EtherCAT

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

EtherCAT in practice

Michael Jost

Beckhoff

Cable

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

Requirements:

Category 5 / class D cable

EtherCAT uses 4 poles

symmetrical assignment 1:1 (no cross-cable is needed)

max. length 100m

Pin M12	**Pin** RJ45	**Wire color** (EIA/TIA-T568B)	**Wire color** (Industrial Ethernet cable)	**Signal**	**Description**
1	1	white-orange	yellow	TD+	Transmission Data +
3	2	orange	orange	TD-	Transmission Data -
2	3	white-green	white	RD+	Receiver Data +
4	6	green	blue	RD-	Receiver Data -

* ZB90x0, Industrial Ethernet cable

Cable

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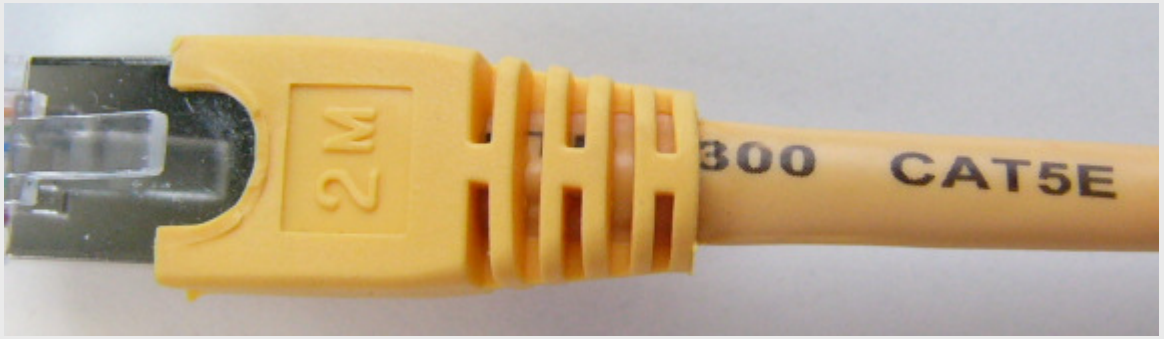
Standard patch cable (min. CAT5) can be used for internal wirings in control cabinets.



EtherCAT

RJ45 connector crimping

- cable and connector
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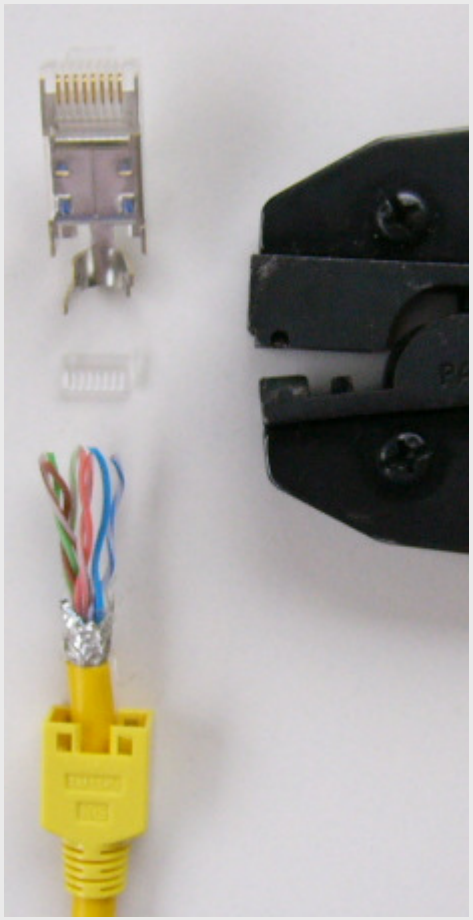
The crimping of RJ45 connectors often causes problems in industrial environments.

