinCAT 3) is a convenient option for automatic downloading of ESI data provided by EtherCAT manufacturers via the Internet into the TwinCAT directory (ESI = EtherCAT slave information). TwinCAT accesses the central ESI ULR directory list stored at ETG; the entries can then be viewed in the Updater dialog, although they cannot be changed there.

The call up takes place under:
“TwinCAT“ → „EtherCAT Devices“ → “Update Device Description (via ETG Website)…“.

5.1.4 Distinction between Online and Offline

The distinction between online and offline refers to the presence of the actual I/O environment (drives, terminals, EJ-modules). If the configuration is to be prepared in advance of the system configuration as a programming system, e.g. on a laptop, this is only possible in “Offline configuration” mode. In this case all components have to be entered manually in the configuration, e.g. based on the electrical design.

If the designed control system is already connected to the EtherCAT system and all components are energised and the infrastructure is ready for operation, the TwinCAT configuration can simply be generated through “scanning” from the runtime system. This is referred to as online configuration.

In any case, during each startup the EtherCAT master checks whether the slaves it finds match the configuration. This test can be parameterised in the extended slave settings. Refer to note “Installation of the latest ESI-XML device description” [▶ 48].

For preparation of a configuration:

- the real EtherCAT hardware (devices, couplers, drives) must be present and installed
- the devices/modules must be connected via EtherCAT cables or in the terminal/ module strand in the same way as they are intended to be used later

- the devices/modules be connected to the power supply and ready for communication
- TwinCAT must be in CONFIG mode on the target system.

The online scan process consists of:

- detecting the EtherCAT device [▶ 58] (Ethernet port at the IPC)
- detecting the connected EtherCAT devices [▶ 59]. This step can be carried out independent of the preceding step
- troubleshooting [▶ 62]

The scan with existing configuration [▶ 63] can also be carried out for comparison.

5.1.5 OFFLINE configuration creation

Creating the EtherCAT device

Create an EtherCAT device in an empty System Manager window.

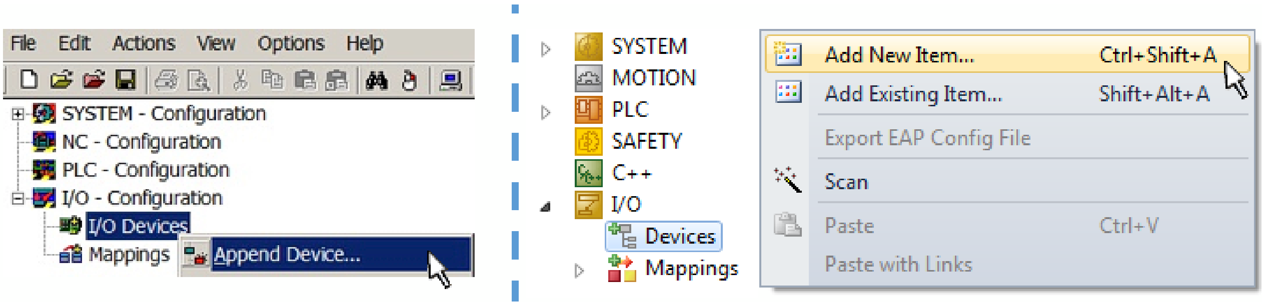


Fig. 42: *Append EtherCAT device (left: TwinCAT 2; right: TwinCAT 3)*

Select type 'EtherCAT' for an EtherCAT I/O application with EtherCAT slaves. For the present publisher/ subscriber service in combination with an EL6601/EL6614 terminal select "EtherCAT Automation Protocol via EL6601".

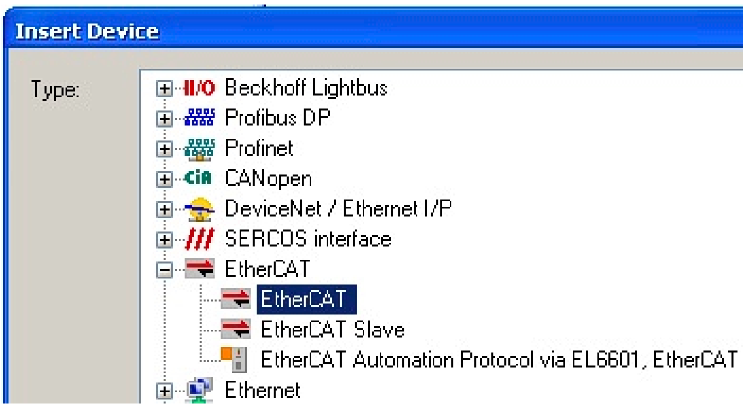


Fig. 43: *Selecting the EtherCAT connection (TwinCAT 2.11, TwinCAT 3)*

Then assign a real Ethernet port to this virtual device in the runtime system.

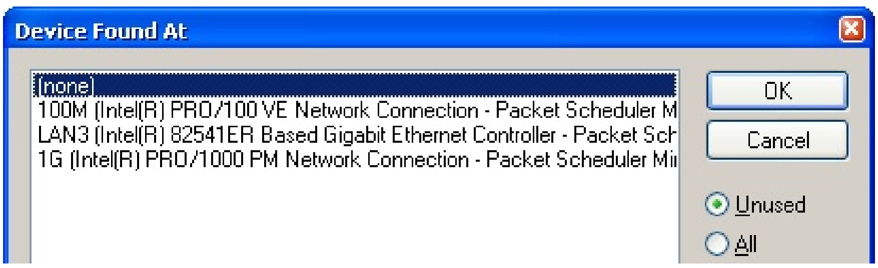


Fig. 44: *Selecting the Ethernet port*

This query may appear automatically when the EtherCAT device is created, or the assignment can be set/modified later in the properties dialog; see Fig. *"EtherCAT device properties (TwinCAT 2)"*.

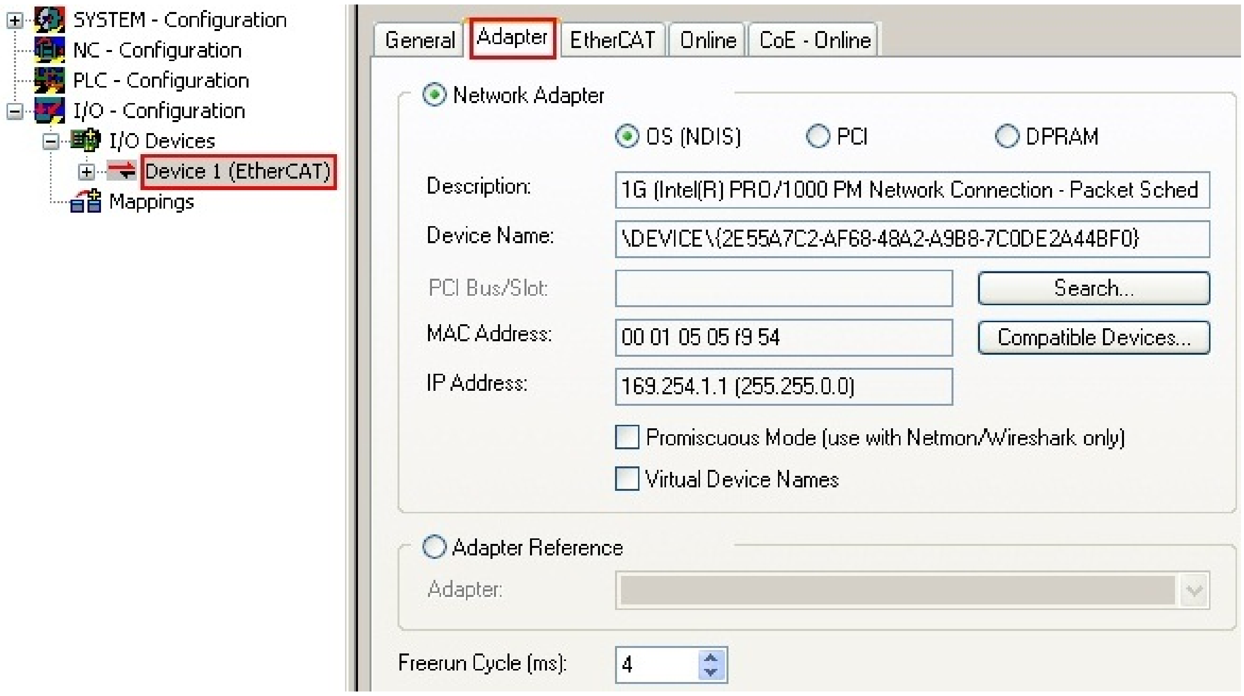
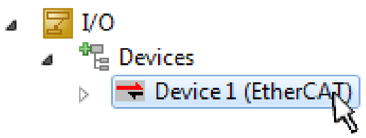


Fig. 45: *EtherCAT device properties (TwinCAT 2)*

TwinCAT 3: the properties of the EtherCAT device can be opened by double click on "Device .. (EtherCAT)" within the Solution Explorer under "I/O":



Selecting the Ethernet port

Ethernet ports can only be selected for EtherCAT devices for which the TwinCAT real-time driver is installed. This has to be done separately for each port. Please refer to the respective installation page [▶ 42].

Defining EtherCAT slaves

Further devices can be appended by right-clicking on a device in the configuration tree.

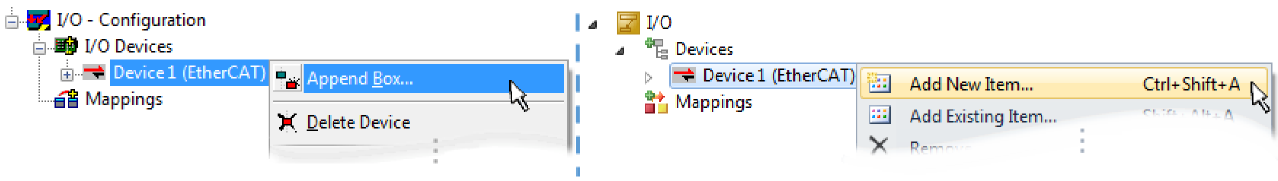


Fig. 46: *Appending EtherCAT devices (left: TwinCAT 2; right: TwinCAT 3)*

The dialog for selecting a new device opens. Only devices for which ESI files are available are displayed.

Only devices are offered for selection that can be appended to the previously selected device. Therefore the physical layer available for this port is also displayed (Fig. *"Selection dialog for new EtherCAT device"*, A). In the case of cable-based Fast-Ethernet physical layer with PHY transfer, then also only cable-based devices are available, as shown in Fig. *"Selection dialog for new EtherCAT device"*. If the preceding device has several free ports (e.g. EK1122 or EK1100), the required port can be selected on the right-hand side (A).

Overview of physical layer

- "Ethernet": cable-based 100BASE-TX: EK couplers, EP boxes, devices with RJ45/M8/M12 connector

- "E-Bus": LVDS "terminal bus", "EJ-module": EL/ES terminals, various modular modules

The search field facilitates finding specific devices (since TwinCAT 2.11 or TwinCAT 3).

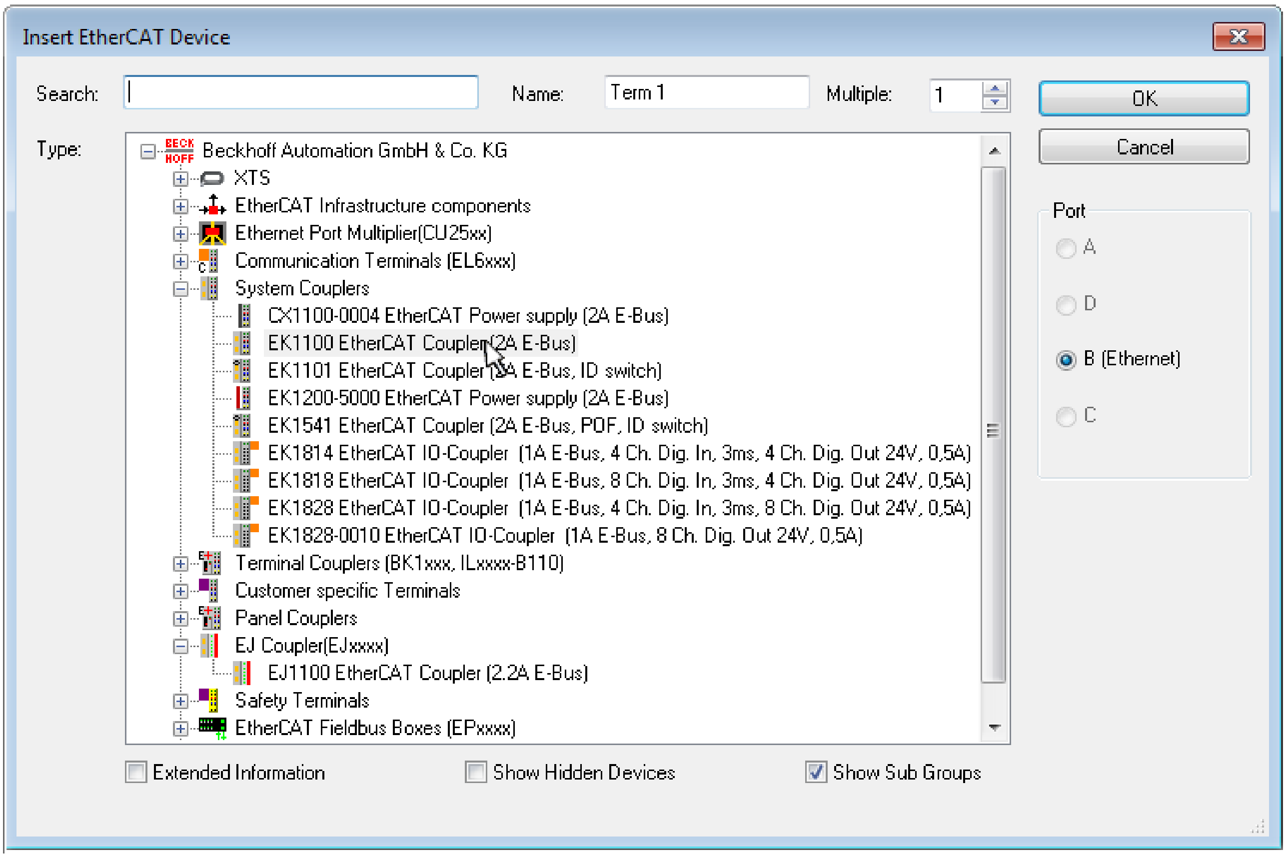


Fig. 47: *Selection dialog for new EtherCAT device*

By default only the name/device type is used as selection criterion. For selecting a specific revision of the device the revision can be displayed as "Extended Information".

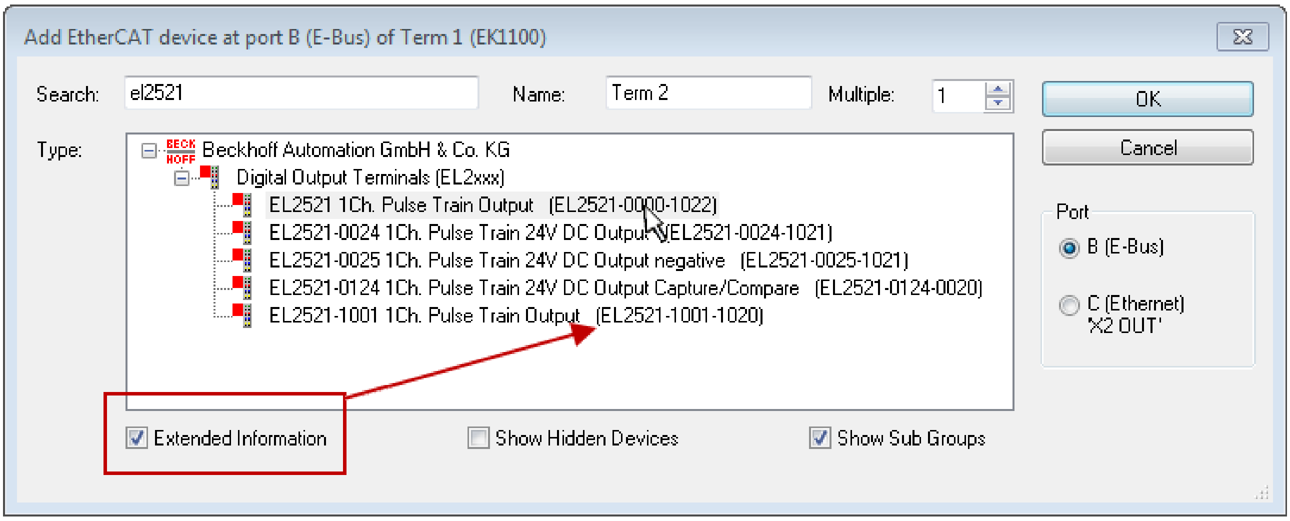


Fig. 48: *Display of device revision*

In many cases several device revisions were created for historic or functional reasons, e.g. through technological advancement. For simplification purposes (see Fig. *"Selection dialog for new EtherCAT device"*) only the last (i.e. highest) revision and therefore the latest state of production is displayed in the selection dialog for Beckhoff devices. To show all device revisions available in the system as ESI descriptions tick the "Show Hidden Devices" check box, see Fig. *"Display of previous revisions"*.

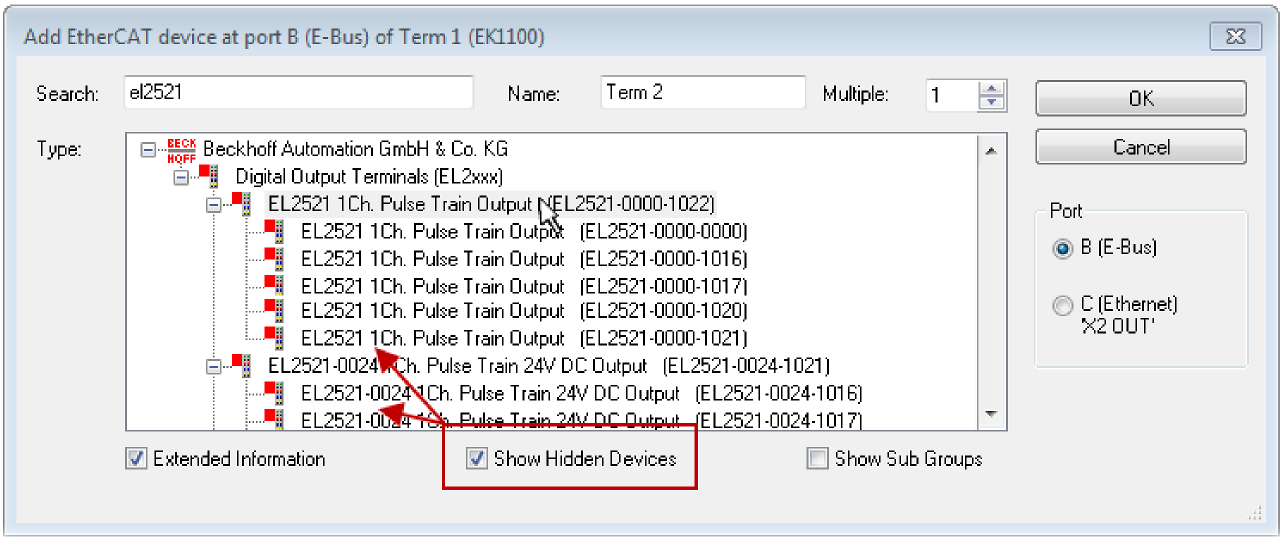


Fig. 49: *Display of previous revisions*

Device selection based on revision, compatibility

The ESI description also defines the process image, the communication type between master and slave/device and the device functions, if applicable. The physical device (firmware, if available) has to support the communication queries/settings of the master. This is backward compatible, i.e. newer devices (higher revision) should be supported if the EtherCAT master addresses them as an older revision. The following compatibility rule of thumb is to be assumed for Beckhoff EtherCAT Terminals/ Boxes/ EJ-modules:

device revision in the system >= device revision in the configuration

This also enables subsequent replacement of devices without changing the configuration (different specifications are possible for drives).

Example:

If an EL2521-0025-**1018** is specified in the configuration, an EL2521-0025-**1018** or higher (-**1019**, -**1020**) can be used in practice.

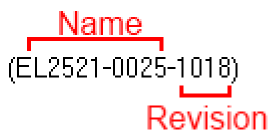


Fig. 50: *Name/revision of the terminal*

If current ESI descriptions are available in the TwinCAT system, the last revision offered in the selection dialog matches the Beckhoff state of production. It is recommended to use the last device revision when creating a new configuration, if current Beckhoff devices are used in the real application. Older revisions should only be used if older devices from stock are to be used in the application.

In this case the process image of the device is shown in the configuration tree and can be parameterised as follows: linking with the task, CoE/DC settings, plug-in definition, startup settings, ...

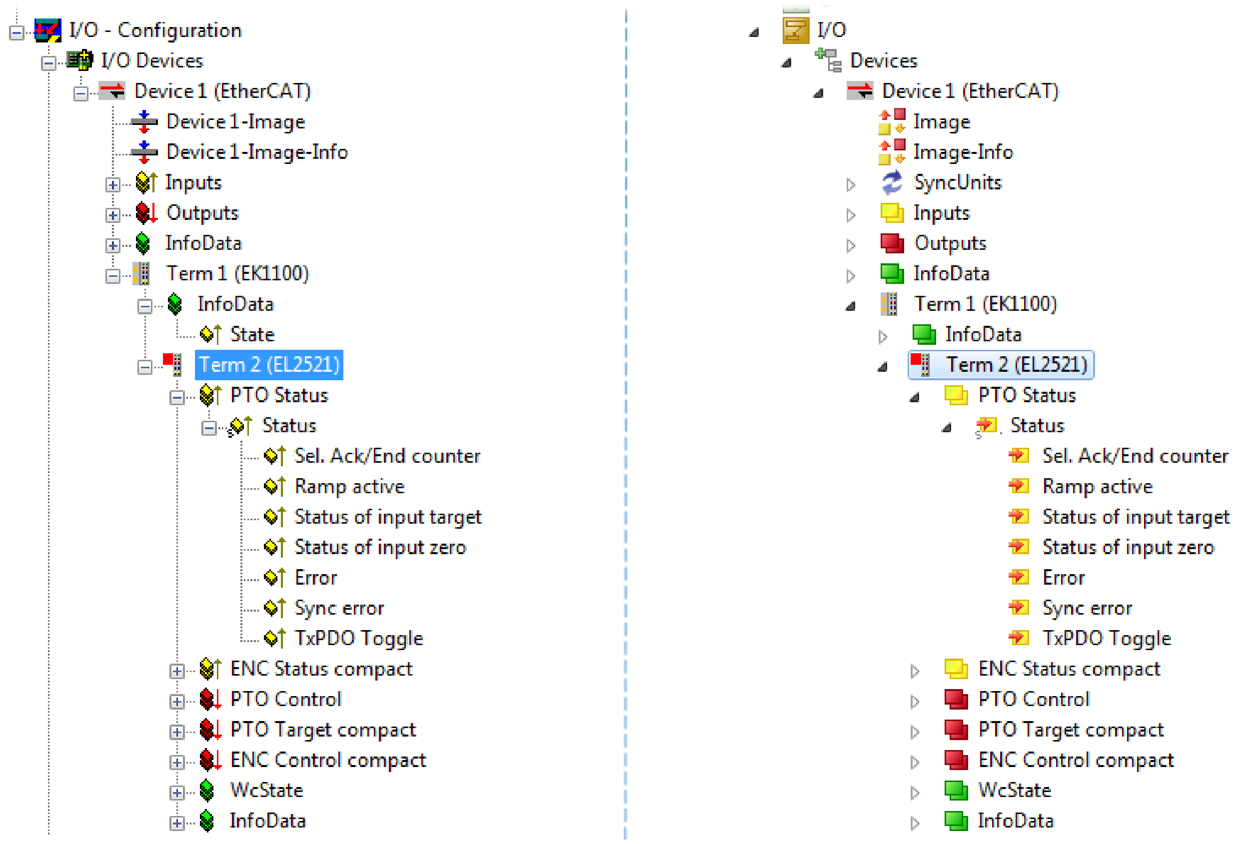


Fig. 51: *EtherCAT terminal in the TwinCAT tree (left: TwinCAT 2; right: TwinCAT 3)*

5.1.6 ONLINE configuration creation

Detecting/scanning of the EtherCAT device

The online device search can be used if the TwinCAT system is in CONFIG mode. This can be indicated by a symbol right below in the information bar:

- on TwinCAT 2 by a blue display “Config Mode” within the System Manager window: 

.
- on TwinCAT 3 within the user interface of the development environment by a symbol  .

TwinCAT can be set into this mode:

- TwinCAT 2: by selection of  in the Menubar or by “Actions” → “Set/Reset TwinCAT to Config Mode…”
- TwinCAT 3: by selection of  in the Menubar or by „TwinCAT“ → “Restart TwinCAT (Config Mode)“

Online scanning in Config mode

The online search is not available in RUN mode (production operation). Note the differentiation between TwinCAT programming system and TwinCAT target system.

The TwinCAT 2 icon () or TwinCAT 3 icon () within the Windows-Taskbar always shows the TwinCAT mode of the local IPC. Compared to that, the System Manager window of TwinCAT 2 or the user interface of TwinCAT 3 indicates the state of the target system.

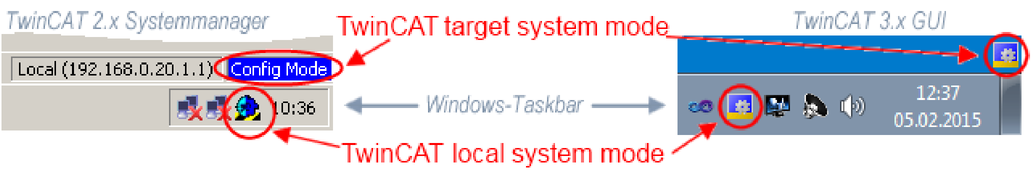


Fig. 52: *Differentiation local/target system (left: TwinCAT 2; right: TwinCAT 3)*

Right-clicking on “I/O Devices” in the configuration tree opens the search dialog.