- **filigree technique in comparison with traditional field bus systems**
- **connector and tool have to match**
- **assembly time is higher**
- **additional tool is required**



EtherCAT

PIN assignment standard RJ45 connector 1/2

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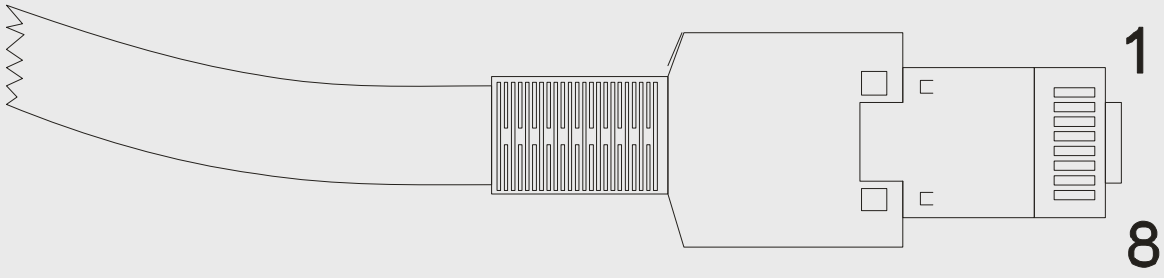

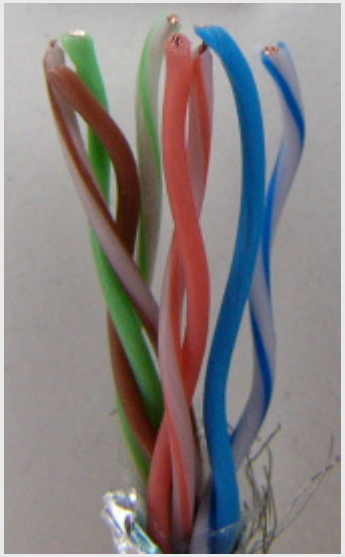

normal assignment

Pin	
1	white-orange
2	orange
3	white-green
4	blue
5	white-blue
6	green
7	white-brown
8	brown

Nach EIA/TIA-T568B

turned assignment

Pin	
1	white-green
2	green
3	white-orange
4	blue
5	white-blue
6	orange
7	white-brown
8	brown

PIN assignment standard RJ45 connector 2/2

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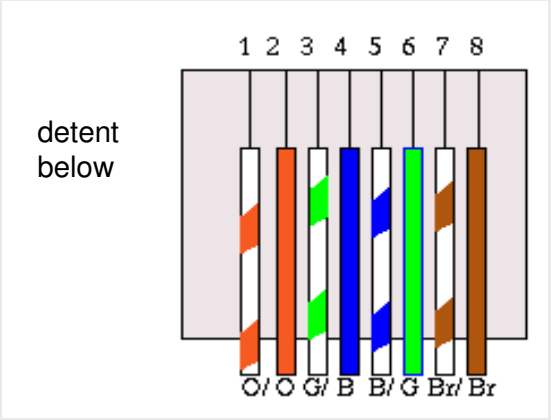

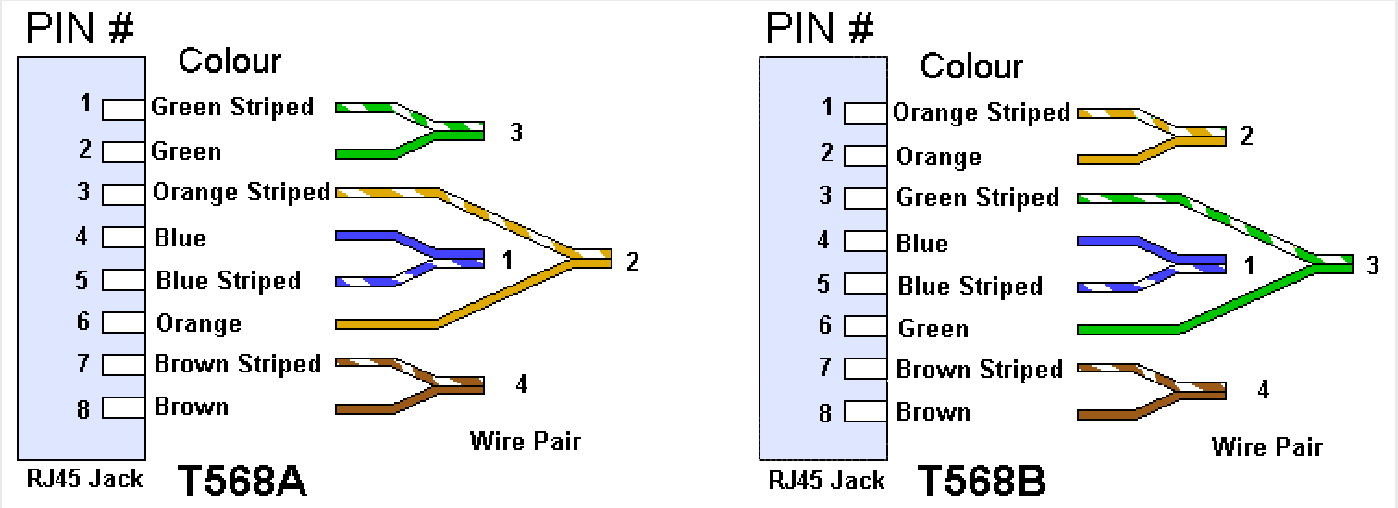

EtherCAT

Cable standardization

- cable and connector
- LED diagnosis
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Twisted Pair cable is divided into different categories according to EIA/TIA* 568-A-5 (ISO/IEC 11801). These correspond to the classes of EN50173.

Class	Applications	Category
Class A	Speech-/Data circuit for low-frequency applications up to 100 KHz for phone and ISDN	
Class B	Data circuit with medium data rates up to 1 MHz for phone and ISDN	
Class C	Data circuit for up to 16 MHz for phone, ISDN, Token Ting, Ethernet	Cat3
Class D	**Data circuits for up to 100/125 MHz for phone, ISDN, Token Ring, Ethernet (Giga Bit Ethernet) , FDDI, TPDDI, 100 VG Anylan**	**Cat5, (Cat5e)**
Class E	Data circuits for up to 250 MHz for Class D plus ATM and Giga Bit Ethernet	Cat6
Class F	Data circuits for up to 600 MHz	Cat7
Class G	CATV-equipments (Video) for up to 1200 MHz with a cable length of max. 50 m	Cat8

*Electronic Industries Alliance / Telecommunications Industry Association

Installation for field assembly connector ZS1090-0003

1/2

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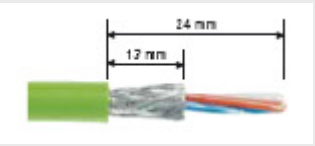
Push the housing over the cable sheath

Stripping



Form the wires

Put up splicing element

Put up housing

Put the data module into the assembly tool

Press data module and element together

Remove

Put on upper shielding shell

Put on lower shielding shell

Push housing and lock it

Tighten connection

Installation for field assembly connector ZS1090-0003

- cable and connector
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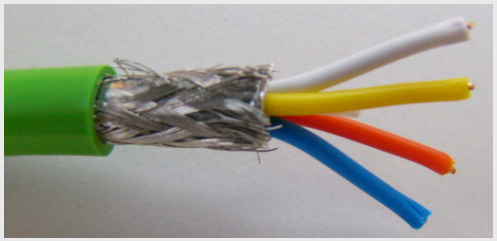
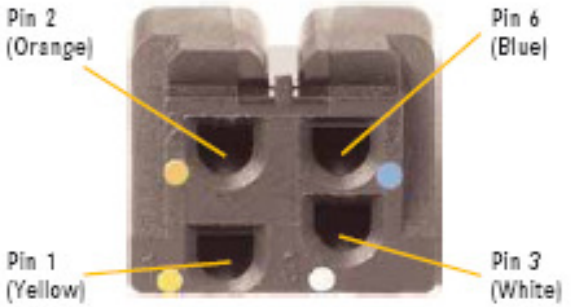
– **assembly with existing tool**
– **error-secure through color code**
– **industrial capable**



Function/ Signal	Wire colour EtherCAT	EIA/TIA 568 A	EIA/TIA 568 B	Pin No.
Transmission Data+/TD+	YE	WH GN	WH OG	1
Transmission Data−/TD−	OG	GN	OG	2
Receiver Data/RD+	WH	WH OG	WH GN	3
Receiver Data/RD−	BU	OG	GN	6



EtherCAT

Link/Act LED

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

All EtherCAT devices with a connector (e.g. RJ45, M12), must have a Link/Activity display. Devices without connector could have such a display.