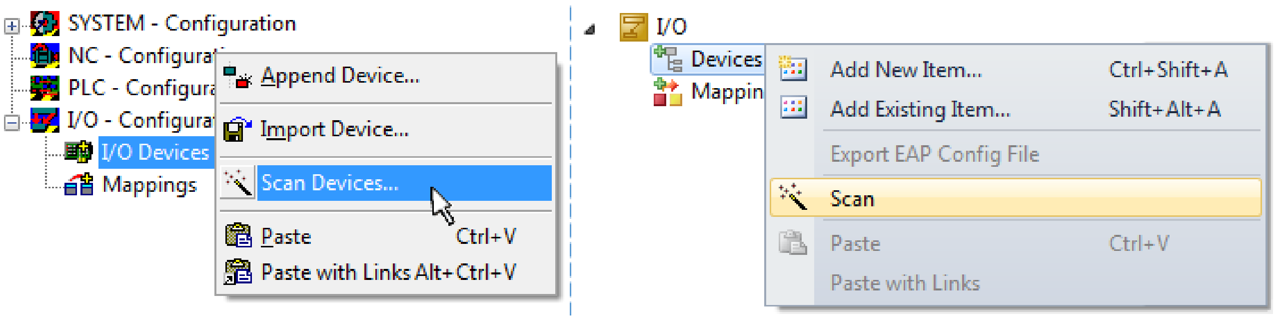


Fig. 53: *Scan Devices (left: TwinCAT 2; right: TwinCAT 3)*

This scan mode attempts to find not only EtherCAT devices (or Ethernet ports that are usable as such), but also NOVRAM, fieldbus cards, SMB etc. However, not all devices can be found automatically.

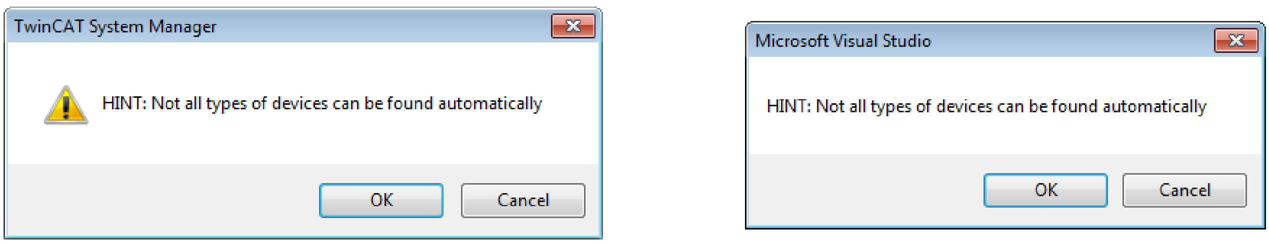


Fig. 54: *Note for automatic device scan (left: TwinCAT 2; right: TwinCAT 3)*

Ethernet ports with installed TwinCAT real-time driver are shown as “RT Ethernet” devices. An EtherCAT frame is sent to these ports for testing purposes. If the scan agent detects from the response that an EtherCAT slave is connected, the port is immediately shown as an “EtherCAT Device” .

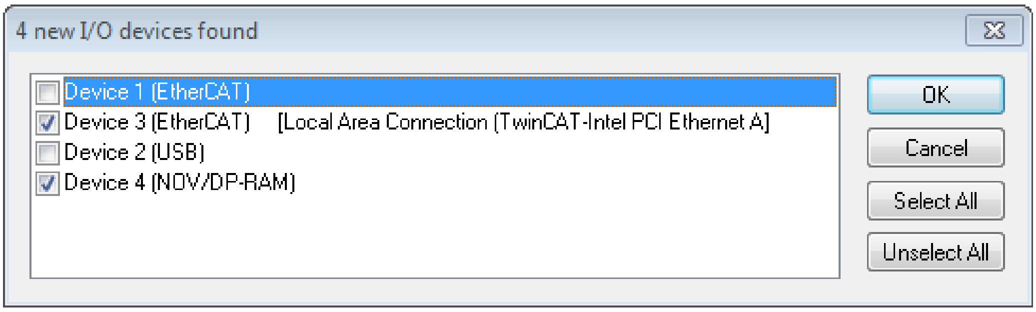


Fig. 55: *Detected Ethernet devices*

Via respective checkboxes devices can be selected (as illustrated in Fig. “*Detected Ethernet devices*” e.g. Device 3 and Device 4 were chosen). After confirmation with “OK” a device scan is suggested for all selected devices, see Fig.: “*Scan query after automatic creation of an EtherCAT device*”.

Selecting the Ethernet port

Ethernet ports can only be selected for EtherCAT devices for which the TwinCAT real-time driver is installed. This has to be done separately for each port. Please refer to the respective installation page [▶ 42].

Detecting/Scanning the EtherCAT devices

Online scan functionality

During a scan the master queries the identity information of the EtherCAT slaves from the slave EEPROM. The name and revision are used for determining the type. The respective devices are located in the stored ESI data and integrated in the configuration tree in the default state defined there.

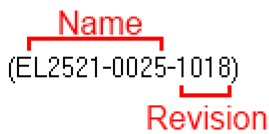


Fig. 56: *Example default state*

NOTE

Slave scanning in practice in series machine production

The scanning function should be used with care. It is a practical and fast tool for creating an initial configuration as a basis for commissioning. In series machine production or reproduction of the plant, however, the function should no longer be used for the creation of the configuration, but if necessary for comparison [▶ 63] with the defined initial configuration.Background: since Beckhoff occasionally increases the revision version of the delivered products for product maintenance reasons, a configuration can be created by such a scan which (with an identical machine construction) is identical according to the device list; however, the respective device revision may differ from the initial configuration.

Example:

Company A builds the prototype of a machine B, which is to be produced in series later on. To do this the prototype is built, a scan of the IO devices is performed in TwinCAT and the initial configuration ‘B.tsm’ is created. The EL2521-0025 EtherCAT terminal with the revision 1018 is located somewhere. It is thus built into the TwinCAT configuration in this way:

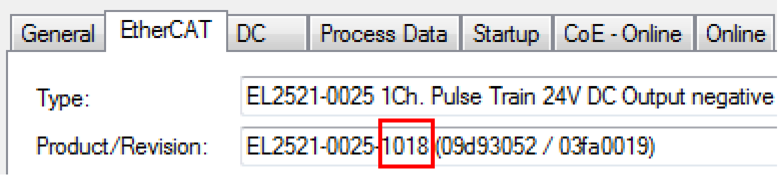


Fig. 57: *Installing EthetCAT terminal with revision -1018*

Likewise, during the prototype test phase, the functions and properties of this terminal are tested by the programmers/commissioning engineers and used if necessary, i.e. addressed from the PLC 'B.pro' or the NC. (the same applies correspondingly to the TwinCAT 3 solution files).

The prototype development is now completed and series production of machine B starts, for which Beckhoff continues to supply the EL2521-0025-0018. If the commissioning engineers of the series machine production department always carry out a scan, a B configuration with the identical contents results again for each machine. Likewise, A might create spare parts stores worldwide for the coming series-produced machines with EL2521-0025-1018 terminals.

After some time Beckhoff extends the EL2521-0025 by a new feature C. Therefore the FW is changed, outwardly recognizable by a higher FW version and **a new revision -1019**. Nevertheless the new device naturally supports functions and interfaces of the predecessor version(s); an adaptation of 'B.tsm' or even 'B.pro' is therefore unnecessary. The series-produced machines can continue to be built with 'B.tsm' and 'B.pro'; it makes sense to perform a comparative scan [▶ 63] against the initial configuration 'B.tsm' in order to check the built machine.

However, if the series machine production department now doesn't use 'B.tsm', but instead carries out a scan to create the productive configuration, the revision **-1019** is automatically detected and built into the configuration:

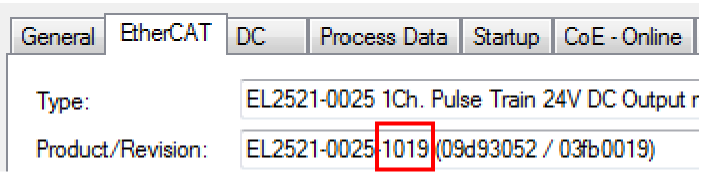


Fig. 58: *Detection of EtherCAT terminal with revision -1019*

This is usually not noticed by the commissioning engineers. TwinCAT cannot signal anything either, since virtually a new configuration is created. According to the compatibility rule, however, this means that no EL2521-0025-**1018** should be built into this machine as a spare part (even if this nevertheless works in the vast majority of cases).

In addition, it could be the case that, due to the development accompanying production in company A, the new feature C of the EL2521-0025-1019 (for example, an improved analog filter or an additional process data for the diagnosis) is discovered and used without in-house consultation. The previous stock of spare part devices are then no longer to be used for the new configuration 'B2.tsm' created in this way.Þ if series machine production is established, the scan should only be performed for informative purposes for comparison with a defined initial configuration. Changes are to be made with care!

If an EtherCAT device was created in the configuration (manually or through a scan), the I/O field can be scanned for devices/slaves.

Fig. 59: *Scan query after automatic creation of an EtherCAT device (left: TwinCAT 2; right: TwinCAT 3)*

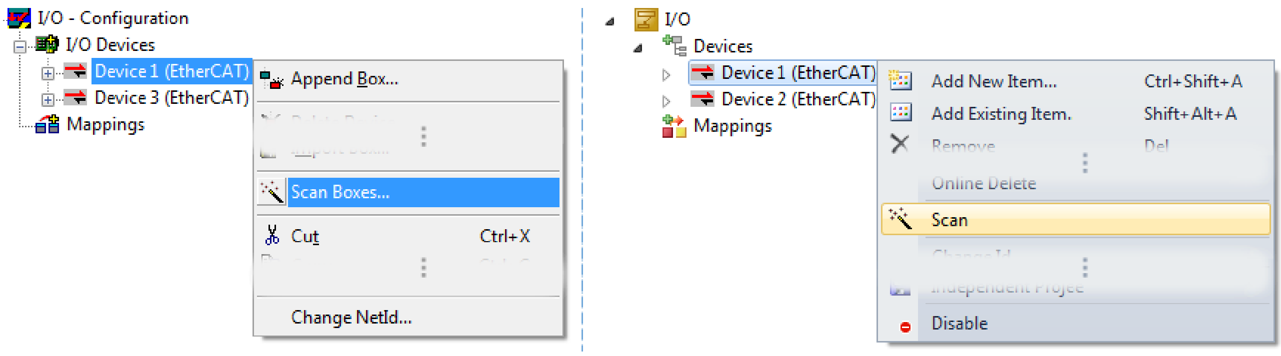


Fig. 60: *Manual triggering of a device scan on a specified EtherCAT device (left: TwinCAT 2; right: TwinCAT 3)*

In the System Manager (TwinCAT 2) or the User Interface (TwinCAT 3) the scan process can be monitored via the progress bar at the bottom in the status bar.

Fig. 61: *Scan progressexemplary by TwinCAT 2*

The configuration is established and can then be switched to online state (OPERATIONAL).

Fig. 62: *Config/FreeRun query (left: TwinCAT 2; right: TwinCAT 3)*

In Config/FreeRun mode the System Manager display alternates between blue and red, and the EtherCAT device continues to operate with the idling cycle time of 4 ms (default setting), even without active task (NC, PLC).

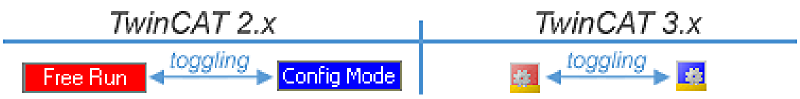


Fig. 63: *Displaying of "Free Run" and "Config Mode" toggling right below in the status bar*

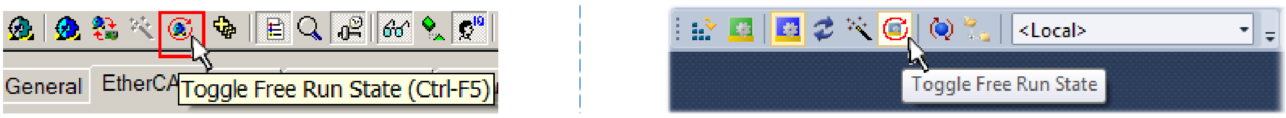


Fig. 64: *TwinCAT can also be switched to this state by using a button (left: TwinCAT 2; right: TwinCAT 3)*

The EtherCAT system should then be in a functional cyclic state, as shown in Fig. *"Online display example"*.

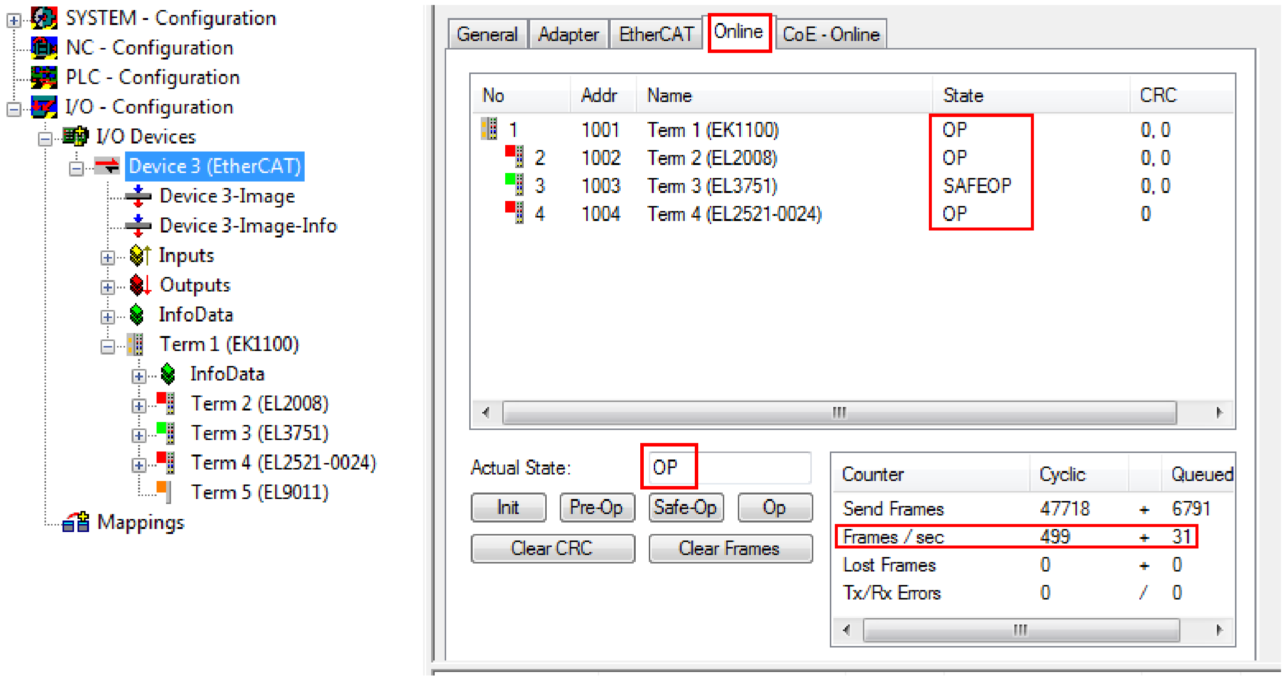


Fig. 65: *Online display example*

Please note:

- all slaves should be in OP state
- the EtherCAT master should be in “Actual State” OP
- “frames/sec” should match the cycle time taking into account the sent number of frames
- no excessive “LostFrames” or CRC errors should occur

The configuration is now complete. It can be modified as described under manual procedure [▶ 53].

Troubleshooting

Various effects may occur during scanning.

- An **unknown device** is detected, i.e. an EtherCAT slave for which no ESI XML description is available. In this case the System Manager offers to read any ESI that may be stored in the device. This case is described in the chapter "Notes regarding ESI device description".
- **Device are not detected properly**
  Possible reasons include:
  - faulty data links, resulting in data loss during the scan
  - slave has invalid device description
  The connections and devices should be checked in a targeted manner, e.g. via the emergency scan. Then re-run the scan.

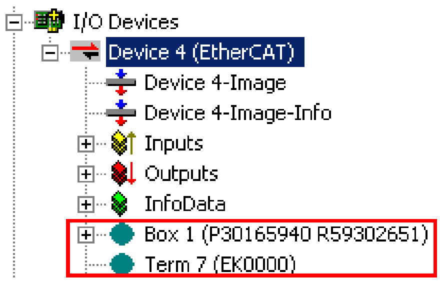


Fig. 66: *Faulty identification*

In the System Manager such devices may be set up as EK0000 or unknown devices. Operation is not possible or meaningful.

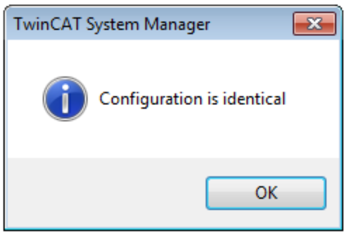
Scan over existing Configuration

NOTE

Change of the configuration after comparison

With this scan (TwinCAT 2.11 or 3.1) only the device properties vendor (manufacturer), device name and revision are compared at present! A ‘ChangeTo’ or ‘Copy’ should only be carried out with care, taking into consideration the Beckhoff IO compatibility rule (see above). The device configuration is then replaced by the revision found; this can affect the supported process data and functions.

If a scan is initiated for an existing configuration, the actual I/O environment may match the configuration exactly or it may differ. This enables the configuration to be compared.



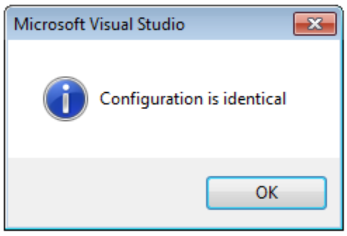


Fig. 67: *Identical configuration (left: TwinCAT 2; right: TwinCAT 3)*

If differences are detected, they are shown in the correction dialog, so that the user can modify the configuration as required.

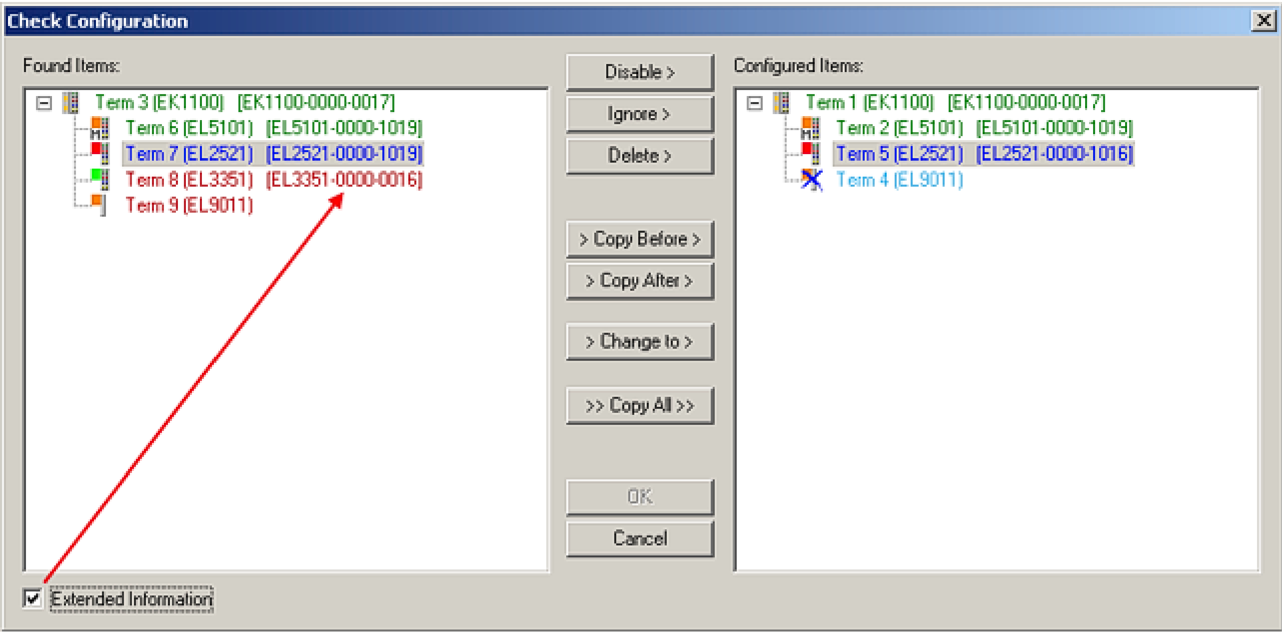


Fig. 68: *Correction dialog*

It is advisable to tick the “Extended Information” check box to reveal differences in the revision.

Colour	Explanation
green	This EtherCAT slave matches the entry on the other side. Both type and revision match.
blue	This EtherCAT slave is present on the other side, but in a different revision. This other revision can have other default values for the process data as well as other/additional functions. If the found revision is higher than the configured revision, the slave may be used provided compatibility issues are taken into account. If the found revision is lower than the configured revision, it is likely that the slave cannot be used. The found device may not support all functions that the master expects based on the higher revision number.
light blue	This EtherCAT slave is ignored (“Ignore” button)
red	• This EtherCAT slave is not present on the other side. • It is present, but in a different revision, which also differs in its properties from the one specified. The compatibility principle then also applies here: if the found revision is higher than the configured revision, use is possible provided compatibility issues are taken into account, since the successor devices should support the functions of the predecessor devices. If the found revision is lower than the configured revision, it is likely that the slave cannot be used. The found device may not support all functions that the master expects based on the higher revision number.

Device selection based on revision, compatibility

The ESI description also defines the process image, the communication type between master and slave/device and the device functions, if applicable. The physical device (firmware, if available) has to support the communication queries/settings of the master. This is backward compatible, i.e. newer devices (higher revision) should be supported if the EtherCAT master addresses them as an older revision. The following compatibility rule of thumb is to be assumed for Beckhoff EtherCAT Terminals/ Boxes/ EJ-modules:

device revision in the system >= device revision in the configuration

This also enables subsequent replacement of devices without changing the configuration (different specifications are possible for drives).

Example:

If an EL2521-0025-**1018** is specified in the configuration, an EL2521-0025-**1018** or higher (-**1019**, -**1020**) can be used in practice.

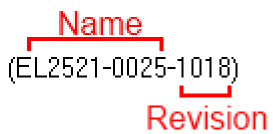


Fig. 69: *Name/revision of the terminal*

If current ESI descriptions are available in the TwinCAT system, the last revision offered in the selection dialog matches the Beckhoff state of production. It is recommended to use the last device revision when creating a new configuration, if current Beckhoff devices are used in the real application. Older revisions should only be used if older devices from stock are to be used in the application.

In this case the process image of the device is shown in the configuration tree and can be parameterised as follows: linking with the task, CoE/DC settings, plug-in definition, startup settings, ...

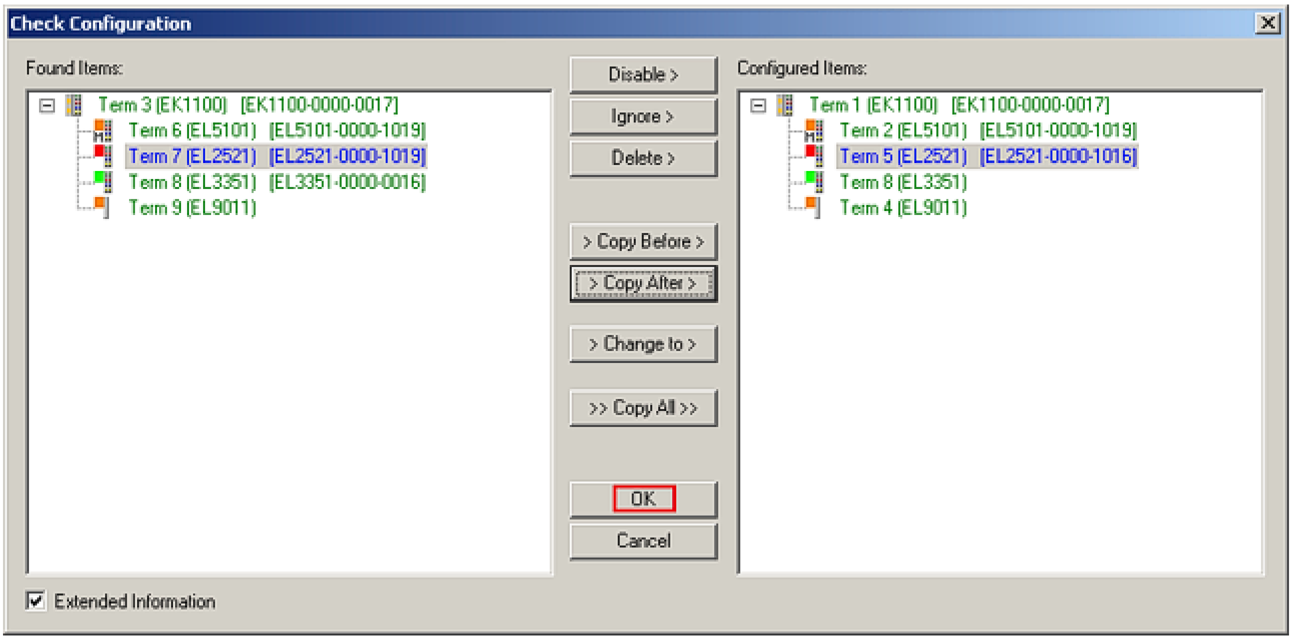


Fig. 70: *Correction dialog with modifications*

Once all modifications have been saved or accepted, click “OK” to transfer them to the real *.tsm configuration.

Change to Compatible Type

TwinCAT offers a function *“Change to Compatible Type…”* for the exchange of a device whilst retaining the links in the task.