- **Status (as with standard Ethernet components)**
  - **LED out: no connection**
  - **LED on: connection**
  - **LED blinking: communication**

EtherCAT

RUN LED

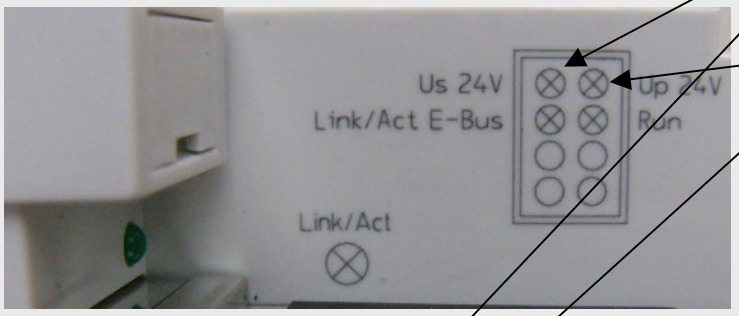
- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

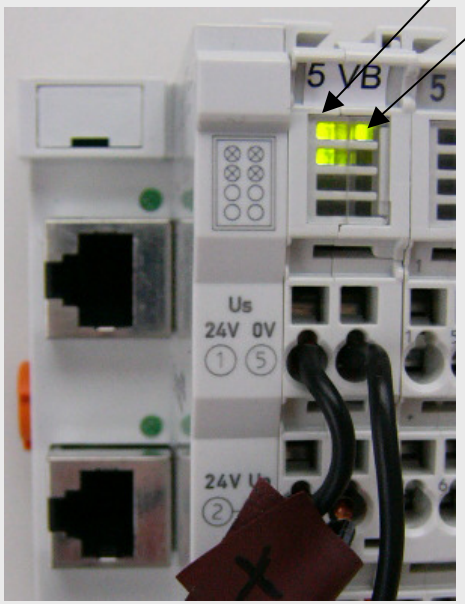
The RUN LED indicates the status of the EtherCAT device -> see State Machine

- **Status:**
  - **off:** **INIT**
  - **blinking** **Pre-Operational**
  - **single flash** **Safe-Operational**
  - **on** **Operational**
  - **flickering** **Bootstrap**

LED‘s at the EK1100

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter



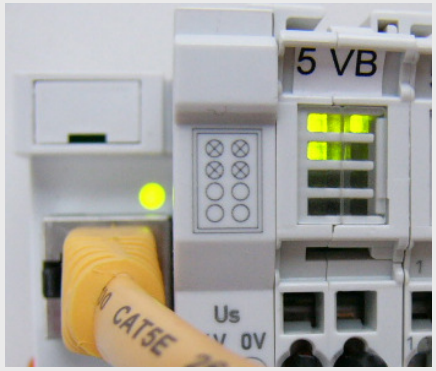


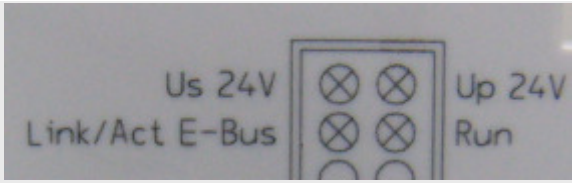
power supply for bus coupler and E-Bus

power supply for power contacts

LED‘s at the EK1100

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter





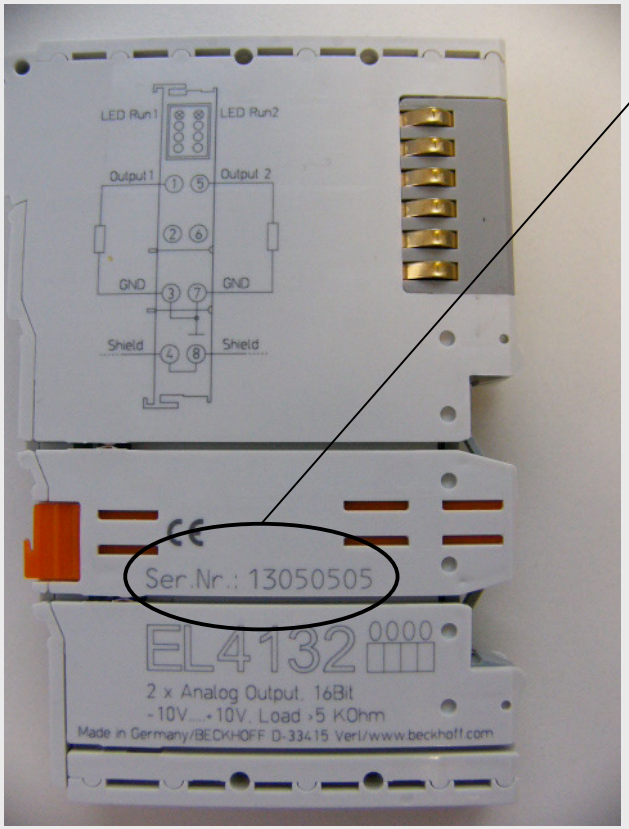
existing EtherCAT connection
over cable and E-Bus;
status EK1100 INIT

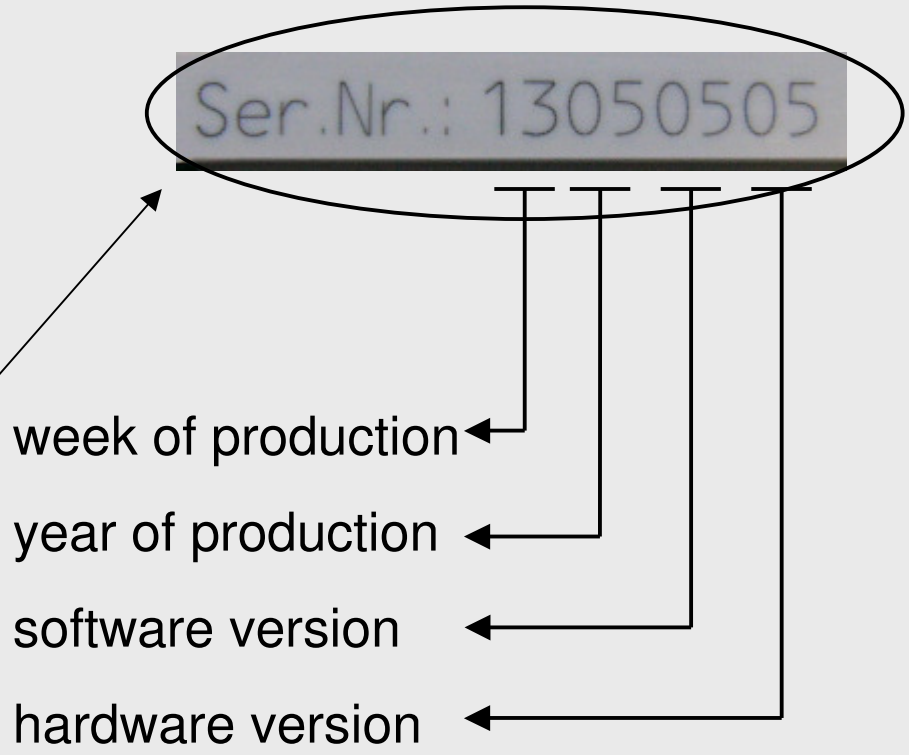
existing EtherCAT connection
over cable and E-Bus;
EK1100 is in status Operational