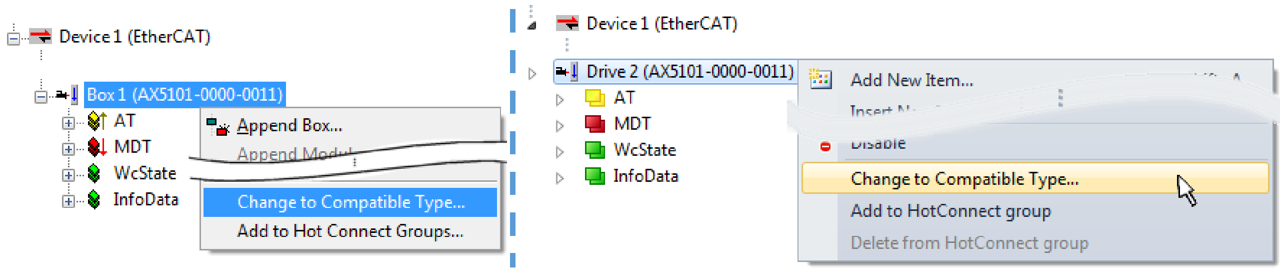


Fig. 71: *Dialog “Change to Compatible Type…” (left: TwinCAT 2; right: TwinCAT 3)*

This function is preferably to be used on AX5000 devices.

Change to Alternative Type

The TwinCAT System Manager offers a function for the exchange of a device: *Change to Alternative Type*

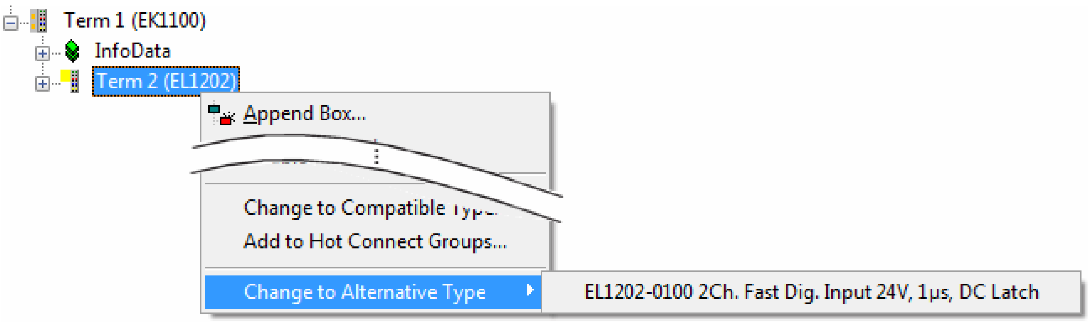


Fig. 72: *TwinCAT 2 Dialog Change to Alternative Type*

If called, the System Manager searches in the procured device ESI (in this example: EL1202-0000) for details of compatible devices contained there. The configuration is changed and the ESI-EEPROM is overwritten at the same time – therefore this process is possible only in the online state (ConfigMode).

5.1.7 EtherCAT subscriber configuration

In the left-hand window of the TwinCAT 2 System Manager or the Solution Explorer of the TwinCAT 3 Development Environment respectively, click on the element of the terminal within the tree you wish to configure (in the example: EL3751 Terminal 3).

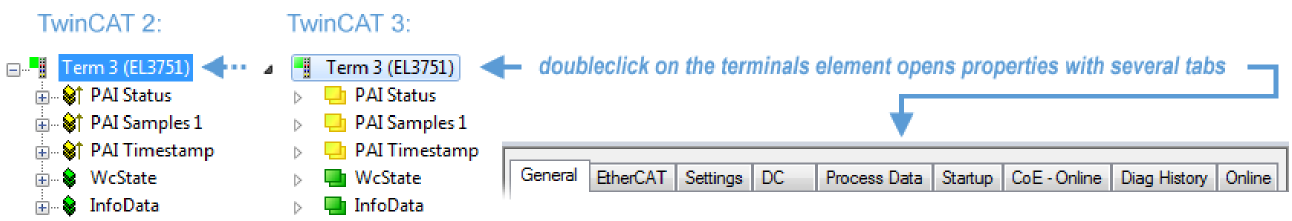


Fig. 73: *Branch element as terminal EL3751*

In the right-hand window of the TwinCAT System manager (TwinCAT 2) or the Development Environment (TwinCAT 3), various tabs are now available for configuring the terminal. And yet the dimension of complexity of a subscriber determines which tabs are provided. Thus as illustrated in the example above the terminal EL3751 provides many setup options and also a respective number of tabs are available. On the contrary by the terminal EL1004 for example the tabs "General", "EtherCAT", "Process Data" and “Online“ are available only. Several terminals, as for instance the EL6695 provide special functions by a tab with its own terminal name, so “EL6695” in this case. A specific tab “Settings” by terminals with a wide range of setup options will be provided also (e.g. EL3751).

„General“ tab

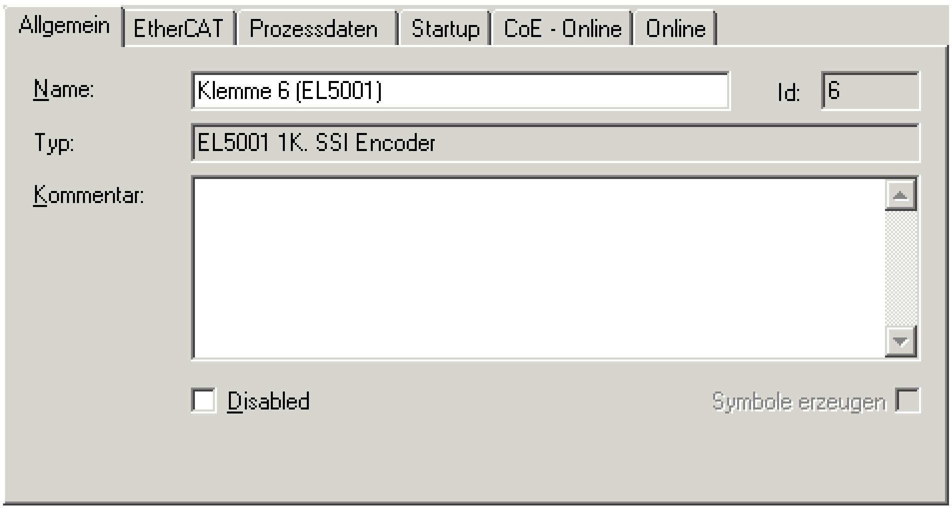


Fig. 74: “General” tab

Name	Name of the EtherCAT device
Id	Number of the EtherCAT device
Type	EtherCAT device type
Comment	Here you can add a comment (e.g. regarding the system).
Disabled	Here you can deactivate the EtherCAT device.
Create symbols	Access to this EtherCAT slave via ADS is only available if this control box is activated.

„EtherCAT“ tab

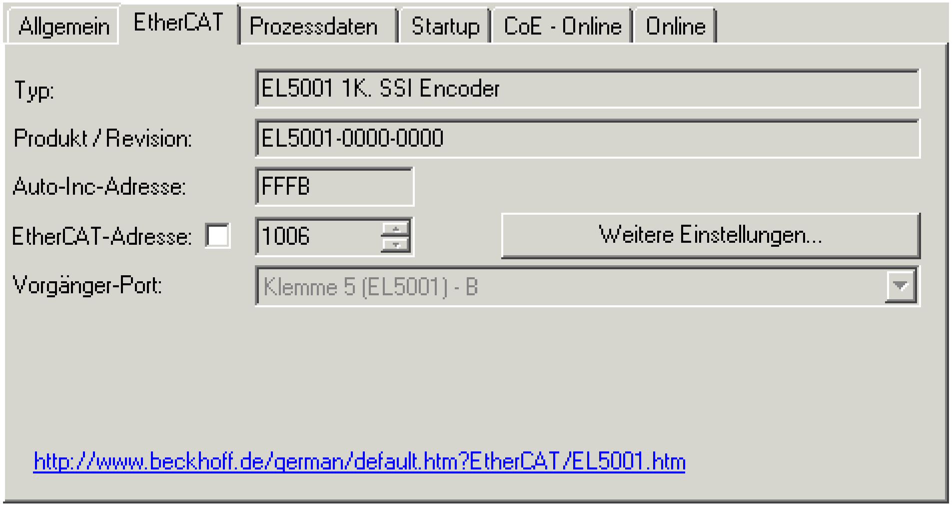


Fig. 75: „EtherCAT“ tab

Type	EtherCAT device type
Product/Revision	Product and revision number of the EtherCAT device
Auto Inc Addr.	Auto increment address of the EtherCAT device. The auto increment address can be used for addressing each EtherCAT device in the communication ring through its physical position. Auto increment addressing is used during the start-up phase when the EtherCAT master allocates addresses to the EtherCAT devices. With auto increment addressing the first EtherCAT slave in the ring has the address 0000_{hex}. For each further slave the address is decremented by 1 ($FFFF_{hex}$, $FFFE_{hex}$ etc.).
EtherCAT Addr.	Fixed address of an EtherCAT slave. This address is allocated by the EtherCAT master during the start-up phase. Tick the control box to the left of the input field in order to modify the default value.
Previous Port	Name and port of the EtherCAT device to which this device is connected. If it is possible to connect this device with another one without changing the order of the EtherCAT devices in the communication ring, then this combination field is activated and the EtherCAT device to which this device is to be connected can be selected.
Advanced Settings	This button opens the dialogs for advanced settings.

The link at the bottom of the tab points to the product page for this EtherCAT device on the web.

“Process Data” tab

Indicates the configuration of the process data. The input and output data of the EtherCAT slave are represented as CANopen process data objects (**P**rocess **D**ata **O**bjects, PDOs). The user can select a PDO via PDO assignment and modify the content of the individual PDO via this dialog, if the EtherCAT slave supports this function.

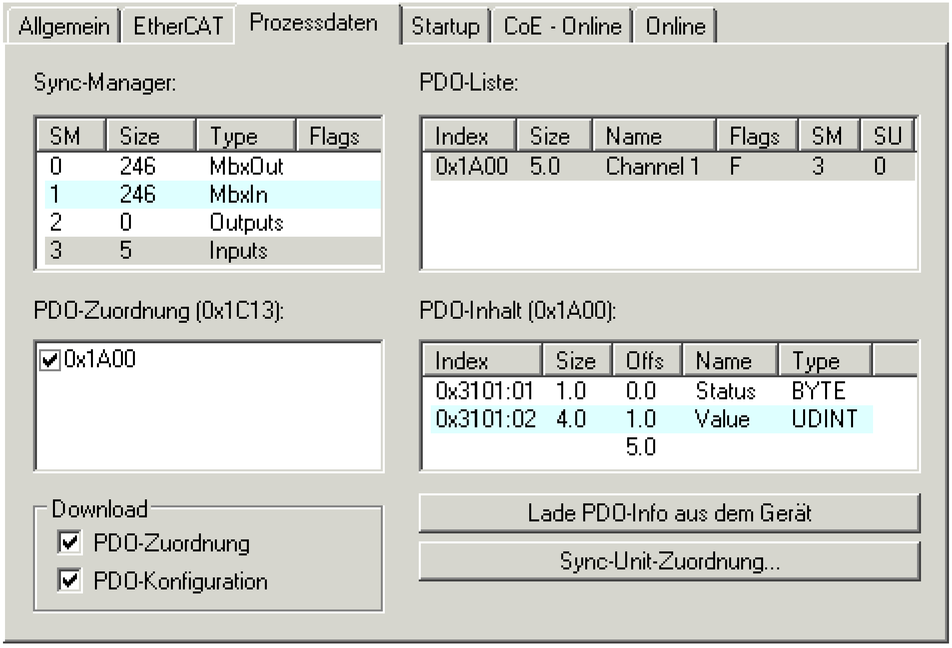


Fig. 76: “Process Data” tab

The process data (PDOs) transferred by an EtherCAT slave during each cycle are user data which the application expects to be updated cyclically or which are sent to the slave. To this end the EtherCAT master (Beckhoff TwinCAT) parameterizes each EtherCAT slave during the start-up phase to define which process data (size in bits/bytes, source location, transmission type) it wants to transfer to or from this slave. Incorrect configuration can prevent successful start-up of the slave.

For Beckhoff EtherCAT EL, ES, EM, EJ and EP slaves the following applies in general:

- The input/output process data supported by the device are defined by the manufacturer in the ESI/XML description. The TwinCAT EtherCAT Master uses the ESI description to configure the slave correctly.
- The process data can be modified in the system manager. See the device documentation.
  Examples of modifications include: mask out a channel, displaying additional cyclic information, 16-bit display instead of 8-bit data size, etc.
- In so-called “intelligent” EtherCAT devices the process data information is also stored in the CoE directory. Any changes in the CoE directory that lead to different PDO settings prevent successful startup of the slave. It is not advisable to deviate from the designated process data, because the device firmware (if available) is adapted to these PDO combinations.

If the device documentation allows modification of process data, proceed as follows (see Figure *“Configuring the process data”*).

- A: select the device to configure
- B: in the “Process Data” tab select Input or Output under SyncManager (C)
- D: the PDOs can be selected or deselected
- H: the new process data are visible as linkable variables in the system manager
  The new process data are active once the configuration has been activated and TwinCAT has been restarted (or the EtherCAT master has been restarted)
- E: if a slave supports this, Input and Output PDO can be modified simultaneously by selecting a so-called PDO record (“predefined PDO settings”).

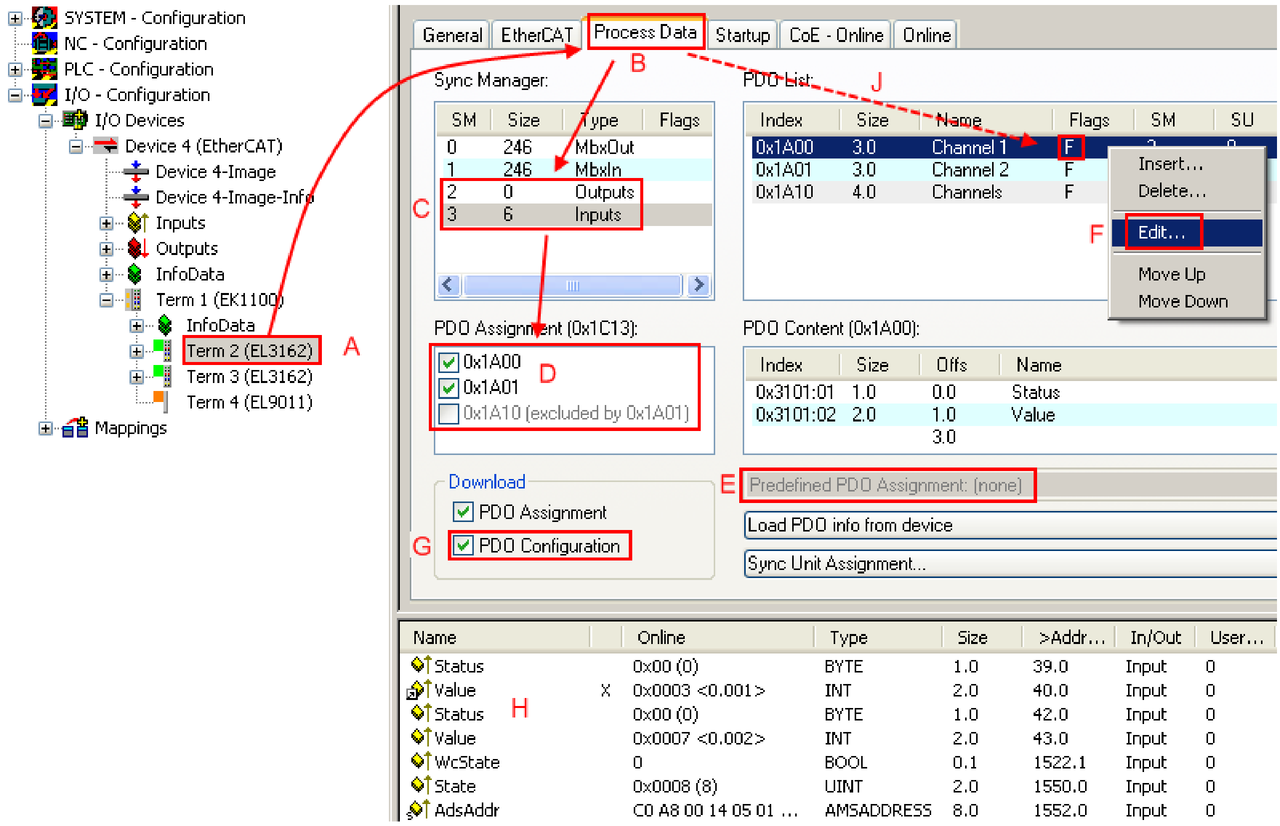


Fig. 77: Configuring the process data

Manual modification of the process data

According to the ESI description, a PDO can be identified as “fixed” with the flag “F” in the PDO overview (Fig. *“Configuring the process data”*, J). The configuration of such PDOs cannot be changed, even if TwinCAT offers the associated dialog (“Edit”). In particular, CoE content cannot be displayed as cyclic process data. This generally also applies in cases where a device supports download of the PDO configuration, “G”. In case of incorrect configuration the EtherCAT slave usually refuses to start and change to OP state. The System Manager displays an “invalid SM cfg” logger message: This error message (“invalid SM IN cfg” or “invalid SM OUT cfg”) also indicates the reason for the failed start.

A detailed description [▸ 74] can be found at the end of this section.

„Startup“ tab

The *Startup* tab is displayed if the EtherCAT slave has a mailbox and supports the *CANopen over EtherCAT* (CoE) or *Servo drive over EtherCAT* protocol. This tab indicates which download requests are sent to the mailbox during startup. It is also possible to add new mailbox requests to the list display. The download requests are sent to the slave in the same order as they are shown in the list.

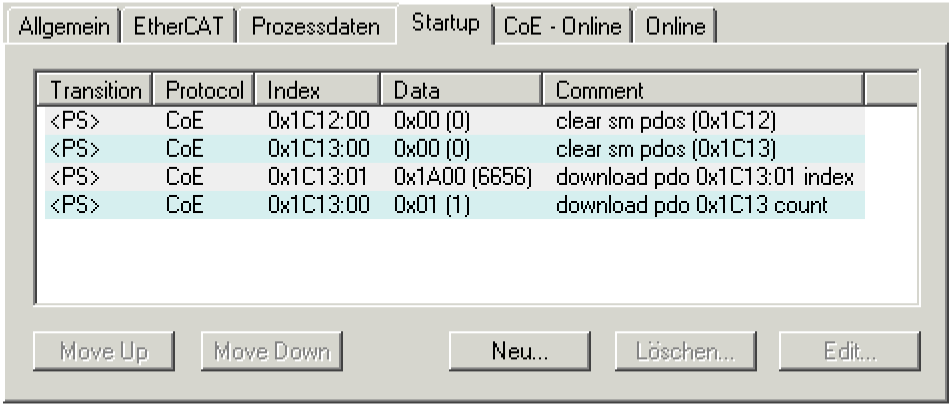


Fig. 78: „Startup“ tab

Column	Description
Transition	Transition to which the request is sent. This can either be • the transition from pre-operational to safe-operational (PS), or • the transition from safe-operational to operational (SO). If the transition is enclosed in "<>" (e.g. <PS>), the mailbox request is fixed and cannot be modified or deleted by the user.
Protocol	Type of mailbox protocol
Index	Index of the object
Data	Date on which this object is to be downloaded.
Comment	Description of the request to be sent to the mailbox

Move Up This button moves the selected request up by one position in the list.

Move Down This button moves the selected request down by one position in the list.

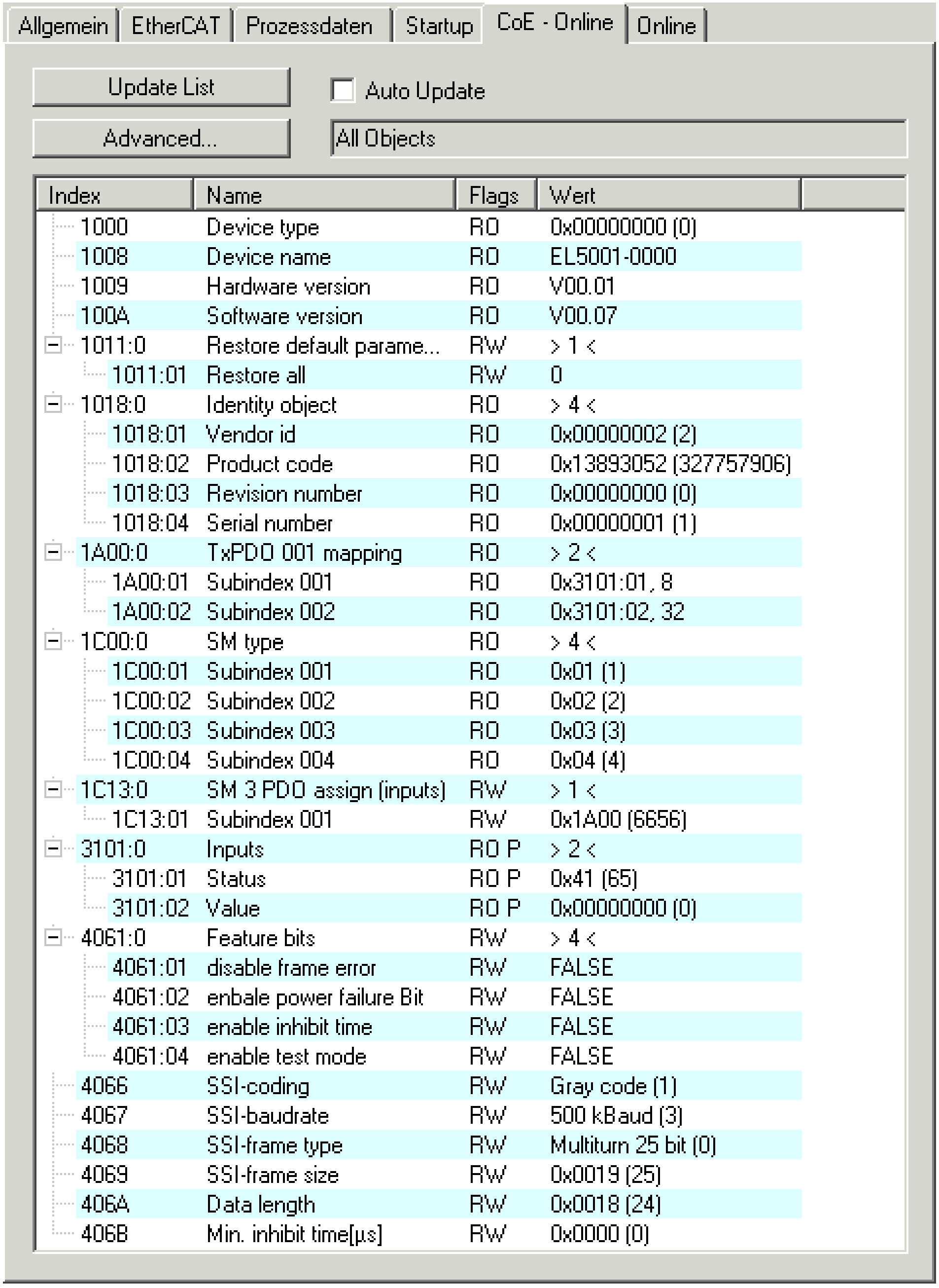
New This button adds a new mailbox download request to be sent during startup.

Delete This button deletes the selected entry.

Edit This button edits an existing request.

“CoE – Online” tab

The additional *CoE - Online* tab is displayed if the EtherCAT slave supports the *CANopen over EtherCAT* (CoE) protocol. This dialog lists the content of the object list of the slave (SDO upload) and enables the user to modify the content of an object from this list. Details for the objects of the individual EtherCAT devices can be found in the device-specific object descriptions.



Allgemein | EtherCAT | Prozessdaten | Startup | CoE - Online | Online

Update List | Auto Update

Advanced... | All Objects

Index	Name	Flags	Wert
1000	Device type	RO	0x00000000 (0)
1008	Device name	RO	EL5001-0000
1009	Hardware version	RO	V00.01
100A	Software version	RO	V00.07
1011:0	Restore default parame...	RW	> 1 <
1011:01	Restore all	RW	0
1018:0	Identity object	RO	> 4 <
1018:01	Vendor id	RO	0x00000002 (2)
1018:02	Product code	RO	0x13893052 (327757906)
1018:03	Revision number	RO	0x00000000 (0)
1018:04	Serial number	RO	0x00000001 (1)
1A00:0	TxPDO 001 mapping	RO	> 2 <
1A00:01	Subindex 001	RO	0x3101:01, 8
1A00:02	Subindex 002	RO	0x3101:02, 32
1C00:0	SM type	RO	> 4 <
1C00:01	Subindex 001	RO	0x01 (1)
1C00:02	Subindex 002	RO	0x02 (2)
1C00:03	Subindex 003	RO	0x03 (3)
1C00:04	Subindex 004	RO	0x04 (4)
1C13:0	SM 3 PDO assign (inputs)	RW	> 1 <
1C13:01	Subindex 001	RW	0x1A00 (6656)
3101:0	Inputs	RO P	> 2 <
3101:01	Status	RO P	0x41 (65)
3101:02	Value	RO P	0x00000000 (0)
4061:0	Feature bits	RW	> 4 <
4061:01	disable frame error	RW	FALSE
4061:02	enbale power failure Bit	RW	FALSE
4061:03	enable inhibit time	RW	FALSE
4061:04	enable test mode	RW	FALSE
4066	SSI-coding	RW	Gray code (1)
4067	SSI-baudrate	RW	500 kBaud (3)
4068	SSI-frame type	RW	Multiturn 25 bit (0)
4069	SSI-frame size	RW	0x0019 (25)
406A	Data length	RW	0x0018 (24)
406B	Min. inhibit time[µs]	RW	0x0000 (0)

Fig. 79: “CoE – Online” tab

Object list display

Column	Description	
Index	Index and sub-index of the object	
Name	Name of the object	
Flags	RW	The object can be read, and data can be written to the object (read/write)
	RO	The object can be read, but no data can be written to the object (read only)
	P	An additional P identifies the object as a process data object.
Value	Value of the object	

Update List	The *Update list* button updates all objects in the displayed list
Auto Update	If this check box is selected, the content of the objects is updated automatically.
Advanced	The *Advanced* button opens the *Advanced Settings* dialog. Here you can specify which objects are displayed in the list.