existing EtherCAT connection
over cable; E-Bus disconnected;
Status EK1100 INIT

Version identification – Hardware

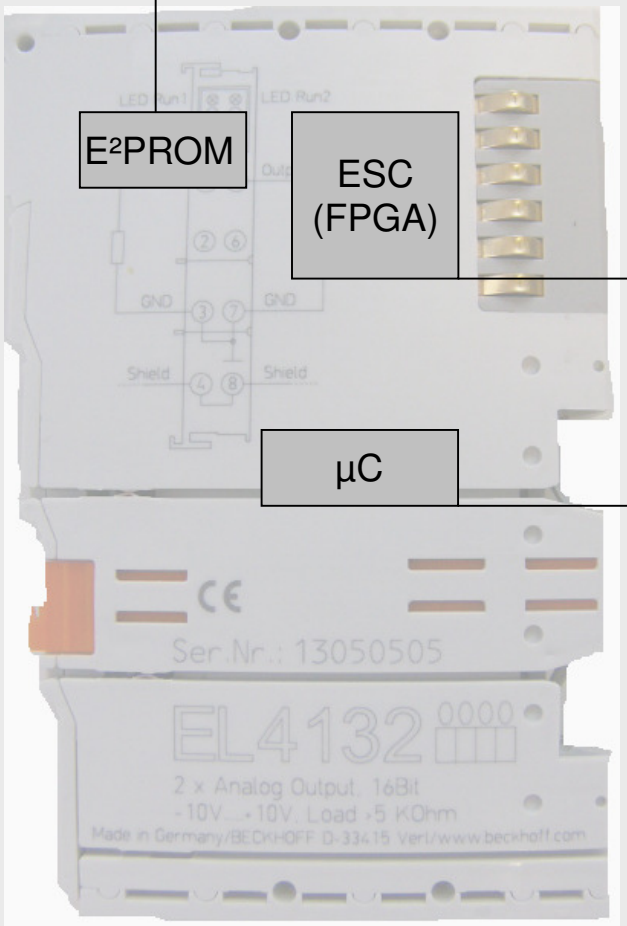
- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter