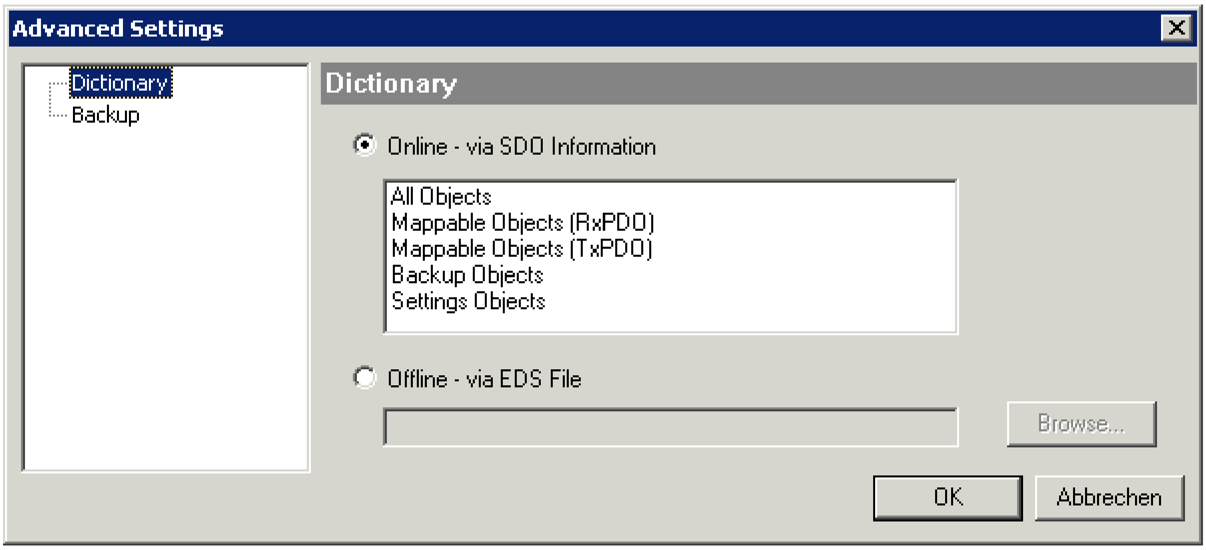


Fig. 80: Dialog “Advanced settings”

Online - via SDO Information	If this option button is selected, the list of the objects included in the object list of the slave is uploaded from the slave via SDO information. The list below can be used to specify which object types are to be uploaded.
Offline - via EDS File	If this option button is selected, the list of the objects included in the object list is read from an EDS file provided by the user.

„Online“ tab

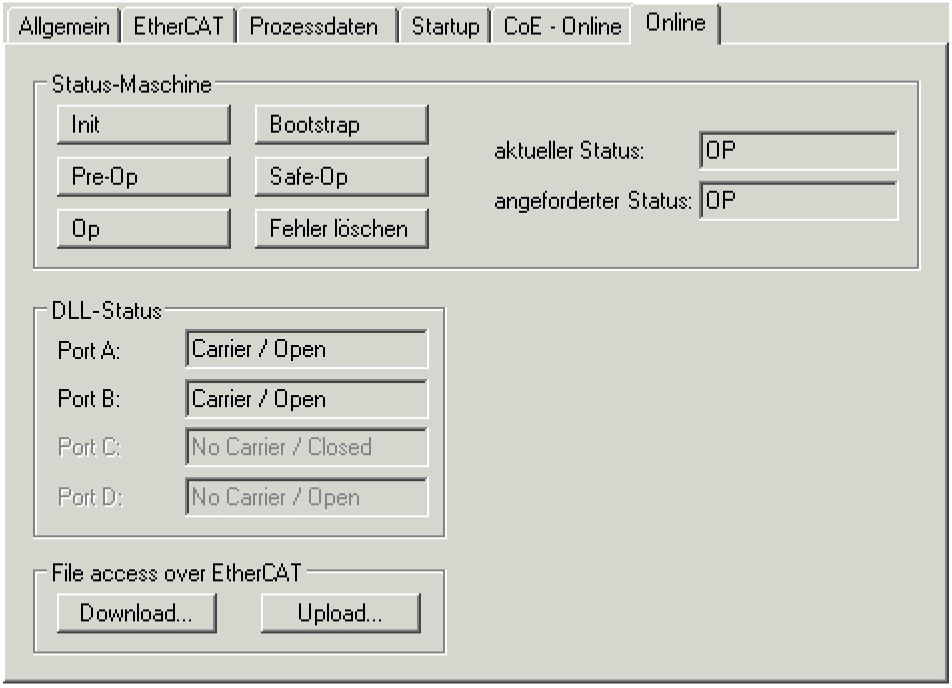


Fig. 81: „Online“ tab

State Machine

Init	This button attempts to set the EtherCAT device to the *Init* state.
Pre-Op	This button attempts to set the EtherCAT device to the *pre-operational* state.
Op	This button attempts to set the EtherCAT device to the *operational* state.
Bootstrap	This button attempts to set the EtherCAT device to the *Bootstrap* state.
Safe-Op	This button attempts to set the EtherCAT device to the *safe-operational* state.
Clear Error	This button attempts to delete the fault display. If an EtherCAT slave fails during change of state it sets an error flag. Example: An EtherCAT slave is in PREOP state (pre-operational). The master now requests the SAFEOP state (safe-operational). If the slave fails during change of state it sets the error flag. The current state is now displayed as ERR PREOP. When the *Clear Error* button is pressed the error flag is cleared, and the current state is displayed as PREOP again.
Current State	Indicates the current state of the EtherCAT device.
Requested State	Indicates the state requested for the EtherCAT device.

DLL Status

Indicates the DLL status (data link layer status) of the individual ports of the EtherCAT slave. The DLL status can have four different states:

Status	Description
No Carrier / Open	No carrier signal is available at the port, but the port is open.
No Carrier / Closed	No carrier signal is available at the port, and the port is closed.
Carrier / Open	A carrier signal is available at the port, and the port is open.
Carrier / Closed	A carrier signal is available at the port, but the port is closed.

File Access over EtherCAT

Download	With this button a file can be written to the EtherCAT device.
Upload	With this button a file can be read from the EtherCAT device.

"DC" tab (Distributed Clocks)

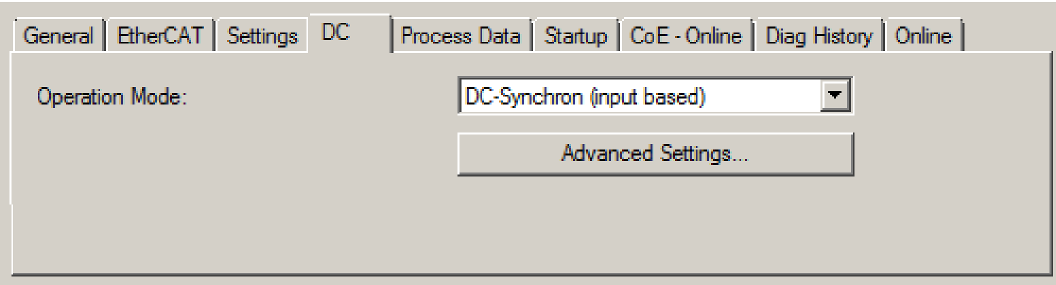


Fig. 82: "DC" tab (Distributed Clocks)

Operation Mode

Options (optional):

- FreeRun
- SM-Synchron
- DC-Synchron (Input based)
- DC-Synchron

Advanced Settings…

Advanced settings for readjustment of the real time determinant TwinCAT-clock

Detailed information to Distributed Clocks are specified on http://infosys.beckhoff.com:

Fieldbus Components → EtherCAT Terminals → EtherCAT System documentation → EtherCAT basics → Distributed Clocks

5.1.7.1 Detailed description of Process Data tab

Sync Manager

Lists the configuration of the Sync Manager (SM).
If the EtherCAT device has a mailbox, SM0 is used for the mailbox output (MbxOut) and SM1 for the mailbox input (MbxIn).
SM2 is used for the output process data (outputs) and SM3 (inputs) for the input process data.

If an input is selected, the corresponding PDO assignment is displayed in the *PDO Assignment* list below.

PDO Assignment

PDO assignment of the selected Sync Manager. All PDOs defined for this Sync Manager type are listed here:

- If the output Sync Manager (outputs) is selected in the Sync Manager list, all RxPDOs are displayed.
- If the input Sync Manager (inputs) is selected in the Sync Manager list, all TxPDOs are displayed.

The selected entries are the PDOs involved in the process data transfer. In the tree diagram of the System Manager these PDOs are displayed as variables of the EtherCAT device. The name of the variable is identical to the *Name* parameter of the PDO, as displayed in the PDO list. If an entry in the PDO assignment list is deactivated (not selected and greyed out), this indicates that the input is excluded from the PDO assignment. In order to be able to select a greyed out PDO, the currently selected PDO has to be deselected first.

Activation of PDO assignment

✓ If you have changed the PDO assignment, in order to activate the new PDO assignment,

a) the EtherCAT slave has to run through the PS status transition cycle (from pre-operational to safe-operational) once (see Online tab [▸ 73]),

b) and the System Manager has to reload the EtherCAT slaves

( button for TwinCAT 2 or  button for TwinCAT 3)

PDO list

List of all PDOs supported by this EtherCAT device. The content of the selected PDOs is displayed in the *PDO Content* list. The PDO configuration can be modified by double-clicking on an entry.

Column	Description	
Index	PDO index.	
Size	Size of the PDO in bytes.	
Name	Name of the PDO. If this PDO is assigned to a Sync Manager, it appears as a variable of the slave with this parameter as the name.	
Flags	F	Fixed content: The content of this PDO is fixed and cannot be changed by the System Manager.
	M	Mandatory PDO. This PDO is mandatory and must therefore be assigned to a Sync Manager! Consequently, this PDO cannot be deleted from the *PDO Assignment* list
SM	Sync Manager to which this PDO is assigned. If this entry is empty, this PDO does not take part in the process data traffic.	
SU	Sync unit to which this PDO is assigned.	

PDO Content

Indicates the content of the PDO. If flag F (fixed content) of the PDO is not set the content can be modified.

Download

If the device is intelligent and has a mailbox, the configuration of the PDO and the PDO assignments can be downloaded to the device. This is an optional feature that is not supported by all EtherCAT slaves.

PDO Assignment

If this check box is selected, the PDO assignment that is configured in the PDO Assignment list is downloaded to the device on startup. The required commands to be sent to the device can be viewed in the Startup [▸ 69] tab.

PDO Configuration

If this check box is selected, the configuration of the respective PDOs (as shown in the PDO list and the PDO Content display) is downloaded to the EtherCAT slave.

5.2 General Notes - EtherCAT Slave Application

This summary briefly deals with a number of aspects of EtherCAT Slave operation under TwinCAT. More detailed information on this may be found in the corresponding sections of, for instance, the EtherCAT System Documentation.

Diagnosis in real time: WorkingCounter, EtherCAT State and Status

Generally speaking an EtherCAT Slave provides a variety of diagnostic information that can be used by the controlling task.

This diagnostic information relates to differing levels of communication. It therefore has a variety of sources, and is also updated at various times.

Any application that relies on I/O data from a fieldbus being correct and up to date must make diagnostic access to the corresponding underlying layers. EtherCAT and the TwinCAT System Manager offer comprehensive diagnostic elements of this kind. Those diagnostic elements that are helpful to the controlling task for diagnosis that is accurate for the current cycle when in operation (not during commissioning) are discussed below.

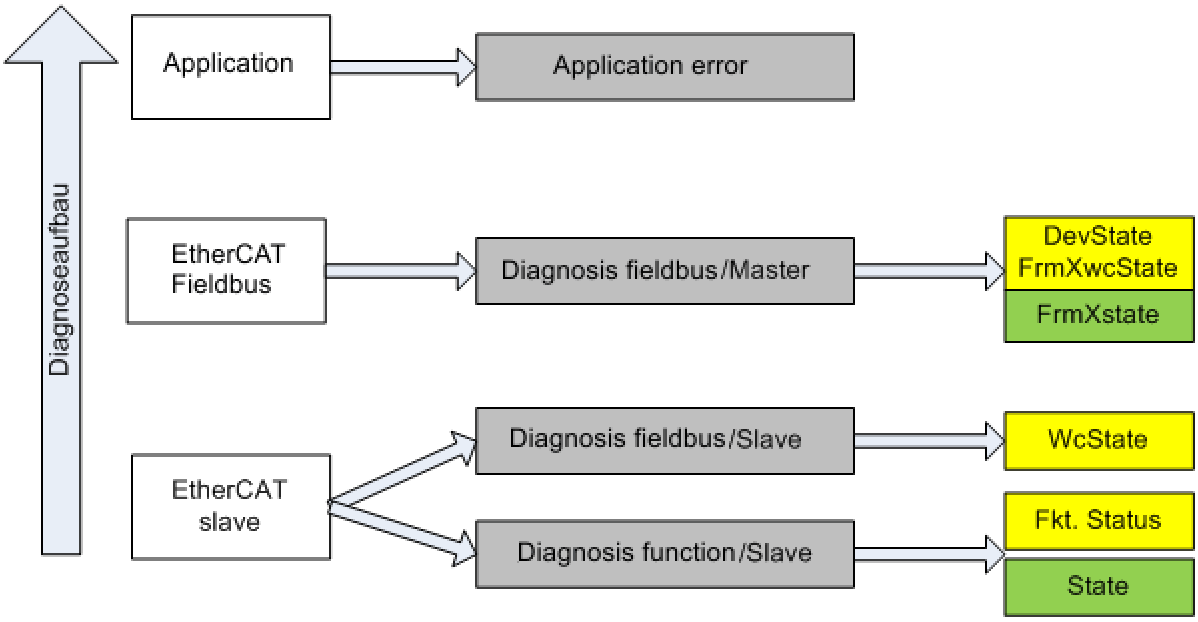


Fig. 83: Selection of the diagnostic information of an EtherCAT Slave

In general, an EtherCAT Slave offers

- communication diagnosis typical for a slave (diagnosis of successful participation in the exchange of process data, and correct operating mode)
  This diagnosis is the same for all slaves.

  as well as
- function diagnosis typical for a channel (device-dependent)
  See the corresponding device documentation

The colors in Fig. *“Selection of the diagnostic information of an EtherCAT Slave”* also correspond to the variable colors in the System Manager, see Fig. *“Basic EtherCAT Slave Diagnosis in the PLC”*.

Colour	Meaning
yellow	Input variables from the Slave to the EtherCAT Master, updated in every cycle
red	Output variables from the Slave to the EtherCAT Master, updated in every cycle
green	Information variables for the EtherCAT Master that are updated acyclically. This means that it is possible that in any particular cycle they do not represent the latest possible status. It is therefore useful to read such variables through ADS.

Fig. *“Basic EtherCAT Slave Diagnosis in the PLC”* shows an example of an implementation of basic EtherCAT Slave Diagnosis. A Beckhoff EL3102 (2-channel analogue input terminal) is used here, as it offers both the communication diagnosis typical of a slave and the functional diagnosis that is specific to a channel. Structures are created as input variables in the PLC, each corresponding to the process image.

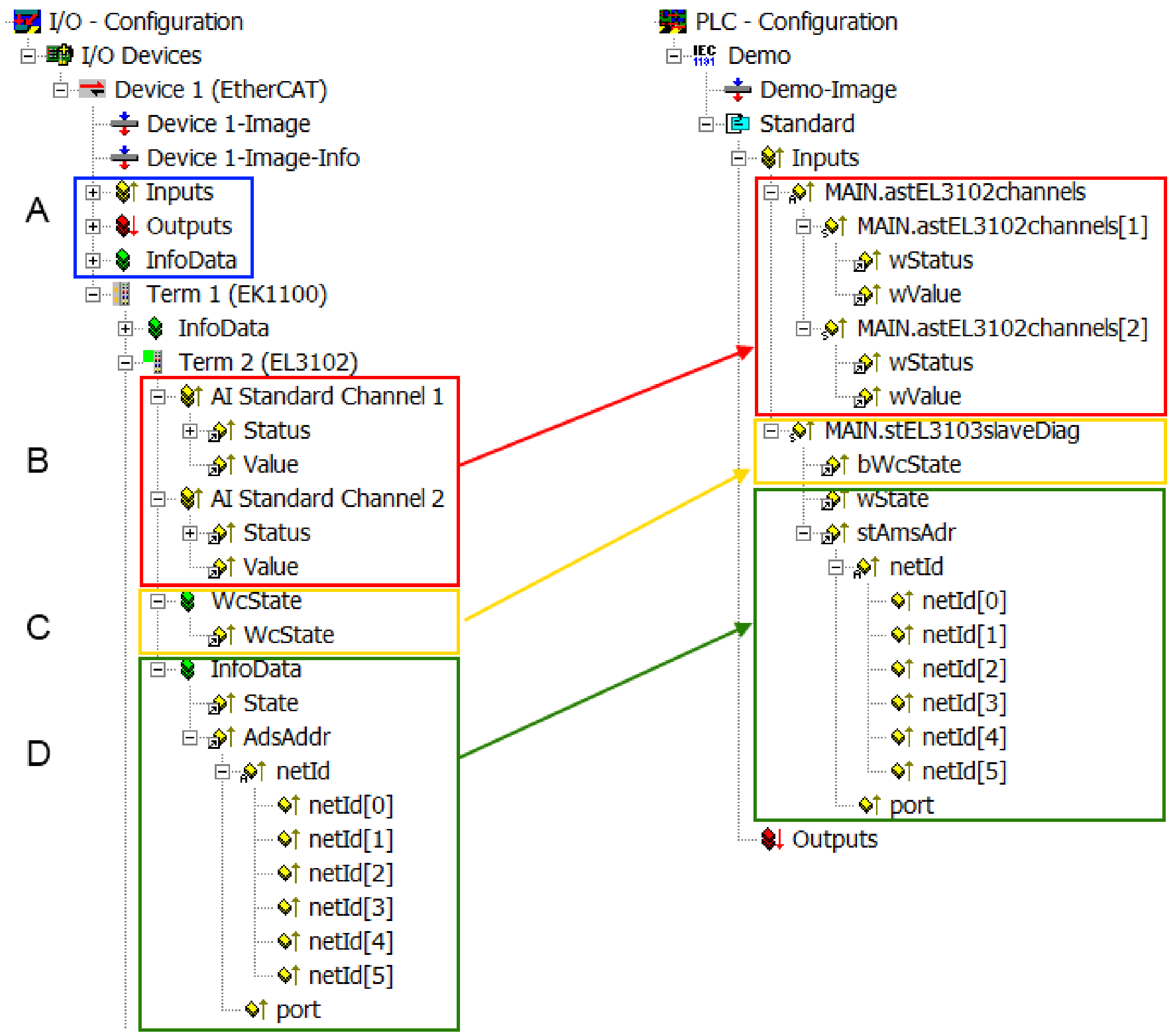


Fig. 84: Basic EtherCAT Slave Diagnosis in the PLC

The following aspects are covered here:

Code	Function	Implementation	Application/evaluation
A	The EtherCAT Master's diagnostic information updated acyclically (yellow) or provided acyclically (green).		At least the DevState is to be evaluated for the most recent cycle in the PLC. The EtherCAT Master's diagnostic information offers many more possibilities than are treated in the EtherCAT System Documentation. A few keywords: • CoE in the Master for communication with/through the Slaves • Functions from *TcEtherCAT.lib* • Perform an OnlineScan
B	In the example chosen (EL3102) the EL3102 comprises two analogue input channels that transmit a single function status for the most recent cycle.	Status • the bit significations may be found in the device documentation • other devices may supply more information, or none that is typical of a slave	In order for the higher-level PLC task (or corresponding control applications) to be able to rely on correct data, the function status must be evaluated there. Such information is therefore provided with the process data for the most recent cycle.
C	For every EtherCAT Slave that has cyclic process data, the Master displays, using what is known as a WorkingCounter, whether the slave is participating successfully and without error in the cyclic exchange of process data. This important, elementary information is therefore provided for the most recent cycle in the System Manager 1. at the EtherCAT Slave, and, with identical contents 2. as a collective variable at the EtherCAT Master (see Point A) for linking.	WcState (Working Counter) 0: valid real-time communication in the last cycle 1: invalid real-time communication This may possibly have effects on the process data of other Slaves that are located in the same SyncUnit	In order for the higher-level PLC task (or corresponding control applications) to be able to rely on correct data, the communication status of the EtherCAT Slave must be evaluated there. Such information is therefore provided with the process data for the most recent cycle.
D	Diagnostic information of the EtherCAT Master which, while it is represented at the slave for linking, is actually determined by the Master for the Slave concerned and represented there. This information cannot be characterized as real-time, because it • is only rarely/never changed, except when the system starts up • is itself determined acyclically (e.g. EtherCAT Status)	State current Status (INIT..OP) of the Slave. The Slave must be in OP (=8) when operating normally. *AdsAddr* The ADS address is useful for communicating from the PLC/task via ADS with the EtherCAT Slave, e.g. for reading/writing to the CoE. The AMS-NetID of a slave corresponds to the AMS-NetID of the EtherCAT Master; communication with the individual Slave is possible via the *port* (= EtherCAT address).	Information variables for the EtherCAT Master that are updated acyclically. This means that it is possible that in any particular cycle they do not represent the latest possible status. It is therefore possible to read such variables through ADS.

NOTE

Diagnostic information

It is strongly recommended that the diagnostic information made available is evaluated so that the application can react accordingly.

CoE Parameter Directory

The CoE parameter directory (CanOpen-over-EtherCAT) is used to manage the set values for the slave concerned. Changes may, in some circumstances, have to be made here when commissioning a relatively complex EtherCAT Slave. It can be accessed through the TwinCAT System Manager, see Fig. *“EL3102, CoE directory”*:

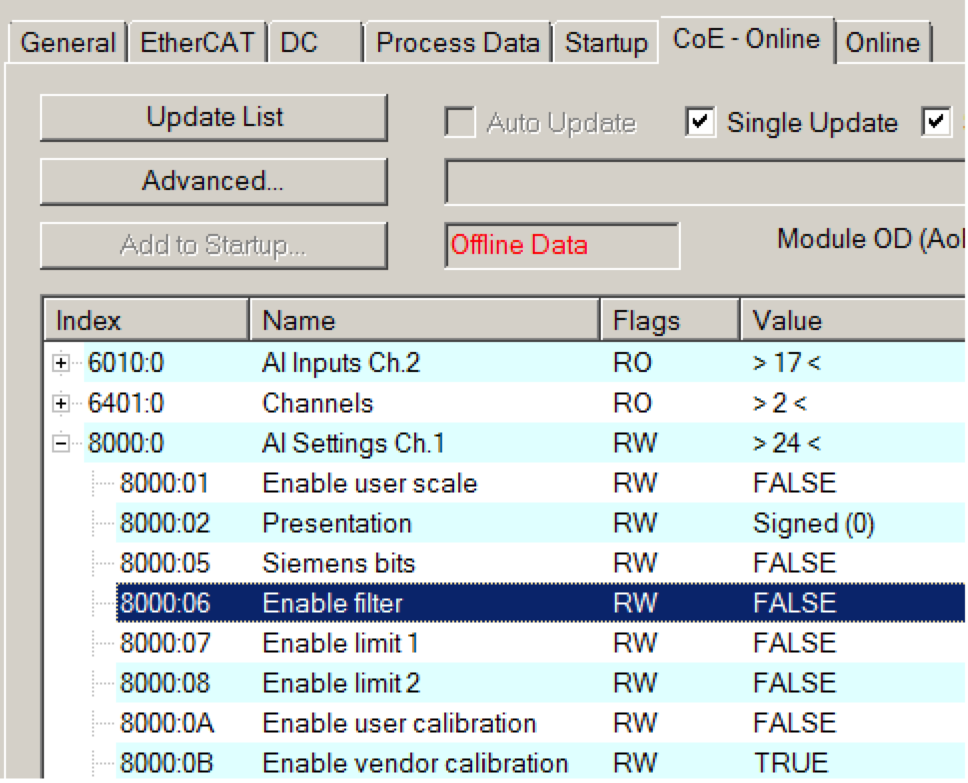


Fig. 85: EL3102, CoE directory

EtherCAT System Documentation

The comprehensive description in the EtherCAT System Documentation (EtherCAT Basics --> CoE Interface) must be observed!

A few brief extracts:

- Whether changes in the online directory are saved locally in the slave depends on the device. EL terminals (except the EL66xx) are able to save in this way.
- The user must manage the changes to the StartUp list.

Commissioning aid in the TwinCAT System Manager

Commissioning interfaces are being introduced as part of an ongoing process for EL/EP EtherCAT devices. These are available in TwinCAT System Managers from TwinCAT 2.11R2 and above. They are integrated into the System Manager through appropriately extended ESI configuration files.