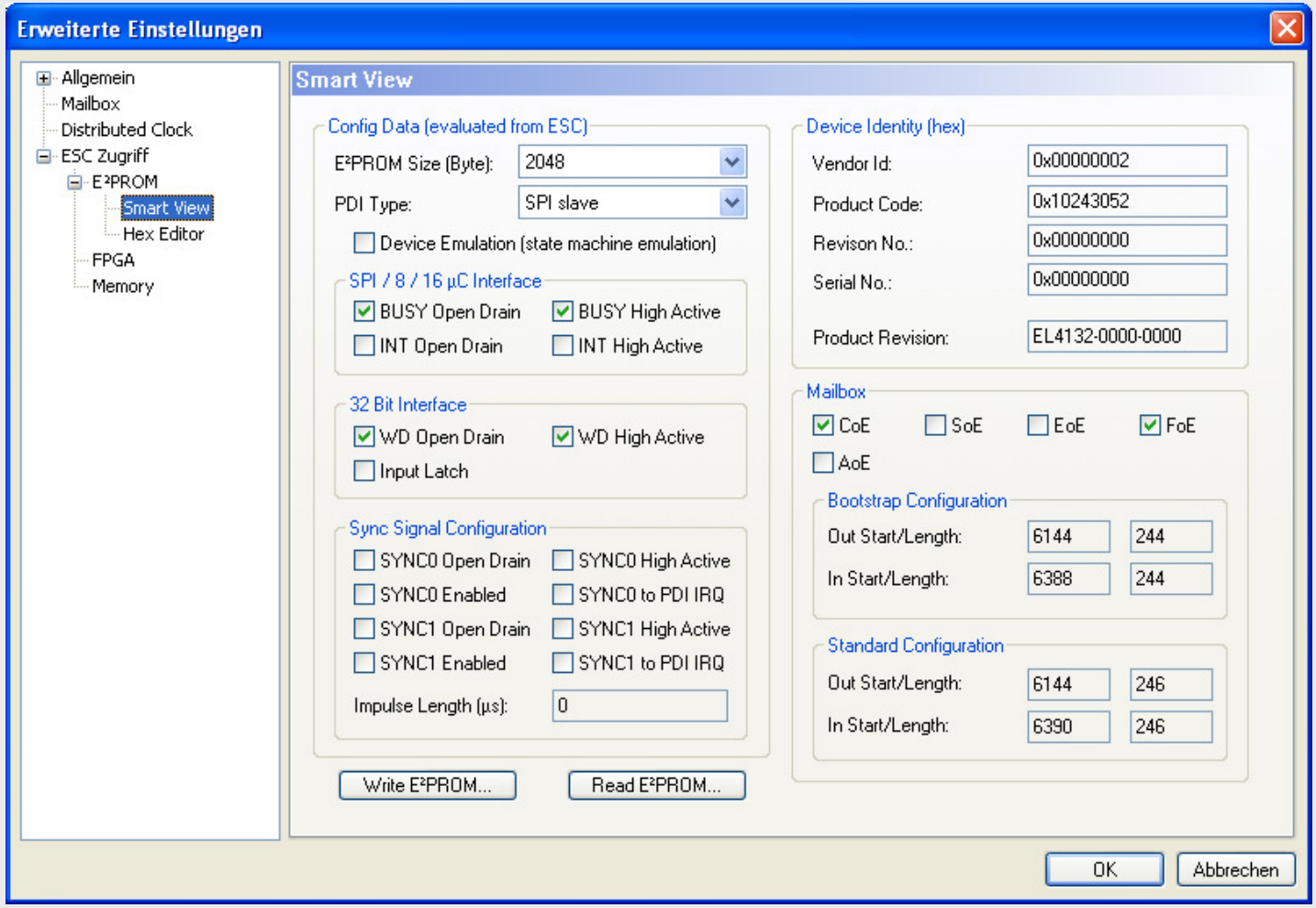
Version identification – Software

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter



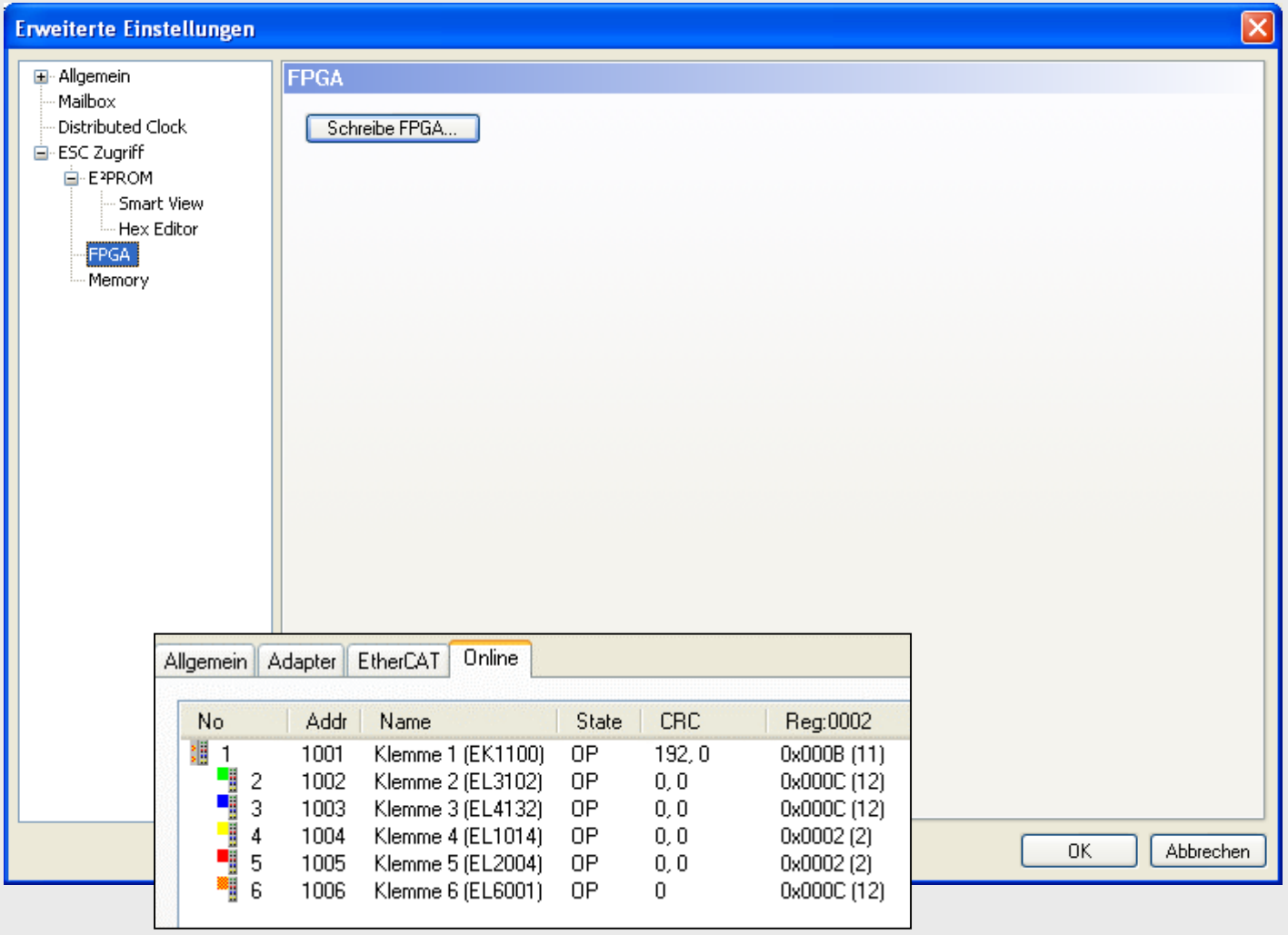
E²PROM

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter



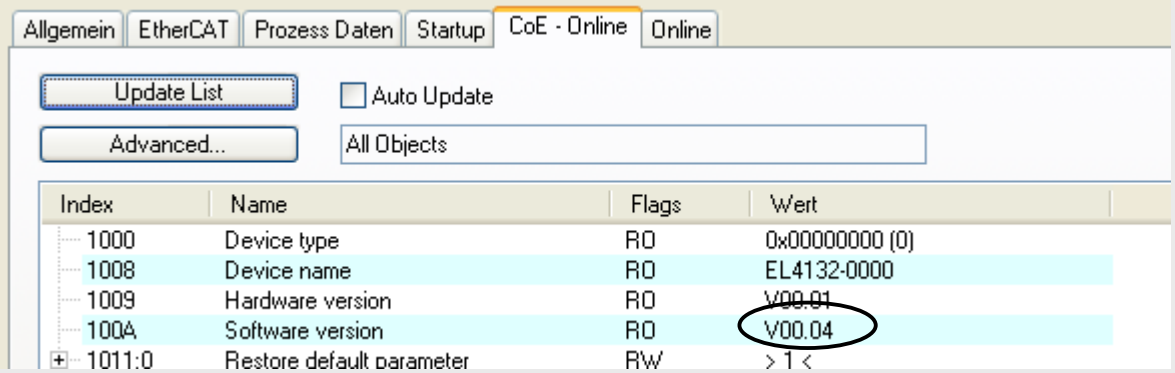
FPGA