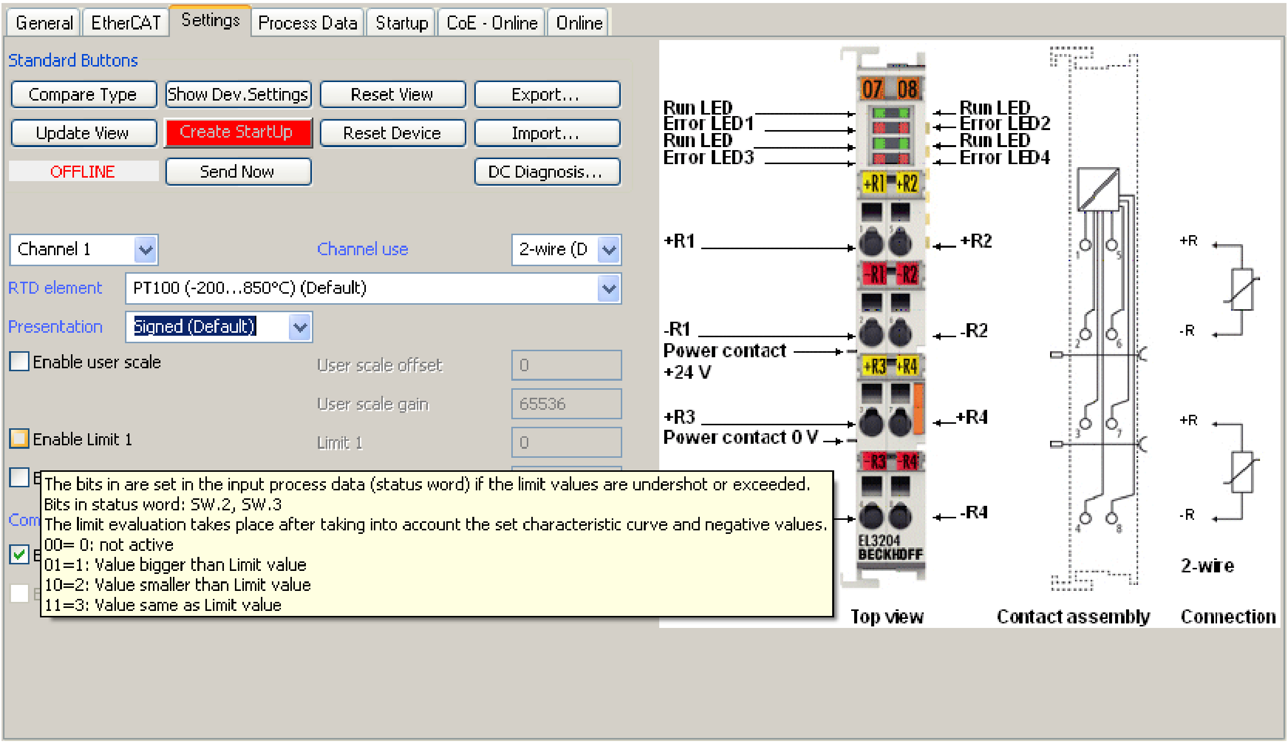


Fig. 86: Example of commissioning aid for a EL3204

This commissioning process simultaneously manages

- CoE Parameter Directory
- DC/FreeRun mode
- the available process data records (PDO)

Although the "Process Data", "DC", "Startup" and "CoE-Online" that used to be necessary for this are still displayed, it is recommended that, if the commissioning aid is used, the automatically generated settings are not changed by it.

The commissioning tool does not cover every possible application of an EL/EP device. If the available setting options are not adequate, the user can make the DC, PDO and CoE settings manually, as in the past.

EtherCAT State: automatic default behaviour of the TwinCAT System Manager and manual operation

After the operating power is switched on, an EtherCAT Slave must go through the following statuses

- INIT
- PREOP
- SAFEOP
- OP

to ensure sound operation. The EtherCAT Master directs these statuses in accordance with the initialization routines that are defined for commissioning the device by the ES/XML and user settings (Distributed Clocks (DC), PDO, CoE). See also the section on "Principles of Communication, EtherCAT State Machine [▶ 24]" in this connection. Depending how much configuration has to be done, and on the overall communication, booting can take up to a few seconds.

The EtherCAT Master itself must go through these routines when starting, until it has reached at least the OP target state.

The target state wanted by the user, and which is brought about automatically at start-up by TwinCAT, can be set in the System Manager. As soon as TwinCAT reaches the status RUN, the TwinCAT EtherCAT Master will approach the target states.

Standard setting

The advanced settings of the EtherCAT Master are set as standard:

- EtherCAT Master: OP
- Slaves: OP
  This setting applies equally to all Slaves.

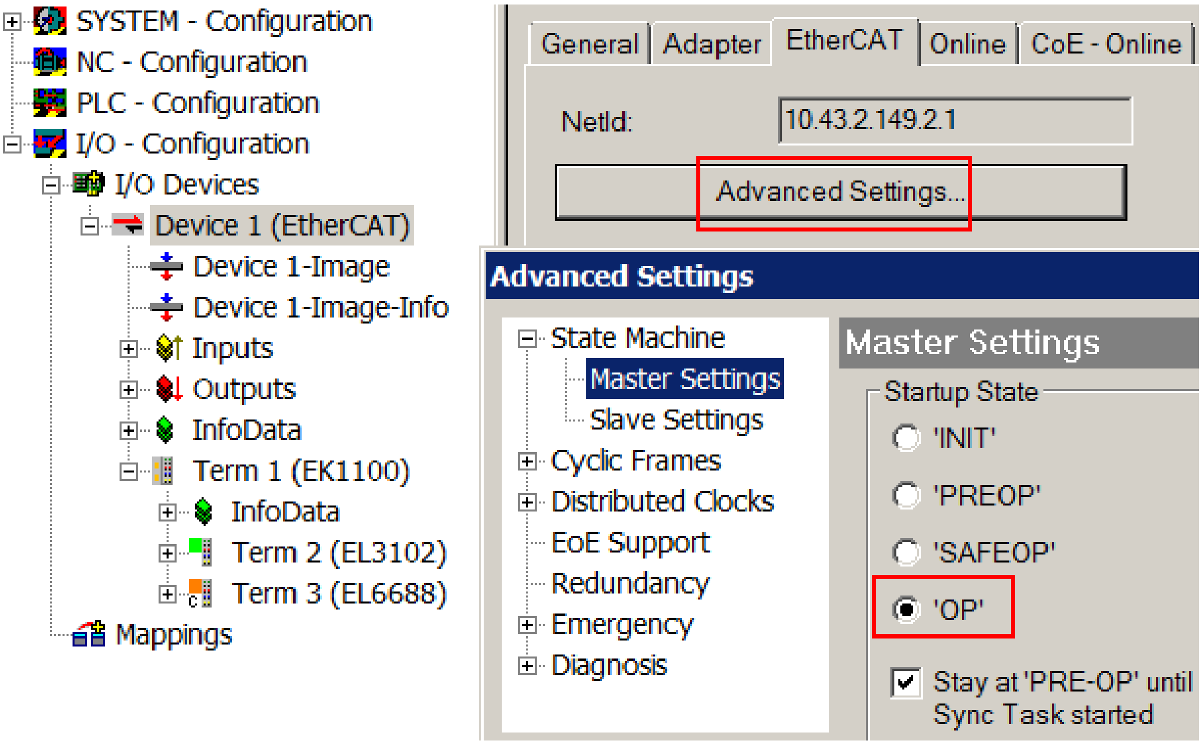


Fig. 87: Default behaviour of the System Manager

In addition, the target state of any particular Slave can be set in the "Advanced Settings" dialogue; the standard setting is again OP.

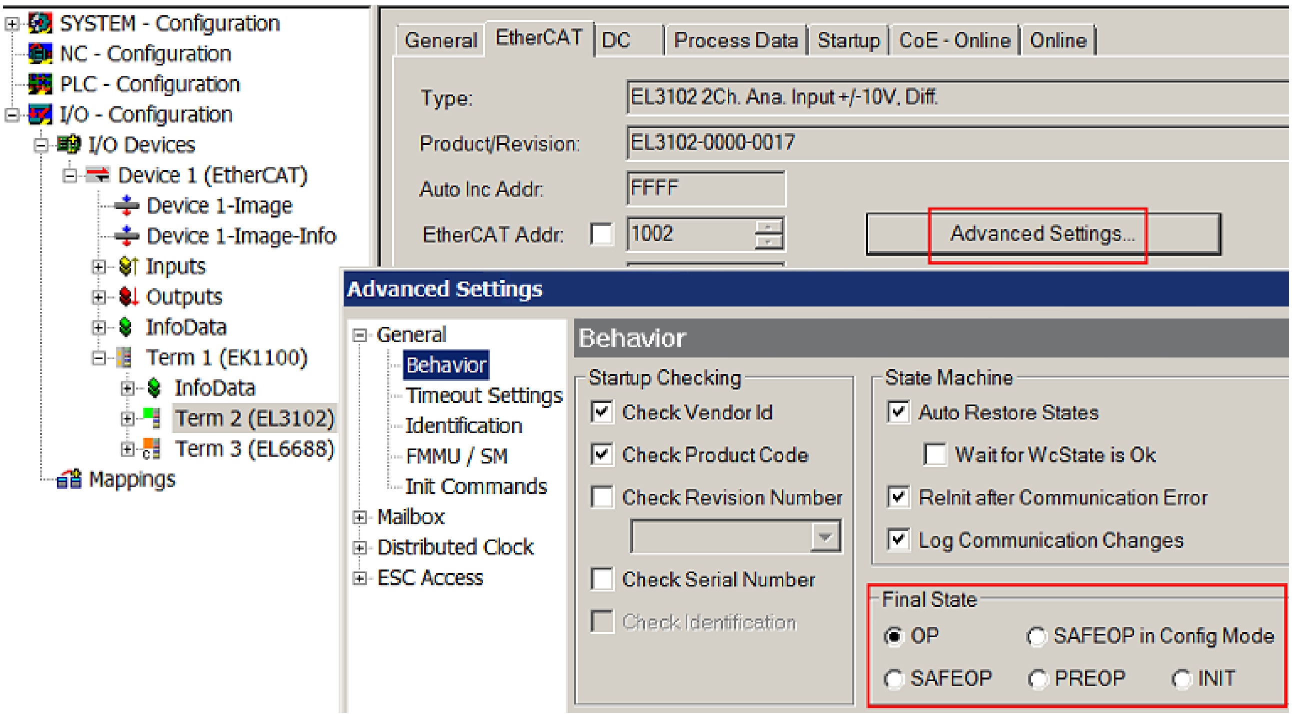


Fig. 88: Default target state in the Slave

Manual Control

There are particular reasons why it may be appropriate to control the states from the application/task/PLC. For instance:

- for diagnostic reasons
- to induce a controlled restart of axes
- because a change in the times involved in starting is desirable

In that case it is appropriate in the PLC application to use the PLC function blocks from the *TcEtherCAT.lib*, which is available as standard, and to work through the states in a controlled manner using, for instance, *FB_EcSetMasterState*.

It is then useful to put the settings in the EtherCAT Master to INIT for master and slave.

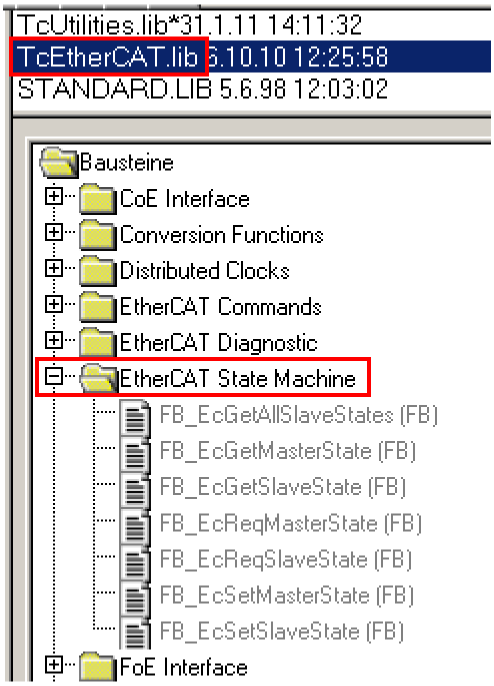
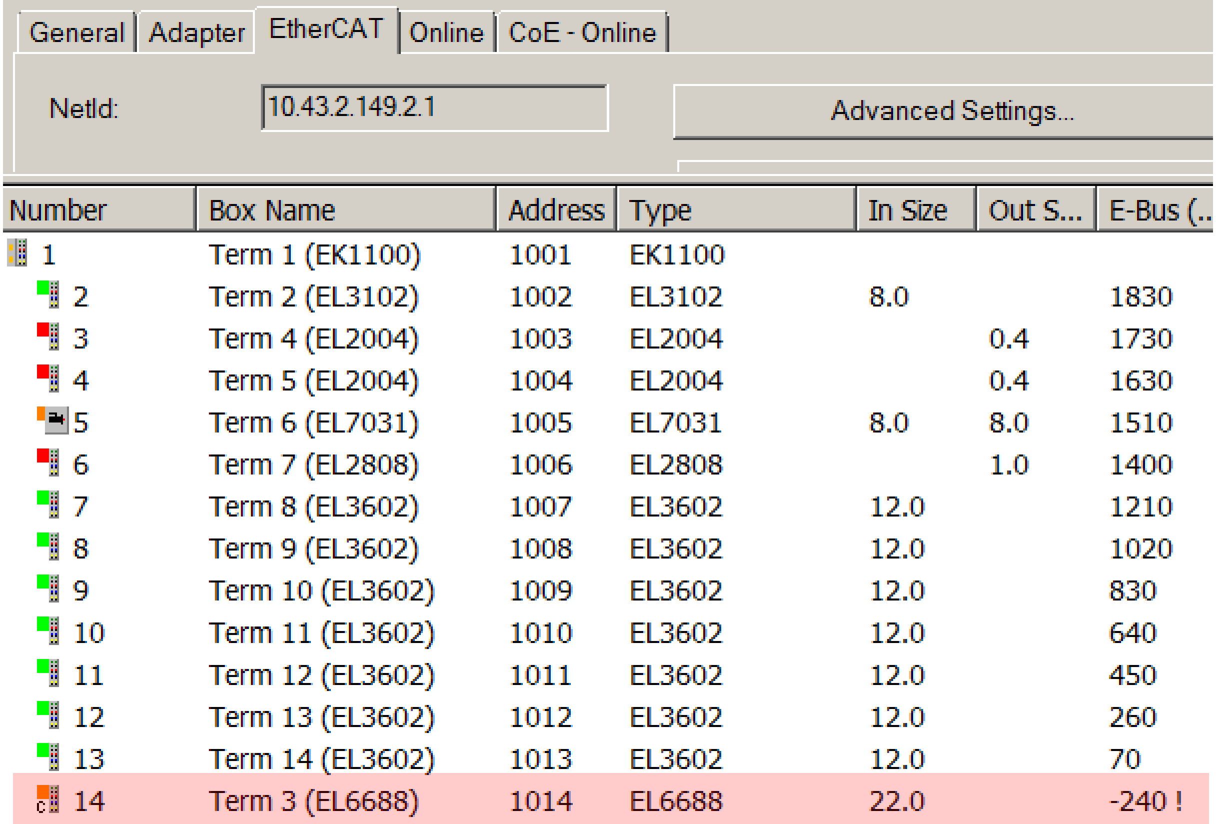


Fig. 89: PLC function blocks

Note regarding E-Bus current

EL/ES terminals are placed on the DIN rail at a coupler on the terminal strand. A Bus Coupler can supply the EL terminals added to it with the E-bus system voltage of 5 V; a coupler is thereby loadable up to 2 A as a rule. Information on how much current each EL terminal requires from the E-bus supply is available online and in the catalogue. If the added terminals require more current than the coupler can supply, then power feed terminals (e.g. EL9410) must be inserted at appropriate places in the terminal strand.

The pre-calculated theoretical maximum E-Bus current is displayed in the TwinCAT System Manager as a column value. A shortfall is marked by a negative total amount and an exclamation mark; a power feed terminal is to be placed before such a position.



Number	Box Name	Address	Type	In Size	Out S...	E-Bus (..
1	Term 1 (EK1100)	1001	EK1100			
2	Term 2 (EL3102)	1002	EL3102	8.0		1830
3	Term 4 (EL2004)	1003	EL2004		0.4	1730
4	Term 5 (EL2004)	1004	EL2004		0.4	1630
5	Term 6 (EL7031)	1005	EL7031	8.0	8.0	1510
6	Term 7 (EL2808)	1006	EL2808		1.0	1400
7	Term 8 (EL3602)	1007	EL3602	12.0		1210
8	Term 9 (EL3602)	1008	EL3602	12.0		1020
9	Term 10 (EL3602)	1009	EL3602	12.0		830
10	Term 11 (EL3602)	1010	EL3602	12.0		640
11	Term 12 (EL3602)	1011	EL3602	12.0		450
12	Term 13 (EL3602)	1012	EL3602	12.0		260
13	Term 14 (EL3602)	1013	EL3602	12.0		70
14	Term 3 (EL6688)	1014	EL6688	22.0		-240 !

Fig. 90: Illegally exceeding the E-Bus current

From TwinCAT 2.11 and above, a warning message "E-Bus Power of Terminal..." is output in the logger window when such a configuration is activated:

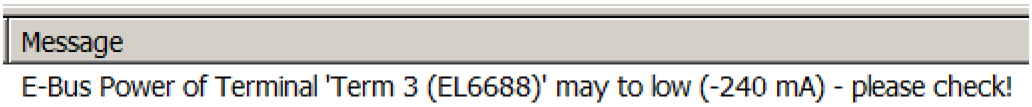


Fig. 91: Warning message for exceeding E-Bus current

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

5.3 Notes to Commissioning

Quick start as slave clock

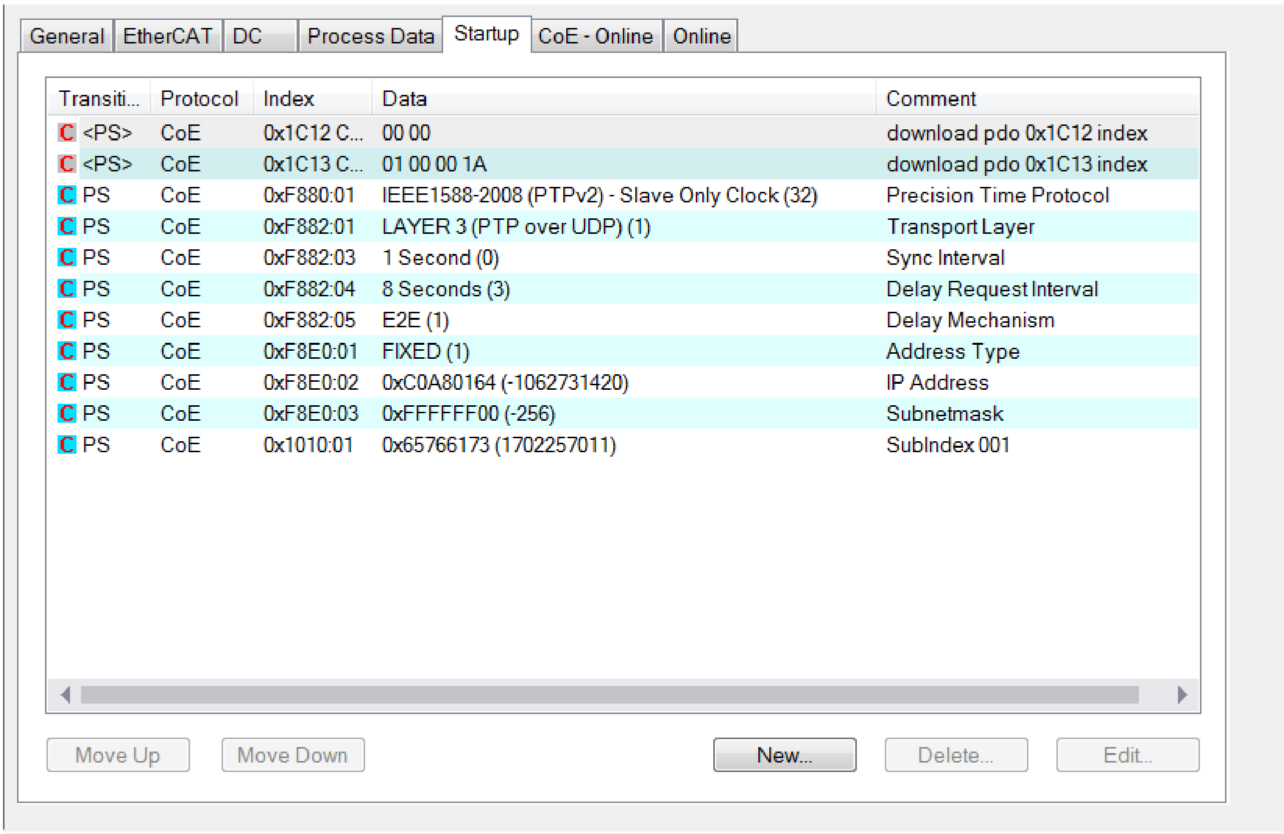
(Point 3 optional - StartUp list for replacement)

1. Generate configuration in TwinCAT: Right-click on EtherCAT devices and "Scan boxes" or manually create configuration

2. Make CoE settings for the EL6688 (in PreOP – see note)

- Set PTP common (0xF880:01) to "IEEE1588-2008 (PTPv2) – Slave Only Clock" (corresponds to 32dec)
- Set the PTPv2 settings (0xF882) as in the PTP_Master (grandmaster) (see Mutual Settings)
- Ethernet Settings (0xF8E0): enter valid IP address and subnet mask
- Subsequently, changes must be permanently saved by writing "0x65766173" into index 0x1010 (see note)

3. Add CoE settings to the StartUp list (in case of replacement)



Transiti...	Protocol	Index	Data	Comment
C <PS>	CoE	0x1C12 C...	00 00	download pdo 0x1C12 index
C <PS>	CoE	0x1C13 C...	01 00 00 1A	download pdo 0x1C13 index
C PS	CoE	0xF880:01	IEEE1588-2008 (PTPv2) - Slave Only Clock (32)	Precision Time Protocol
C PS	CoE	0xF882:01	LAYER 3 (PTP over UDP) (1)	Transport Layer
C PS	CoE	0xF882:03	1 Second (0)	Sync Interval
C PS	CoE	0xF882:04	8 Seconds (3)	Delay Request Interval
C PS	CoE	0xF882:05	E2E (1)	Delay Mechanism
C PS	CoE	0xF8E0:01	FIXED (1)	Address Type
C PS	CoE	0xF8E0:02	0xC0A80164 (-1062731420)	IP Address
C PS	CoE	0xF8E0:03	0xFFFFFF00 (-256)	Subnetmask
C PS	CoE	0x1010:01	0x65766173 (1702257011)	SubIndex 001

Fig. 92: StartUp list

Special features or startup behavior

If a new terminal with factory settings is used from Beckhoff's warehouse in the event of replacement, it comes with the standard settings. Therefore, it is recommended to anchor all changes in the CoE directory of an EtherCAT slave in the startup list of the slave, which is sent to the slave in the PreOP/SafeOP or SafeOP/OP transition each time the EtherCAT fieldbus is started.

In this way, a new EtherCAT slave is also automatically parameterized with the user's specifications in the event of an exchange.

Please note with the EL6688: As soon as the terminal starts up, the PTP Clock is started with the parameters stored in the CoE, i.e. already in state INIT. A change of the PTP settings in the CoE e.g. by the startup list in the later PreOp/SafeOP state only becomes effective at the next/following start from INIT, since the PTP clock cannot be changed during operation.
After changing the PTP settings, the terminal must pass through the INIT state once, e.g. by restarting EtherCAT, PowerOn/Off of the terminal or state change from the PLC.

This also applies to the special case of initial commissioning with factory settings or after changes to the PTP settings: the PTP Clock only works as intended during the startup after INIT.

4. Check EtherCAT master settings

- a) Master Settings → Info Data: enable "Include DC Time Offsets"
- b) Distributed Clocks → DC Mode: DC in use -> DC Time controlled by External Sync Device (External Mode) - as a result, this TwinCAT System now becomes a time slave and follows the external PTP time

5. If not already done, create a task and link it with EtherCAT
e.g. cycle time :e.g.: 1 ms, if necessary with autostart:

6. Check that, at the latest from now on, the EL6688 is connected to the grandmaster via the X1-port (RJ45)

7. Activate TwinCAT configuration and start TwinCAT in RUN mode

8. Diagnosis via PTP Diag (0xFA80)

- a) PTP state should change from "LISTENING" to "SLAVE" after 10 - 15 seconds
- b) "Sync Event Sequence Counter" should count up according to the sync interval of the grandmaster
- c) "Offset From Master" should now settle around "0" in accordance with the hardware in use and its accuracy (typ. less than ±1000 ns = 1 µs)

If there are problems here, refer to "Answers to frequently asked questions"

General notes

Changing the settings

Always use the following procedure for changing CoE settings in the EL6688:
1. Set EL6688 to PREOP
2. Change parameters
3. Enter the value 0x65766173 in index 0x1010 [▸ 90]:01.
4. Set EL6688 to INIT and then OP

- EtherCAT cycle time: 1 ms is recommended; the slower the cycle time, the less accurate the synchronization
- Due to the BMCA it takes several seconds before the EL6688 can supply analyzable data. After the clock startup the bus is monitored for approx. 10 seconds so that any available grandmasters can be found. The EL6688 is ready for operation when the toggle bits in the process data are operational.
- Synchronization accuracy: with the EL6688 precisions of up to ±350 ns can be achieved, depending on the hardware type used.
The shorter the sync interval selected, the better the synchronization accuracy and settling will be after the TwinCAT start.

- Basics regarding the time synchronization direction EL6688 (Slave) → TwinCAT:
  In this mode of operation the EL6688 receives the PTP frames and operates itself as a PTP Slave Clock. In the TwinCAT/EtherCAT system it operates as an external reference clock, but not necessarily as the EtherCAT reference clock at the same time. The forwarding of the time control is incumbent on the EtherCAT master employed (TwinCAT). Hence, the control sequence as follows:
  - The processor of the EL6688 receives the PTP frames several times per second. The frame contains the so-called external timestamp, if necessary with adjustment information.
    In the same moment as it receives a PTP frame, the processor reads the DC time – the internal timestamp – from the local EtherCAT Distributed Clock in the ESC.
    Hence pairs are continuously formed from internal and external timestamp, from which the readjustment requirement can be derived.
  - These pairs are not processed in the EL6688, but conveyed as cyclic process data to the EtherCAT master (TwinCAT).
  - The latter evaluates these pairs at its own discretion/ability and
    - if necessary regulates its own real-time, which controls the sending of the EtherCAT frames.
    - adjusts the DC reference clock, which is usually realized in the first DC-capable EtherCAT slave.
    Hence, the Distributed Clock system follows the external PTP Master Clock. As a consequence of this the cyclic ARMW command of the EtherCAT master in turn distributes this "DC reference" time to subordinated DC slaves further back in the EtherCAT strand

    The functional chain is thus represented as follows: External PTP master clock → EL6688 as PTP slave clock → Internal /external timestamp as PDO to the EtherCAT master → Adjustment of the internal real-time and adjustment of the DC reference clock.
    The position of the EL6688 in the EtherCAT strand is thus insignificant for the time control; the EL6688 itself has no possibility to affect its own Distributed Clock..

Process data

Sync Mode	0: no synchronization 1: device operates as SYNC master 2: device operates as SYNC slave
Control Value Update Toggle	toggles every time when the control value was updated
Time Stamp Update Toggle	toggles every time when the time stamps were updated
External device not connected	TRUE: no external synchronization found
Internal Time Stamp	only for SYNC slave. DC time stamp at the same time as the external time stamp This is a cyclically calculated time, not the absolute DC time.
External Time Stamp	only for SYNC slave. external time stamp recalculated in DC units (ns) This is a cyclically calculated time, not the absolute time from the last PTP telegram.
Time Control Value	TwinCAT does not use this value.

Answers to frequently-asked questions

Question	Answer
What timebase is suitable for the synchronization of distributed systems?	In order avoid time jumps (which can lead to undesired effects within a plant), it is advisable to use a constantly advancing time (e.g. without leap seconds), such as the international atomic time [French Temps Atomique International (TAI)]. The Coordinated Universal Time (UTC), conversely, bears the risk of time jumps (due to leap seconds), but is on the other hand synchronous to the sun time and thus more suitable for "everyday use" in many processes. Despite that the use of UTC is inadvisable, since time jumps (which are unforeseeable for the controller) can considerably interfere with the proper operation of a plant.
What needs to be considered if sun times (e.g. UTC) are to be used?	If a time containing a leap second is selected, various items of information are provided for this in the CoE that can be processed in the controller. The current number of leap seconds (CoE: CurrentUtcOffset (0xFA80.0B)) as well as announcements of possible further leap events (CoE: Leap61 (0xFA80.0D) for plus 1s and Leap59 (0xFA80.0E) for minus 1s) are transmitted and should be evaluated by the user in order, for example, to be able to place axes in a safe state in such a case as a precautionary measure.
How is an absolute time, e.g. UTC, calculated?	If an external time source (e.g. a GPS-assisted PTP master) is connected with TwinCAT via the EL6688, the UTC can be calculated using the following equation: UTCabsolut := F_GetCurDcTaskTime64() + DcToTcTimeOffset + leapSeconds + DcToExtTimeOffset ● UTCabsolute - task current UTC time expressed as a distance from 1.1.2000 00:00 in nanoseconds. ● F_GetCurDcTaskTime64() – supplies the start time (as T_DCTIME64 alias ULINT) of the task in which it is called. Part of the PLC library: Tc2_EtherCAT.lib ● DcToTcTimeOffset - during the TwinCAT system start the TC time is initialized by the Windows clock. If the external clock is also available during the system start, deviations between these clocks are thus compensated. ● leapSeconds - since TwinCAT works internally with the TAI time, any leap seconds introduced up to now must be added (status July 2015: 36 seconds) (see also EL6688-CoE: CurrentUtcOffset (0xFA80.0B)). ● DcToExtTimeOffset - TwinCAT uses this offset variable to handle larger deviations between the external clock and the DC time that occur during operation (e.g. due to loss of the connection to the external clock) and can no longer be automatically compensated.
Why is DcToTcTimeOffset sometimes 0 and DcToExtTimeOffset other times 0?	During the development phase of a controller, the "Auto Boot" setting in "Boot Settings" in the TwinCAT system may still be set to "Config Mode". If this is the case, TwinCAT cannot access the external clock during the start phase (not even if there is a physical connection between PTP master and EL6688). Thus DcToTcTimeOffset remains 0 and the difference is entered by TwinCAT in DcToExtTimeOffset. Only after setting "Auto Boot" to "Run Mode (Enable)" can TwinCAT also access the external clock during the start phase and thus process the offset and save it in the variable "DcToTcTimeOffset".
How is a T_DCTIME64 variable turned into something user readable?	sXXX := DCTIME64_TO_STRING(tXXX) ● tXXX - 503764149978700026 - DCTIME64 alias ULINT: time expressed as a distance from 1.1.2000 00:00 in nanoseconds ● sXXX - '2015-12-18-14:29:09.978700026' - STRING(29): ● DCTIME64_TO_STRING() - Converts a T_DCTIME64 to a string with a length of 29 characters. Part of the PLC library: Tc2_EtherCAT
Error in PTP diagnosis: PTP state does not change from "LISTENING" to "SLAVE"	● Check the correlation of the PTP settings of the PTP master and those of the EL6688 (CoE: 0xF882). ● Compare the network settings of the PTP Master and those of the EL6688 (CoE: 0xF8E0). The IP address must not be zero.
Error in PTP diagnosis: "Offset From Master" does not settle around "0".	● Check that "Auto Boot" is set to "Run Mode" and restart the system. ● According to the hardware in use and its accuracy (e.g. less than ±1000 ns = 1 µs with a GPS-assisted system), the value "Offset From Master" varies according to this accuracy. Increasing the sync interval (CoE: OxF882.3) can improve the accuracy, but it also increases the traffic on the network side.

Default state

- PTPv1 Slave (Index 0xF880:01)
- SyncInterval (Index 0xF881:03): 2 seconds
- DomainName (Index 0xF881:01): _DFLT
- Own IP: 0.0.0.0
- Own MAC: 00.01.05.xx.xx.xx (Beckhoff)

Supported PTP modes

Operation mode	Note
PTPv1 SlaveOnly	from SW02
PTPv1 Grandmaster	from SW03
PTPv1 Best Master Clock	on request
PTPv2 SlaveOnly	from SW03
PTPv2 Grandmaster	from SW07
PTPv2 Best Master Clock	on request

Mutual settings

Depending on the protocol used, the following settings must match in the grandmaster clock and the slave clock(s). For setting the EL6688 see the CoE list from index 0xF880. Changes must be saved permanently by writing 0x65766173 into index 0x1010:01.

- PTPv1
  - DomainName
  - SyncInterval
  - Delay Request Interval
- PTPv2
  - TransportLayer
  - DomainNumber
  - DelayMechanism (disabled, End2End, Peer2Peer [not yet supported])
  - SyncInterval
  - Delay Request Interval

Quality settings

For setting the EL6688 see the CoE list from index 0xF880. Changes must be saved permanently by writing 0x65766173 into index 0x1010:01.

- PTPv1
  "Clock Stratum": the smaller this value, the better the quality the master assigns
  "Preferred": this flag indicates a master preference for the clock
  Both value influence the BMCA in the network.
- PTPv2
  Priority1+2, for example, corresponds to Stratum+Preferred

TwinCAT settings

Distributed clock (DC) timing settings

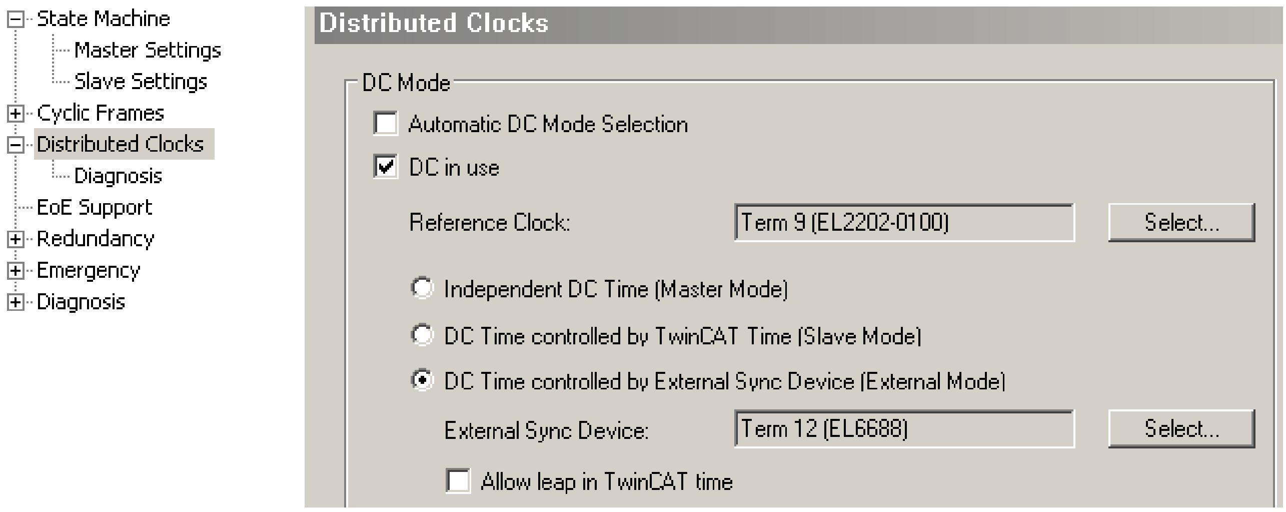


Fig. 93: TwinCAT 2.11 DC settings

We recommended manually selecting the EL6688 as reference clock through "DC in use".

- **Independent DC Time:** one of the EL terminals (generally the first terminal supporting DC) is the reference clock to which all other DC terminals are adjusted. Even an EL6688 that may be present in the system is adjusted to this reference clock as a DC slave. Selection of the reference clock in the dialog above.
  This setting is useful if the EL6688 is operated as PTP grandmaster clock and another EtherCAT system is to be synchronized.
- **DC Time controlled by TwinCAT:** the DC reference clock is adjusted to the local TwinCAT time.
- **DC Time controlled by External Sync Device**: if the EtherCAT system is to be adjusted to a higher-level clock, the external sync device can be selected here.
  This setting is useful if the EL6688 is operated as PTP slave clock and another EtherCAT system is to be used for synchronization.

TwinCAT behavior

After the EtherCAT startup the EL6688 takes a few seconds before it can supply data for the synchronization. This is indicated by toggling bits in the process data. Depending on the environment, a few more seconds may elapse before full synchronization is achieved.

Operation of the EL6688 as PTPv1 master

The SyncInterval of the sent SyncTelegrams can be changed. The default is 2 sec.

Stratum = 0 is automatically set, forcing this clock to act as grandmaster for the network.

In master mode the EL6688 reports "External device not connected" in the process data

Operation of the EL6688 as PTPv1/v2 slave

Stratum = 255 is set to prevent this clock being use as grandmaster in the network.

Own IP address: the EL6688 can be allocated a dedicated IP address, under which it sends its DelayRequest messages, for example. It can also be used for ping control. Depending on the PTP master used an IP address ≠ 0 is required in the PTP slaves.

Also see about this

Objects for commissioning [▸ 90]

5.4 Object description and parameterization

EtherCAT XML Device Description

The display matches that of the CoE objects from the EtherCAT XML Device Description. We recommend downloading the latest XML file from the download area of the Beckhoff website and installing it according to installation instructions.

Parameterization via the CoE list (CAN over EtherCAT)

The terminal is parameterized via the CoE - Online tab (double-click on the respective object) or via the Process Data tab (allocation of PDOs). Please note the following general CoE information [▸ 26] when using/manipulating the CoE parameters:

- Keep a startup list if components have to be replaced
- Differentiation between online/offline dictionary, existence of current XML description
- “CoE-Reload” for resetting the changes

Introduction

The CoE overview contains objects for different intended applications:

- Objects required for parameterization [▸ 90] during commissioning

- Objects intended for regular operation [▶ 91], e.g. through ADS access.
- Objects for indicating internal settings [▶ 91] (may be fixed)

The following section first describes the objects required for normal operation, followed by a complete overview of missing objects.

5.4.1 Objects for commissioning

Index 0x1010 Store parameters

Index (hex)	Name	Meaning	Data type	Flags	Default
1010:0	Store parameters	Max. Subindex	UINT8	RO	0x01 (1_{dec})
1010:01	SubIndex 001	Changes in the configuration can be saved permanently by entering **0x65766173**	UINT32	RW	0x00000000 (0_{dec})

Index 0x1011 Restore default parameters

Index (hex)	Name	Meaning	Data type	Flags	Default
1011:0	Restore default parameters	Restore default parameters	UINT8	RO	0x01 (1_{dec})
1011:01	SubIndex 001	If this object is set to "**0x64616F6C**" in the set value dialog, all backup objects are reset to their delivery state.	UINT32	RW	0x00000000 (0_{dec})

Index 0xF880 PTP Common

Index (hex)	Name	Meaning	Data type	Flags	Default
F880:0	PTP Common	Max. Subindex	UINT8	RO	0x01 (1_{dec})
F880:01	Precision Time Protocol	EL6688 mode setting: PTPV1/2	UINT16	RW	0x0010 (16_{dec})

Index 0xF881 PTPv1 Settings

Index (hex)	Name	Meaning	Data type	Flags	Default
F881:0	PTPv1 Settings	Max. Subindex	UINT8	RO	0x07 (7_{dec})
F881:01	Subdomain Name	Name of the SubDomain: _DFLT, _ALT1, _ALT2, _ALT3	UINT16	RW	0x0000 (0_{dec})
F881:02	Subdomain Name (user)	Subdomain Name (user)	STRING	RW	
F881:03	Sync Interval	Interval of the sync telegrams from the PTP master	UINT16	RW	0x0001 (1_{dec})
F881:04	Delay Request Interval	Interval of the DelayRequest telegrams from the PTP slave	UINT16	RW	0x0005 (5_{dec})
F881:05	Clock is preferred	1: The clock tries to become grandmaster	UINT16	RW	0x0000 (0_{dec})
F881:06	Clock Stratum	Information about the time quality of the own clock within the PTP network	UINT16	RW	0x0004 (4_{dec})
F881:07	Management	Management	UINT16	RW	0x0000 (0_{dec})

Index 0xF882 PTPv2 Settings

Index (hex)	Name	Meaning	Data type	Flags	Default
F882:0	PTPv2 Settings	Max. Subindex	UINT8	RO	0x09 (9_{dec})
F882:01	Transport Layer	Transport Layer	UINT16	RW	0x0001 (1_{dec})
F882:02	Domain Number	Domain Number	UINT16	RW	0x0000 (0_{dec})
F882:03	Sync Interval	Sync Interval	UINT16	RW	0x0000 (0_{dec})
F882:04	Delay Request Interval	Delay Request Interval	UINT16	RW	0x0000 (0_{dec})
F882:05	Delay Mechanism	Delay Mechanism	UINT16	RW	0x0001 (1_{dec})
F882:06	Announce Interval	Announce Interval	UINT16	RW	0x0001 (1_{dec})
F882:07	Announce Interval Timeout	Announce Interval Timeout	UINT16	RW	0x0003 (3_{dec})
F882:08	Priority1	Priority1	UINT16	RW	0x0080 (128_{dec})
F882:09	Priority2	Priority2	UINT16	RW	0x0080 (128_{dec})

Index 0xF8E0 Ethernet Settings

Index (hex)	Name	Meaning	Data type	Flags	Default
F8E0:0	Ethernet Settings	Max. Subindex	UINT8	RO	0x04 (4_{dec})
F8E0:01	Address Type	default: FIXED	UINT16	RW	0x0001 (1_{dec})
F8E0:02	IP Address	IP address under which a PTP device is accessible or sends its telegrams	UINT32	RW	0x00000000 (0_{dec})
F8E0:03	Subnetmask	Subnetmask	UINT32	RW	0x00000000 (0_{dec})
F8E0:04	Gateway	Gateway	UINT32	RW	0x00000000 (0_{dec})

5.4.2 Objects for regular operation

The EL6688 has no such objects.

5.4.3 Other objects 0x1000-0xFFFF

Complete overview

Standard objects (0x1000-0x1FFF)

Standard objects have the same meaning for all EtherCAT slaves.

Index 0x1000 Device type

Index (hex)	Name	Meaning	Data type	Flags	Default
1000:0	Device type	Device type of the EtherCAT slave: the Lo-Word contains the CoE profile used (5001). The Hi-Word contains the module profile according to the modular device profile.	UINT32	RO	0x00001389 (5001_{dec})

Index 0x1008 Device name

Index (hex)	Name	Meaning	Data type	Flags	Default
1008:0	Device name	Device name of the EtherCAT slave	STRING	RO	EL6688

Index 0x1009 Hardware version

Index (hex)	Name	Meaning	Data type	Flags	Default
1009:0	Hardware version	Hardware version of the EtherCAT slave	STRING	RO	02

Index 0x100A Software version

Index (hex)	Name	Meaning	Data type	Flags	Default
100A:0	Software version	Firmware version of the EtherCAT slave	STRING	RO	02

Index 0x1018 Identity

Index (hex)	Name	Meaning	Data type	Flags	Default
1018:0	Identity	Information for identifying the slave	UINT8	RO	0x04 (4_{dec})
1018:01	Vendor ID	Vendor ID of the EtherCAT slave	UINT32	RO	0x00000002 (2_{dec})
1018:02	Product code	Product code of the EtherCAT slave	UINT32	RO	0x1A203052 (438317138_{dec})
1018:03	Revision	Revision number of the EtherCAT slave; the low word (bit 0-15) indicates the special terminal number, the high word (bit 16-31) refers to the device description	UINT32	RO	0x00110000 (1114112_{dec})
1018:04	Serial number	Serial number of the EtherCAT slave; the low byte (bit 0-7) of the low word contains the year of production, the high byte (bit 8-15) of the low word contains the week of production, the high word (bit 16-31) is 0	UINT32	RO	0x00000000 (0_{dec})

Index 0x10F0 Backup parameter handling

Index (hex)	Name	Meaning	Data type	Flags	Default
10F0:0	Backup parameter handling	Information for standardized loading and saving of backup entries	UINT8	RO	0x01 (1_{dec})
10F0:01	Checksum	Checksum across all backup entries of the EtherCAT slave	UINT32	RO	0x00000000 (0_{dec})

Index 0x10F4 External synchronization status

Index (hex)	Name	Meaning	Data type	Flags	Default
10F4:0	External synchronization status	Max. Subindex	UINT8	RO	0x13 (19_{dec})
10F4:01	Sync Mode	Sync Mode	BIT2	RO	0x00 (0_{dec})
10F4:0E	Control value update toggle	Control value update toggle	BOOLEAN	RO	0x00 (0_{dec})
10F4:0F	Time stamp update toggle	Time stamp update toggle	BOOLEAN	RO	0x00 (0_{dec})
10F4:10	External device not connected	External device not connected	BOOLEAN	RO	0x00 (0_{dec})
10F4:11	Internal time stamp	Internal time stamp	UINT64	RO	
10F4:12	External time stamp	External time stamp	UINT64	RO	
10F4:13	Control Value for DC Master Clock	Control Value for DC Master Clock	INT32	RO	0x00000000 (0_{dec})

Index 0x10F5 External synchronization settings

Index (hex)	Name	Meaning	Data type	Flags	Default
10F5:0	External synchronizatio n settings	Max. Subindex	UINT8	RO	0x12 (18_{dec})
10F5:01	Sync master	Sync master	BOOLEAN	RW	0x00 (0_{dec})
10F5:02	32 Bit time stamps	32 Bit time stamps	BOOLEAN	RW	0x00 (0_{dec})
10F5:11	Control Interval (ms)	Control Interval (ms)	UINT16	RW	0x0000 (0_{dec})
10F5:12	Additional System Time	Additional System Time	UINT64	RW	

Index 0x1800 TxPDO-Par External Sync

Index (hex)	Name	Meaning	Data type	Flags	Default
1800:0	TxPDO-Par External Sync	PDO Parameter TxPDO 1	UINT8	RO	0x06 (6_{dec})
1800:06	Exclude TxPDOs	Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 1	OCTET-STRING[4]	RO	01 1A 02 1A

Index 0x1801 TxPDO-Par External Sync (32 Bit)

Index (hex)	Name	Meaning	Data type	Flags	Default
1801:0	TxPDO-Par External Sync (32 Bit)	PDO Parameter TxPDO 2	UINT8	RO	0x06 (6_{dec})
1801:06	Exclude TxPDOs	Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 2	OCTET-STRING[4]	RO	00 1A 02 1A

Index 0x1802 TxPDO-Par External Sync Compact

Index (hex)	Name	Meaning	Data type	Flags	Default
1802:0	TxPDO-Par External Sync Compact	PDO Parameter TxPDO 3	UINT8	RO	0x06 (6_{dec})
1802:06	Exclude TxPDOs	Specifies the TxPDOs (index of TxPDO mapping objects) that must not be transferred together with TxPDO 3	OCTET-STRING[4]	RO	00 1A 01 1A

Index 0x1A00 TxPDO-Map External Sync

Index (hex)	Name	Meaning	Data type	Flags	Default
1A00:0	TxPDO-Map External Sync	PDO Mapping TxPDO 1	UINT8	RO	0x09 (9_{dec})
1A00:01	SubIndex 001	1. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x02)	UINT32	RO	0x10F4:02, 2
1A00:02	SubIndex 002	2. PDO Mapping entry (6 bits align)	UINT32	RO	0x0000:00, 6
1A00:03	SubIndex 003	3. PDO Mapping entry (5 bits align)	UINT32	RO	0x0000:00, 5
1A00:04	SubIndex 004	4. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0E (Control value update toggle))	UINT32	RO	0x10F4:0E, 1
1A00:05	SubIndex 005	5. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0F (Time stamp update toggle))	UINT32	RO	0x10F4:0F, 1
1A00:06	SubIndex 006	6. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x10 (External device not connected))	UINT32	RO	0x10F4:10, 1
1A00:07	SubIndex 007	7. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x11 (Internal time stamp))	UINT32	RO	0x10F4:11, 64
1A00:08	SubIndex 008	8. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x12 (External time stamp))	UINT32	RO	0x10F4:12, 64
1A00:09	SubIndex 009	9. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x13 (Control Value for DC Master Clock))	UINT32	RO	0x10F4:13, 32

Index 0x1A01 TxPDO-Map External Sync (32 Bit)

Index (hex)	Name	Meaning	Data type	Flags	Default
1A01:0	TxPDO-Map External Sync (32 Bit)	PDO Mapping TxPDO 2	UINT8	RO	0x09 (9_{dec})
1A01:01	SubIndex 001	1. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x02)	UINT32	RO	0x10F4:02, 2
1A01:02	SubIndex 002	2. PDO Mapping entry (6 bits align)	UINT32	RO	0x0000:00, 6
1A01:03	SubIndex 003	3. PDO Mapping entry (5 bits align)	UINT32	RO	0x0000:00, 5
1A01:04	SubIndex 004	4. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0E (Control value update toggle))	UINT32	RO	0x10F4:0E, 1
1A01:05	SubIndex 005	5. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0F (Time stamp update toggle))	UINT32	RO	0x10F4:0F, 1
1A01:06	SubIndex 006	6. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x10 (External device not connected))	UINT32	RO	0x10F4:10, 1
1A01:07	SubIndex 007	7. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x11 (Internal time stamp))	UINT32	RO	0x10F4:11, 32
1A01:08	SubIndex 008	8. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x12 (External time stamp))	UINT32	RO	0x10F4:12, 32
1A01:09	SubIndex 009	9. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x13 (Control Value for DC Master Clock))	UINT32	RO	0x10F4:13, 32

Index 0x1A02 TxPDO-Map External Sync Compact

Index (hex)	Name	Meaning	Data type	Flags	Default
1A02:0	TxPDO-Map External Sync Compact	PDO Mapping TxPDO 3	UINT8	RO	0x06 (6_{dec})
1A02:01	SubIndex 001	1. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x02)	UINT32	RO	0x10F4:02, 2
1A02:02	SubIndex 002	2. PDO Mapping entry (6 bits align)	UINT32	RO	0x0000:00, 6
1A02:03	SubIndex 003	3. PDO Mapping entry (5 bits align)	UINT32	RO	0x0000:00, 5
1A02:04	SubIndex 004	4. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0E (Control value update toggle))	UINT32	RO	0x10F4:0E, 1
1A02:05	SubIndex 005	5. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x0F (Time stamp update toggle))	UINT32	RO	0x10F4:0F, 1
1A02:06	SubIndex 006	6. PDO Mapping entry (object 0x10F4 (External synchronization status), entry 0x10 (External device not connected))	UINT32	RO	0x10F4:10, 1

Index 0x1C00 Sync manager type

Index (hex)	Name	Meaning	Data type	Flags	Default
1C00:0	Sync manager type	Using the sync managers	UINT8	RO	0x04 (4_{dec})
1C00:01	SubIndex 001	Sync-Manager Type Channel 1: Mailbox Write	UINT8	RO	0x01 (1_{dec})
1C00:02	SubIndex 002	Sync-Manager Type Channel 2: Mailbox Read	UINT8	RO	0x02 (2_{dec})
1C00:03	SubIndex 003	Sync-Manager Type Channel 3: Process Data Write (Outputs)	UINT8	RO	0x03 (3_{dec})
1C00:04	SubIndex 004	Sync-Manager Type Channel 4: Process Data Read (Inputs)	UINT8	RO	0x04 (4_{dec})

Index 0x1C12 RxPDO assign

Index (hex)	Name	Meaning	Data type	Flags	Default
1C12:0	RxPDO assign	PDO Assign Outputs	UINT8	RW	0x00 (0_{dec})

Index 0x1C13 TxPDO assign

Index (hex)	Name	Meaning	Data type	Flags	Default
1C13:0	TxPDO assign	PDO Assign Inputs	UINT8	RW	0x01 (1_{dec})
1C13:01	SubIndex 001	1. allocated TxPDO (contains the index of the associated TxPDO mapping object)	UINT16	RW	0x1A00 (6656_{dec})

Index 0x1C33 SM input parameter

Index (hex)	Name	Meaning	Data type	Flags	Default
1C33:0	SM input parameter	Synchronization parameters for the inputs	UINT8	RO	0x20 (32_{dec})
1C33:01	Sync mode	Current synchronization mode: • 0: Free Run • 1: Synchron with SM 3 Event (no outputs available) • 2: DC - Synchron with SYNC0 Event • 3: DC - Synchron with SYNC1 Event • 34: Synchron with SM 2 Event (outputs available)	UINT16	RW	0x0000 (0_{dec})
1C33:02	Cycle time	as 1C32:02	UINT32	RW	0x000F4240 (1000000_{dec})
1C33:03	Shift time	Time between SYNC0 event and reading of the inputs (in ns, only DC mode)	UINT32	RO	0x00000000 (0_{dec})
1C33:04	Sync modes supported	Supported synchronization modes: • Bit 0: free run is supported • Bit 1: Synchronous with SM 2 Event is supported (outputs available) • Bit 1: Synchronous with SM 3 Event is supported (no outputs available) • Bit 2-3 = 01: DC mode is supported • Bit 4-5 = 01: input shift through local event (outputs available) • Bit 4-5 = 10: input shift with SYNC1 event (no outputs available) • Bit 14 = 1: dynamic times (measurement through writing of 1C32:08 or 1C33:08 [▶ 97])	UINT16	RO	0xC007 (49159_{dec})
1C33:05	Minimum cycle time	as 1C32:05	UINT32	RO	0x000F4240 (1000000_{dec})
1C33:06	Calc and copy time	Time between reading of the inputs and availability of the inputs for the master (in ns, only DC mode)	UINT32	RO	0x00000000 (0_{dec})
1C33:08	Command	as 1C32:08	UINT16	RW	0x0000 (0_{dec})
1C33:09	Delay time	Time between SYNC1 event and reading of the inputs (in ns, only DC mode)	UINT32	RO	0x00000000 (0_{dec})
1C33:0B	SM event missed counter	as 1C32:11	UINT16	RO	0x0000 (0_{dec})
1C33:0C	Cycle exceeded counter	as 1C32:12	UINT16	RO	0x0000 (0_{dec})
1C33:0D	Shift too short counter	as 1C32:13	UINT16	RO	0x0000 (0_{dec})
1C33:20	Sync error	as 1C32:32	BOOLEAN	RO	0x00 (0_{dec})

Profile-specific objects (0x6000-0xFFFF)

Profile-specific objects have the same meaning for all EtherCAT slaves that support the profile 5001.

Index 0xF000 Modular device profile

Index (hex)	Name	Meaning	Data type	Flags	Default
F000:0	Modular device profile	General information for the modular device profile	UINT8	RO	0x02 (2_{dec})
F000:01	Module index distance	Index distance of the objects of the individual channels	UINT16	RO	0x0010 (16_{dec})
F000:02	Maximum number of modules	Number of channels	UINT16	RO	0x0000 (0_{dec})

Index 0xF008 Code word

Index (hex)	Name	Meaning	Data type	Flags	Default
F008:0	Code word	reserved	UINT32	RW	0x00000000 (0_{dec})

Index 0xF8F0 Vendor data

Index (hex)	Name	Meaning	Data type	Flags	Default
F8F0:0	Vendor data	Max. Subindex	UINT8	RO	0x01 (1_{dec})
F8F0:01	MAC_Address	MAC_Address	OCTET-STRING[6]	RW	{0}

6 Appendix

6.1 EtherCAT AL Status Codes

For detailed information please refer to the EtherCAT system description.

6.2 Firmware compatibility

Beckhoff EtherCAT devices are delivered with the latest available firmware version. Compatibility of firmware and hardware is mandatory; not every combination ensures compatibility. The overview below shows the hardware versions on which a firmware can be operated.

Note

- It is recommended to use the newest possible firmware for the respective hardware
- Beckhoff is not under any obligation to provide customers with free firmware updates for delivered products.

NOTE

Risk of damage to the device!

Pay attention to the instructions for firmware updates on the separate page. If a device is placed in BOOT-STRAP mode for a firmware update, it does not check when downloading whether the new firmware is suitable. This can result in damage to the device! Therefore, always make sure that the firmware is suitable for the hardware version!

EL6688			
Hardware (HW)	**Firmware (FW)**	**Revision no.**	**Release date**
02	01	EL6688-0000-0016	05/2008
02 - 04	02	EL6688-0000-0017	05/2009
	03		05/2009
03 - 09	04	EL6688-0000-0018	03/2010
	05	EL6688-0000-0019	02/2011
		EL6688-0000-0020	10/2012
	06	EL6688-0000-0021	07/2014
10 – 11*	07	EL6688-0000-0022	02/2016
	08		07/2016
	09		02/2017
	10*		10/2017

*) This is the current compatible firmware/hardware version at the time of the preparing this documentation. Check on the Beckhoff web page whether more up-to-date documentation is available.

6.3 Firmware Update EL/ES/EM/EPxxxx

This section describes the device update for Beckhoff EtherCAT slaves from the EL/ES, EM, EK and EP series. A firmware update should only be carried out after consultation with Beckhoff support.

Storage locations

An EtherCAT slave stores operating data in up to 3 locations:

- Depending on functionality and performance EtherCAT slaves have one or several local controllers for processing I/O data. The corresponding program is the so-called **firmware** in *.efw format.

- In some EtherCAT slaves the EtherCAT communication may also be integrated in these controllers. In this case the controller is usually a so-called **FPGA** chip with *.rbf firmware.
- In addition, each EtherCAT slave has a memory chip, a so-called **ESI-EEPROM**, for storing its own device description (ESI: EtherCAT Slave Information). On power-up this description is loaded and the EtherCAT communication is set up accordingly. The device description is available from the download area of the Beckhoff website at (http://www.beckhoff.de). All ESI files are accessible there as zip files.

Customers can access the data via the EtherCAT fieldbus and its communication mechanisms. Acyclic mailbox communication or register access to the ESC is used for updating or reading of these data.

The TwinCAT System Manager offers mechanisms for programming all 3 parts with new data, if the slave is set up for this purpose. Generally the slave does not check whether the new data are suitable, i.e. it may no longer be able to operate if the data are unsuitable.

Simplified update by bundle firmware

The update using so-called **bundle firmware** is more convenient: in this case the controller firmware and the ESI description are combined in a *.efw file; during the update both the firmware and the ESI are changed in the terminal. For this to happen it is necessary

- for the firmware to be in a packed format: recognizable by the file name, which also contains the revision number, e.g. ELxxxx-xxxx_REV0016_SW01.efw
- for password=1 to be entered in the download dialog. If password=0 (default setting) only the firmware update is carried out, without an ESI update.
- for the device to support this function. The function usually cannot be retrofitted; it is a component of many new developments from year of manufacture 2016.

Following the update, its success should be verified

- ESI/Revision: e.g. by means of an online scan in TwinCAT ConfigMode/FreeRun – this is a convenient way to determine the revision
- Firmware: e.g. by looking in the online CoE of the device

NOTE

Risk of damage to the device!

Note the following when downloading new device files

• Firmware downloads to an EtherCAT device must not be interrupted
• Flawless EtherCAT communication must be ensured. CRC errors or LostFrames must be avoided.
• The power supply must adequately dimensioned. The signal level must meet the specification.

In the event of malfunctions during the update process the EtherCAT device may become unusable and require re-commissioning by the manufacturer.

6.3.1 Device description ESI file/XML

NOTE

Attention regarding update of the ESI description/EEPROM

Some slaves have stored calibration and configuration data from the production in the EEPROM. These are irretrievably overwritten during an update.

The ESI device description is stored locally on the slave and loaded on start-up. Each device description has a unique identifier consisting of slave name (9 characters/digits) and a revision number (4 digits). Each slave configured in the System Manager shows its identifier in the EtherCAT tab:

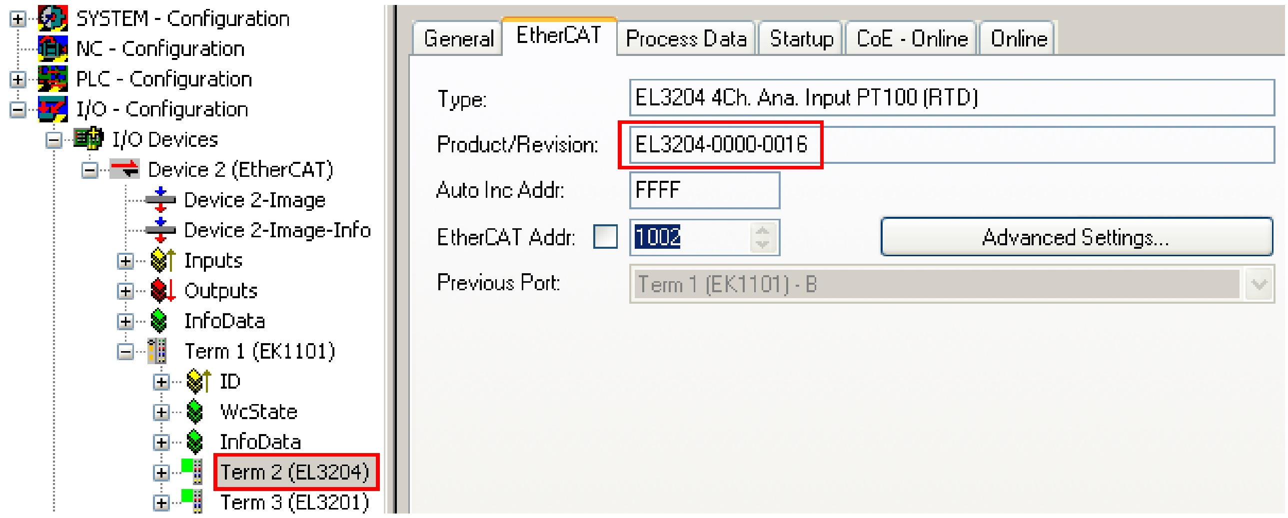


Fig. 94: Device identifier consisting of name EL3204-0000 and revision -0016

The configured identifier must be compatible with the actual device description used as hardware, i.e. the description which the slave has loaded on start-up (in this case EL3204). Normally the configured revision must be the same or lower than that actually present in the terminal network.

For further information on this, please refer to the EtherCAT system documentation.

Update of XML/ESI description

The device revision is closely linked to the firmware and hardware used. Incompatible combinations lead to malfunctions or even final shutdown of the device. Corresponding updates should only be carried out in consultation with Beckhoff support.

Display of ESI slave identifier

The simplest way to ascertain compliance of configured and actual device description is to scan the EtherCAT boxes in TwinCAT mode Config/FreeRun:

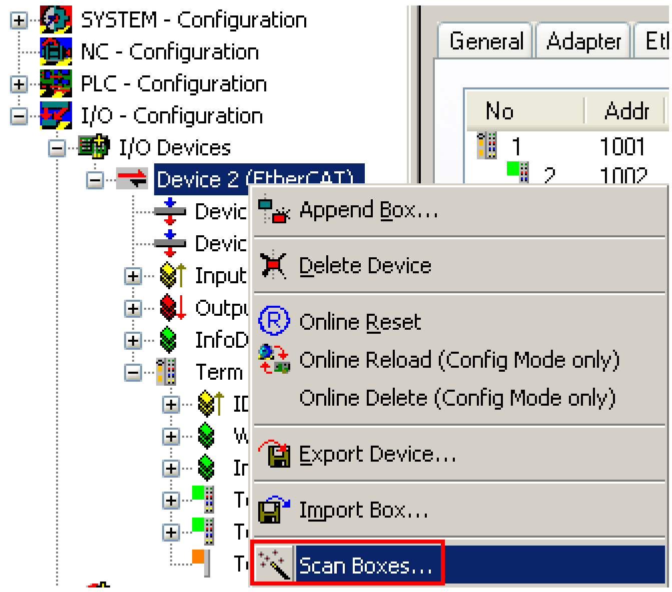


Fig. 95: Scan the subordinate field by right-clicking on the EtherCAT device

If the found field matches the configured field, the display shows

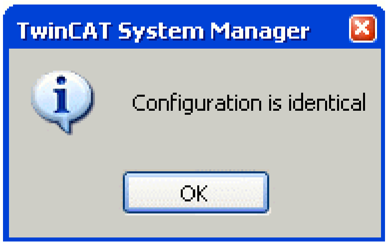


Fig. 96: *Configuration is identical*

otherwise a change dialog appears for entering the actual data in the configuration.

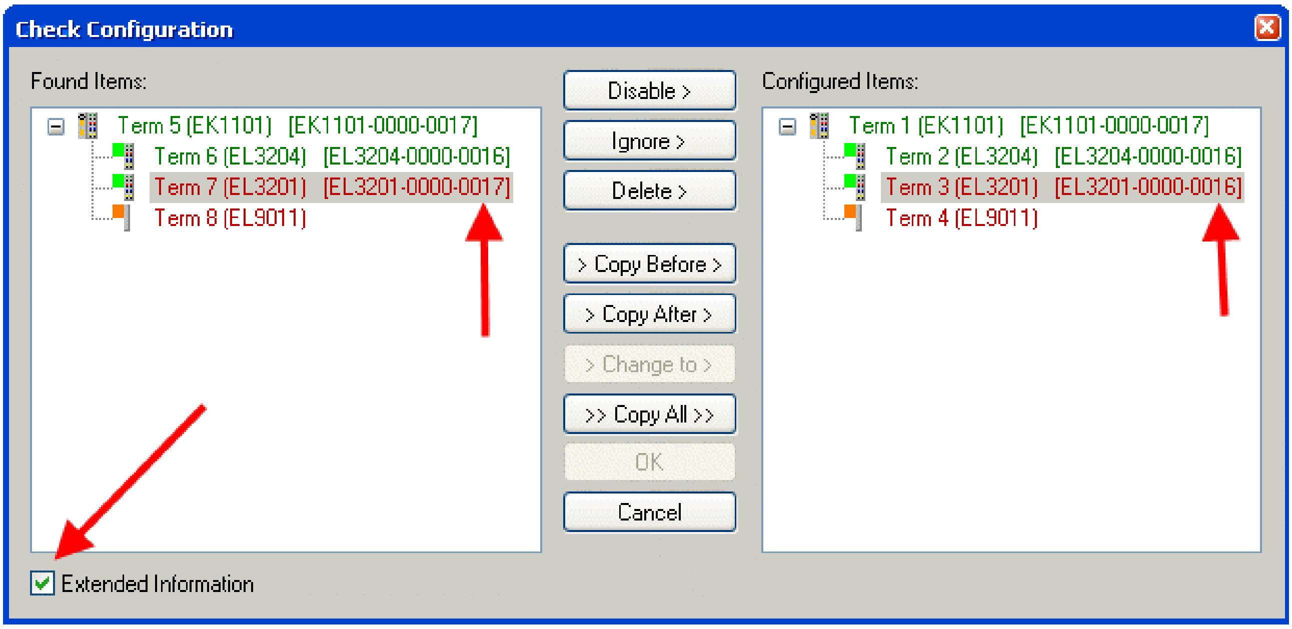


Fig. 97: *Change dialog*

In this example in Fig. *Change dialog*, an EL3201-0000-**0017** was found, while an EL3201-0000-**0016** was configured. In this case the configuration can be adapted with the *Copy Before* button. The *Extended Information* checkbox must be set in order to display the revision.

Changing the ESI slave identifier

The ESI/EEPROM identifier can be updated as follows under TwinCAT:

- Trouble-free EtherCAT communication must be established with the slave.
- The state of the slave is irrelevant.
- Right-clicking on the slave in the online display opens the *EEPROM Update* dialog, Fig. *EEPROM Update*

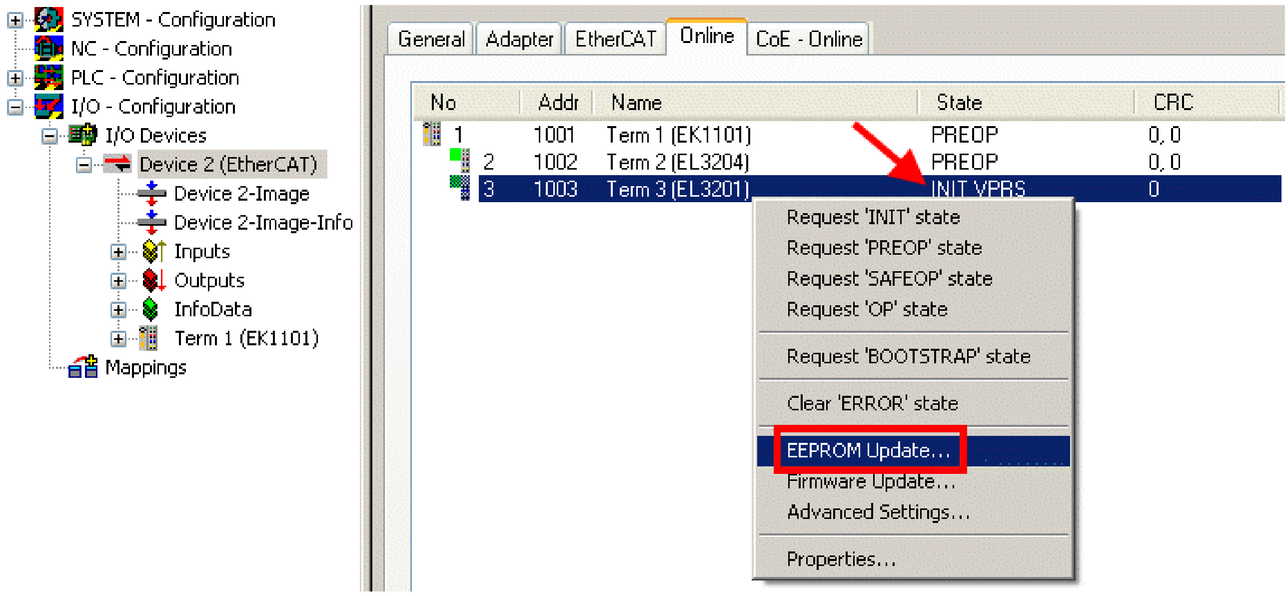


Fig. 98: EEPROM Update

The new ESI description is selected in the following dialog, see Fig. *Selecting the new ESI.* The checkbox *Show Hidden Devices* also displays older, normally hidden versions of a slave.

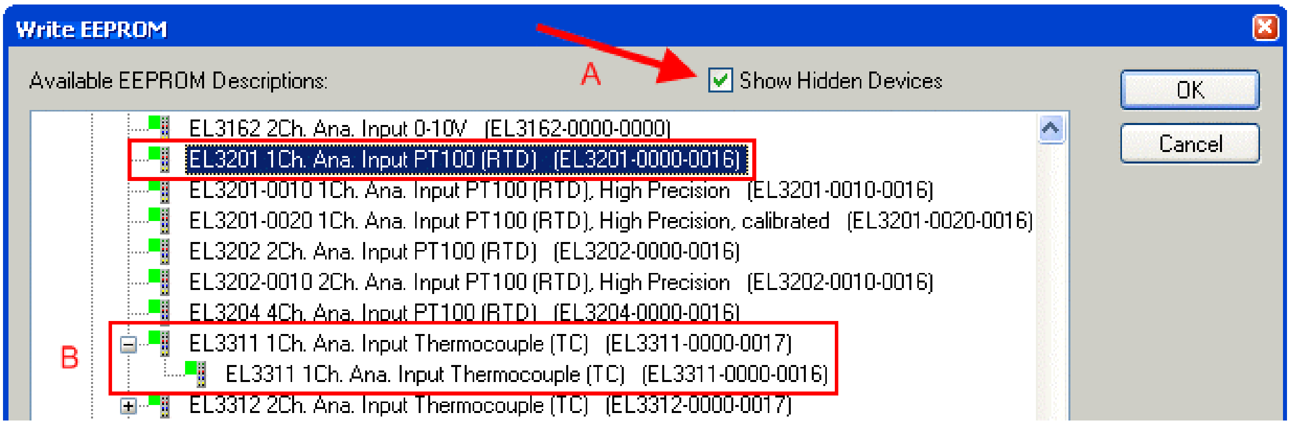


Fig. 99: Selecting the new ESI

A progress bar in the System Manager shows the progress. Data are first written, then verified.

The change only takes effect after a restart.

Most EtherCAT devices read a modified ESI description immediately or after startup from the INIT. Some communication settings such as distributed clocks are only read during power-on. The EtherCAT slave therefore has to be switched off briefly in order for the change to take effect.

6.3.2 Firmware explanation

Determining the firmware version

Determining the version on laser inscription

Beckhoff EtherCAT slaves feature serial numbers applied by laser. The serial number has the following structure: **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.: 12 10 03 02:

12 - week of production 12
10 - year of production 2010
03 - firmware version 03
02 - hardware version 02

Determining the version via the System Manager

The TwinCAT System Manager shows the version of the controller firmware if the master can access the slave online. Click on the E-Bus Terminal whose controller firmware you want to check (in the example terminal 2 (EL3204)) and select the tab *CoE Online* (CAN over EtherCAT).

CoE Online and Offline CoE

Two CoE directories are available:
• **online**: This is offered in the EtherCAT slave by the controller, if the EtherCAT slave supports this. This CoE directory can only be displayed if a slave is connected and operational.
• **offline**: The EtherCAT Slave Information ESI/XML may contain the default content of the CoE. This CoE directory can only be displayed if it is included in the ESI (e.g. "Beckhoff EL5xxx.xml").

The Advanced button must be used for switching between the two views.

In Fig. *Display of EL3204 firmware version* the firmware version of the selected EL3204 is shown as 03 in CoE entry 0x100A.

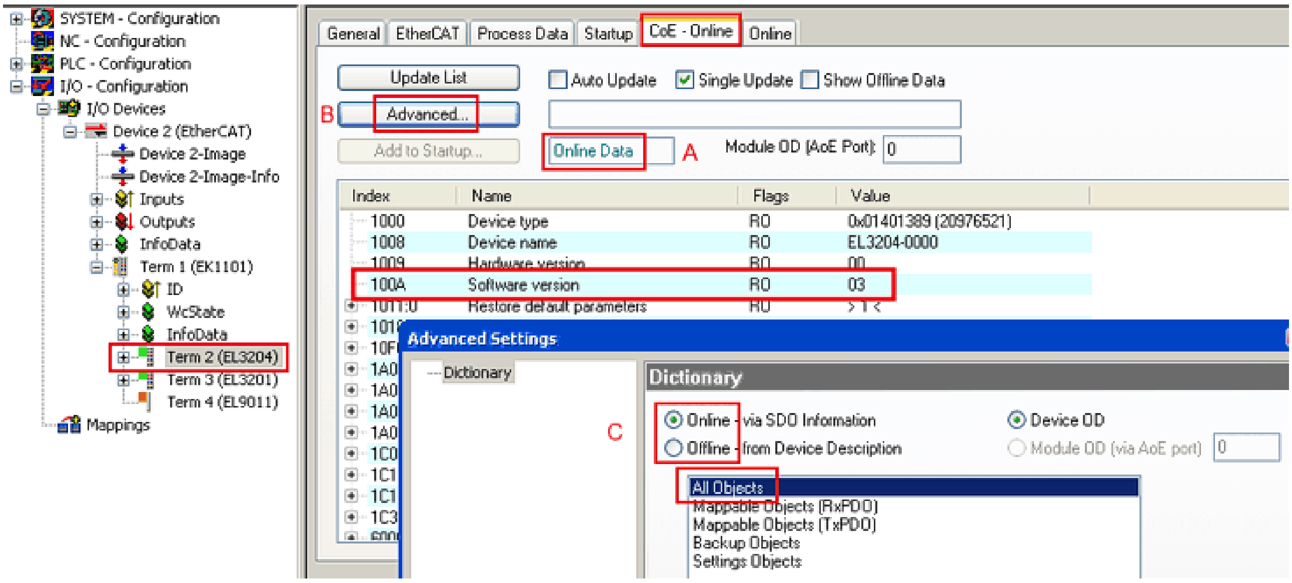


Fig. 100: Display of EL3204 firmware version

In (A) TwinCAT 2.11 shows that the Online CoE directory is currently displayed. If this is not the case, the Online directory can be loaded via the *Online* option in Advanced Settings (B) and double-clicking on *AllObjects*.

6.3.3 Updating controller firmware *.efw

CoE directory

The Online CoE directory is managed by the controller and stored in a dedicated EEPROM, which is generally not changed during a firmware update.

Switch to the *Online* tab to update the controller firmware of a slave, see Fig. *Firmware Update.*

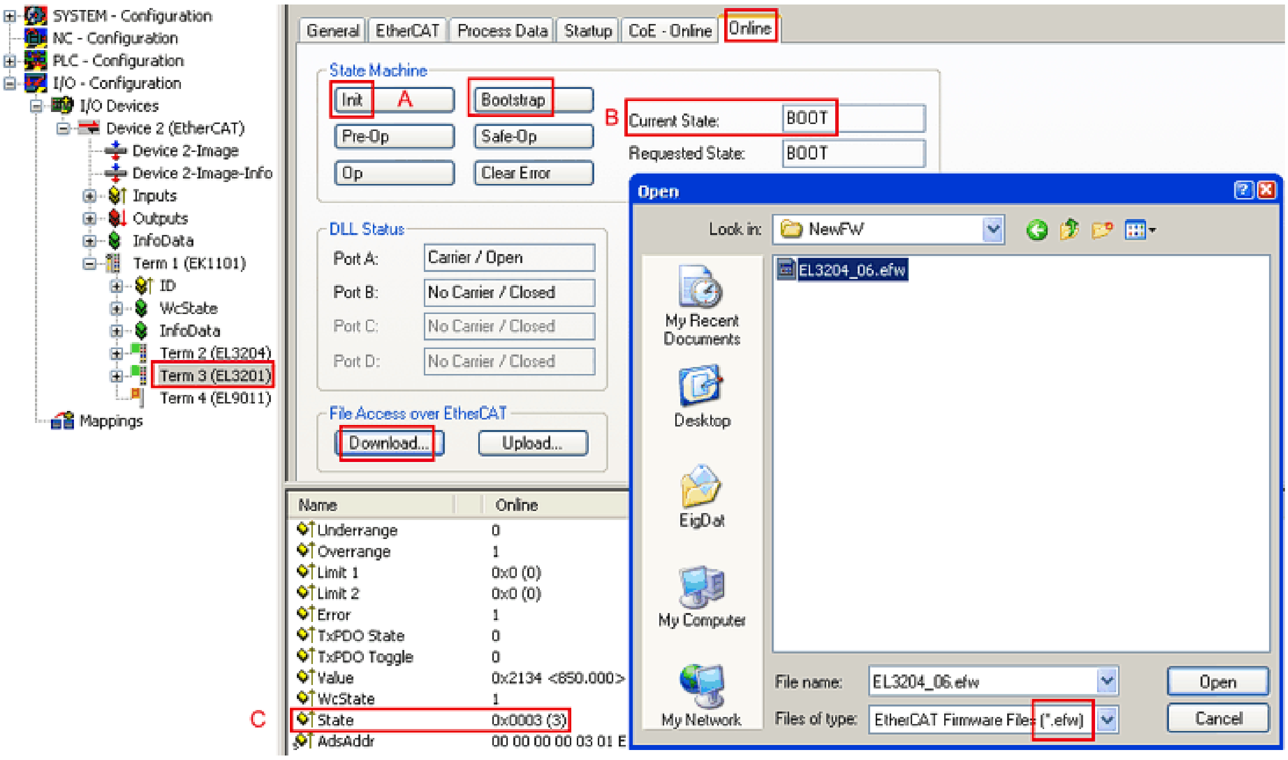
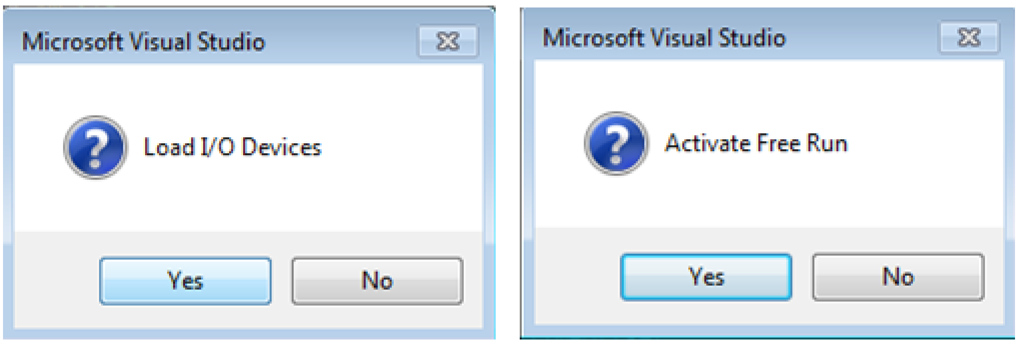


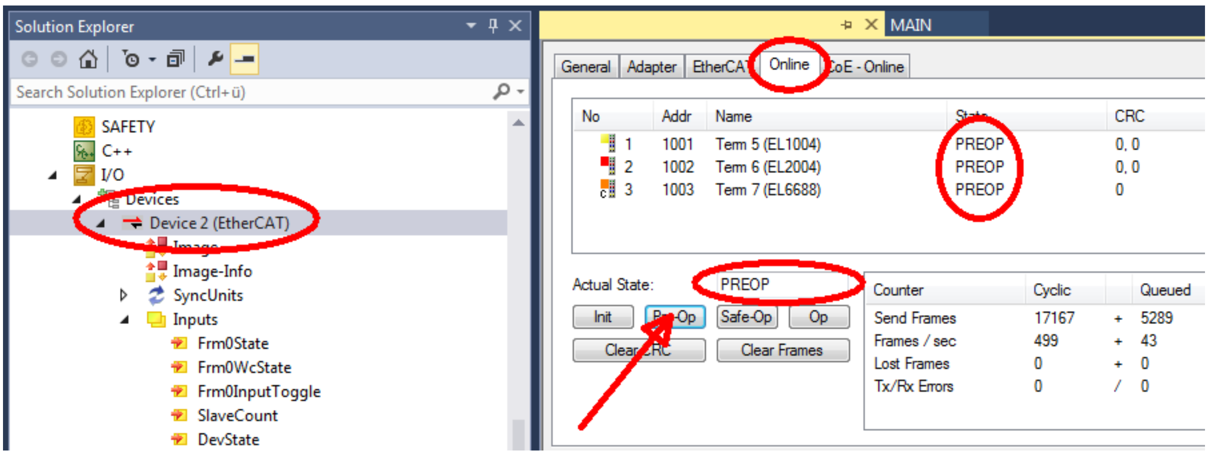
Fig. 101: Firmware Update

Proceed as follows, unless instructed otherwise by Beckhoff support. Valid for TwinCAT 2 and 3 as EtherCAT master.

- Switch TwinCAT system to ConfigMode/FreeRun with cycle time >= 1 ms (default in ConfigMode is 4 ms). A FW-Update during real time operation is not recommended.

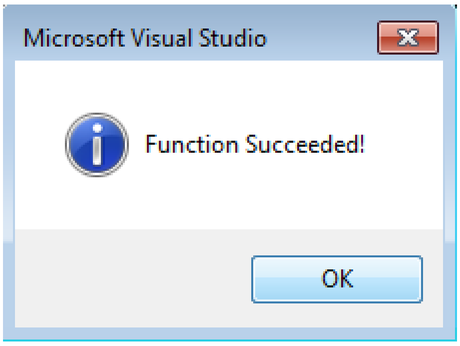


- Switch EtherCAT Master to PreOP



- Switch slave to INIT (A)
- Switch slave to BOOTSTRAP

- Check the current status (B, C)
- Download the new *efw file (wait until it ends). A pass word will not be neccessary usually.



- After the download switch to INIT, then PreOP
- Switch off the slave briefly (don't pull under voltage!)
- Check within CoE 0x100A, if the FW status was correctly overtaken.

6.3.4 FPGA firmware *.rbf

If an FPGA chip deals with the EtherCAT communication an update may be accomplished via an *.rbf file.

- Controller firmware for processing I/O signals
- FPGA firmware for EtherCAT communication (only for terminals with FPGA)

The firmware version number included in the terminal serial number contains both firmware components. If one of these firmware components is modified this version number is updated.

Determining the version via the System Manager

The TwinCAT System Manager indicates the FPGA firmware version. Click on the Ethernet card of your EtherCAT strand (Device 2 in the example) and select the *Online* tab.

The *Reg:0002* column indicates the firmware version of the individual EtherCAT devices in hexadecimal and decimal representation.

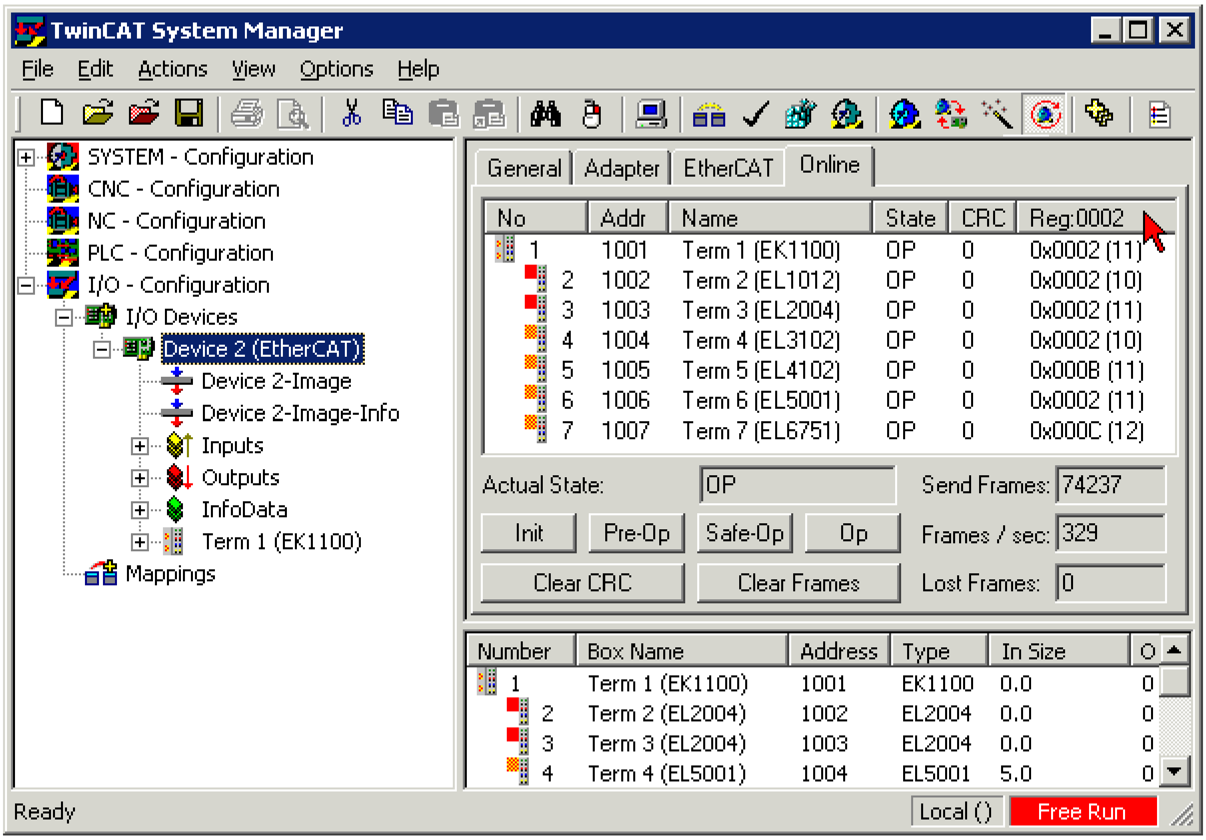


Fig. 102: FPGA firmware version definition

If the column *Reg:0002* is not displayed, right-click the table header and select *Properties* in the context menu.

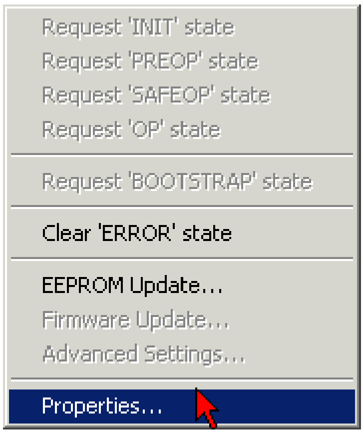


Fig. 103: Context menu *Properties*

The *Advanced Settings* dialog appears where the columns to be displayed can be selected. Under *Diagnosis/***Online View** select the *'0002 ETxxxx Build'* check box in order to activate the FPGA firmware version display.

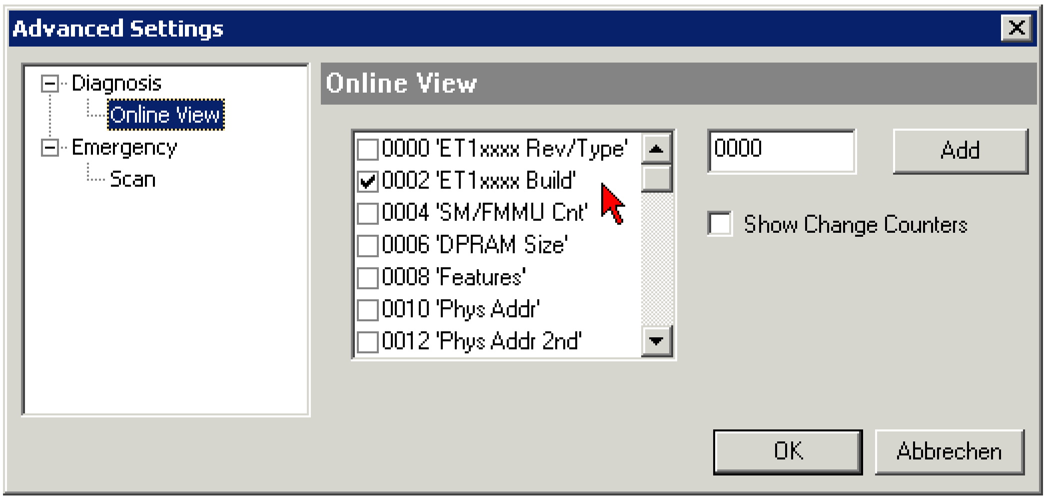


Fig. 104: Dialog *Advanced Settings*

Update

For updating the FPGA firmware

- of an EtherCAT coupler the coupler must have FPGA firmware version 11 or higher;
- of an E-Bus Terminal the terminal must have FPGA firmware version 10 or higher.

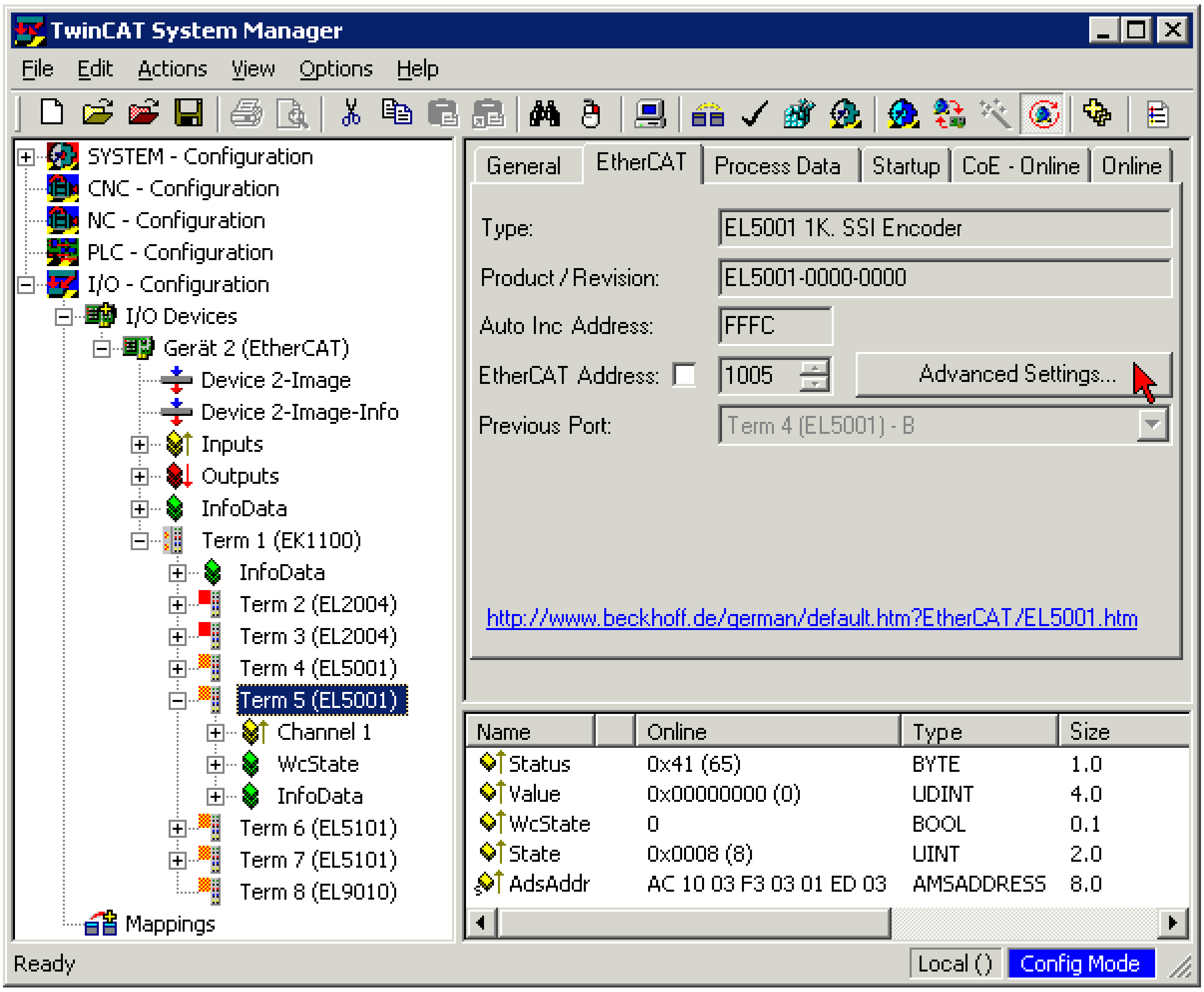
Older firmware versions can only be updated by the manufacturer!

Updating an EtherCAT device

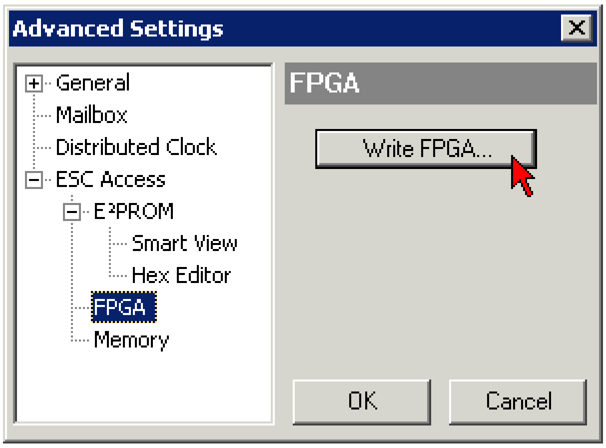
The following sequence order have to be met if no other specifications are given (e.g. by the Beckhoff support):

- Switch TwinCAT system to ConfigMode/FreeRun with cycle time >= 1 ms (default in ConfigMode is 4 ms). A FW-Update during real time operation is not recommended.

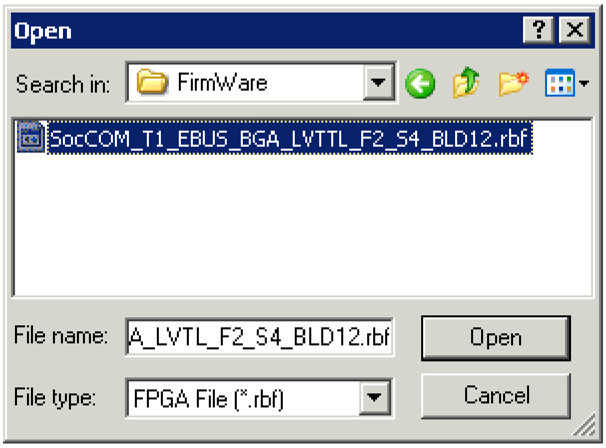
- In the TwinCAT System Manager select the terminal for which the FPGA firmware is to be updated (in the example: Terminal 5: EL5001) and
  click the *Advanced Settings* button in the *EtherCAT* tab:



- The *Advanced Settings* dialog appears. Under *ESC Access/E²PROM*/FPGA click on *Write FPGA* button:



- Select the file (*.rbf) with the new FPGA firmware, and transfer it to the EtherCAT device:



- Wait until download ends
- Switch slave current less for a short time (don't pull under voltage!). In order to activate the new FPGA firmware a restart (switching the power supply off and on again) of the EtherCAT device is required.
- Check the new FPGA status

NOTE

Risk of damage to the device!

A download of firmware to an EtherCAT device must not be interrupted in any case! If you interrupt this process by switching off power supply or disconnecting the Ethernet link, the EtherCAT device can only be recommissioned by the manufacturer!

6.3.5 Simultaneous updating of several EtherCAT devices

The firmware and ESI descriptions of several devices can be updated simultaneously, provided the devices have the same firmware file/ESI.

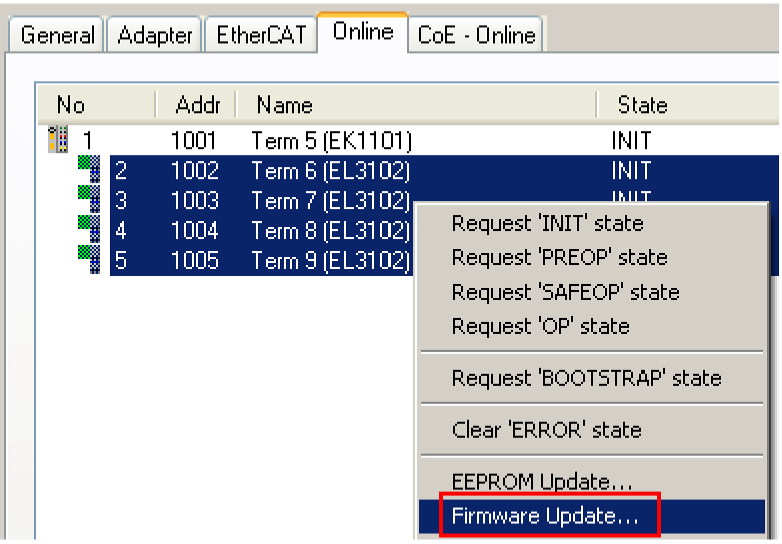


Fig. 105: *Multiple selection and firmware update*

Select the required slaves and carry out the firmware update in BOOTSTRAP mode as described above.

6.4 Restoring the delivery state

To restore the delivery state for backup objects in ELxxxx terminals, the CoE object Restore default parameters, *SubIndex 001* can be selected in the TwinCAT System Manager (Config mode) (see Fig. *Selecting the Restore default parameters PDO*)

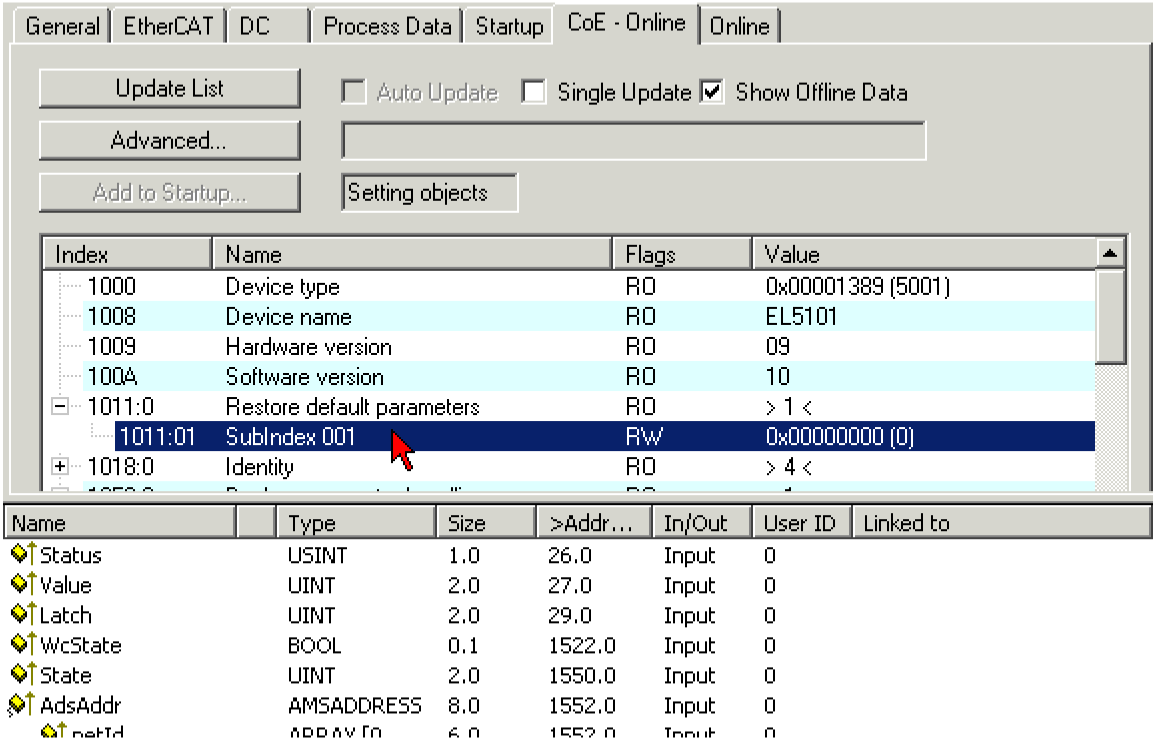


Fig. 106: Selecting the "Restore default parameters" PDO

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* (Fig. *Entering a restore value in the Set Value dialog*). All backup objects are reset to the delivery state.

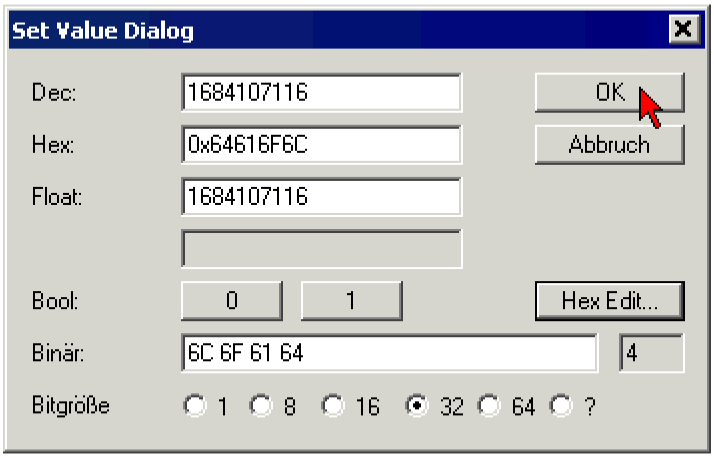


Fig. 107: Entering a restore value in the Set Value dialog

Alternative restore value

In some older terminals the backup objects can be switched with an alternative restore value: Decimal value: 1819238756, Hexadecimal value: 0x6C6F6164An incorrect entry for the restore value has no effect.

6.5 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.

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Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone:	+49(0)5246/963-0
Fax:	+49(0)5246/963-198
e-mail:	info@beckhoff.com

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