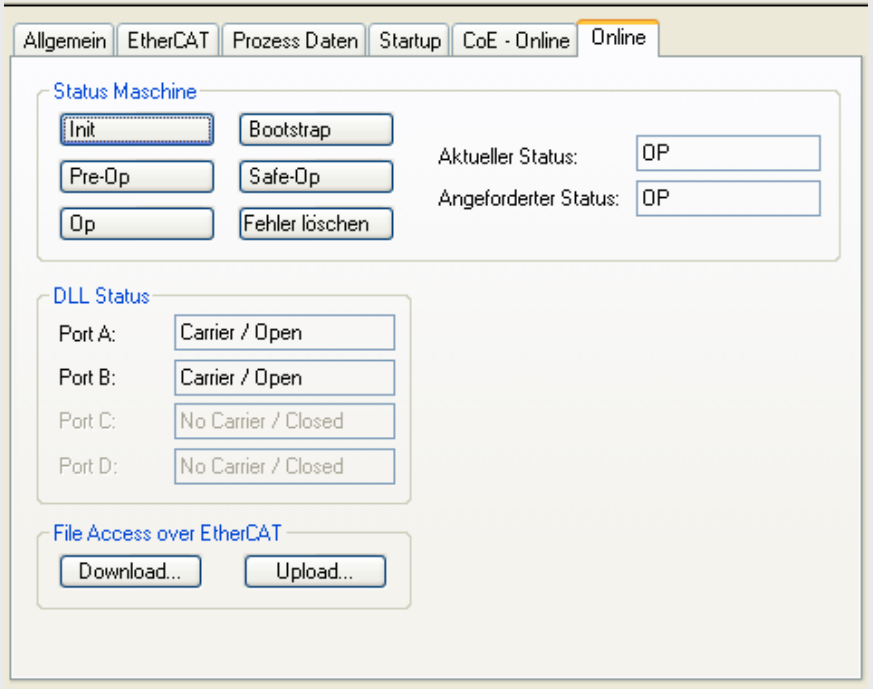
- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter



µC

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter





EtherCAT State Machine

- cable and connector
- LED diagnosis
- version identification
- state machine
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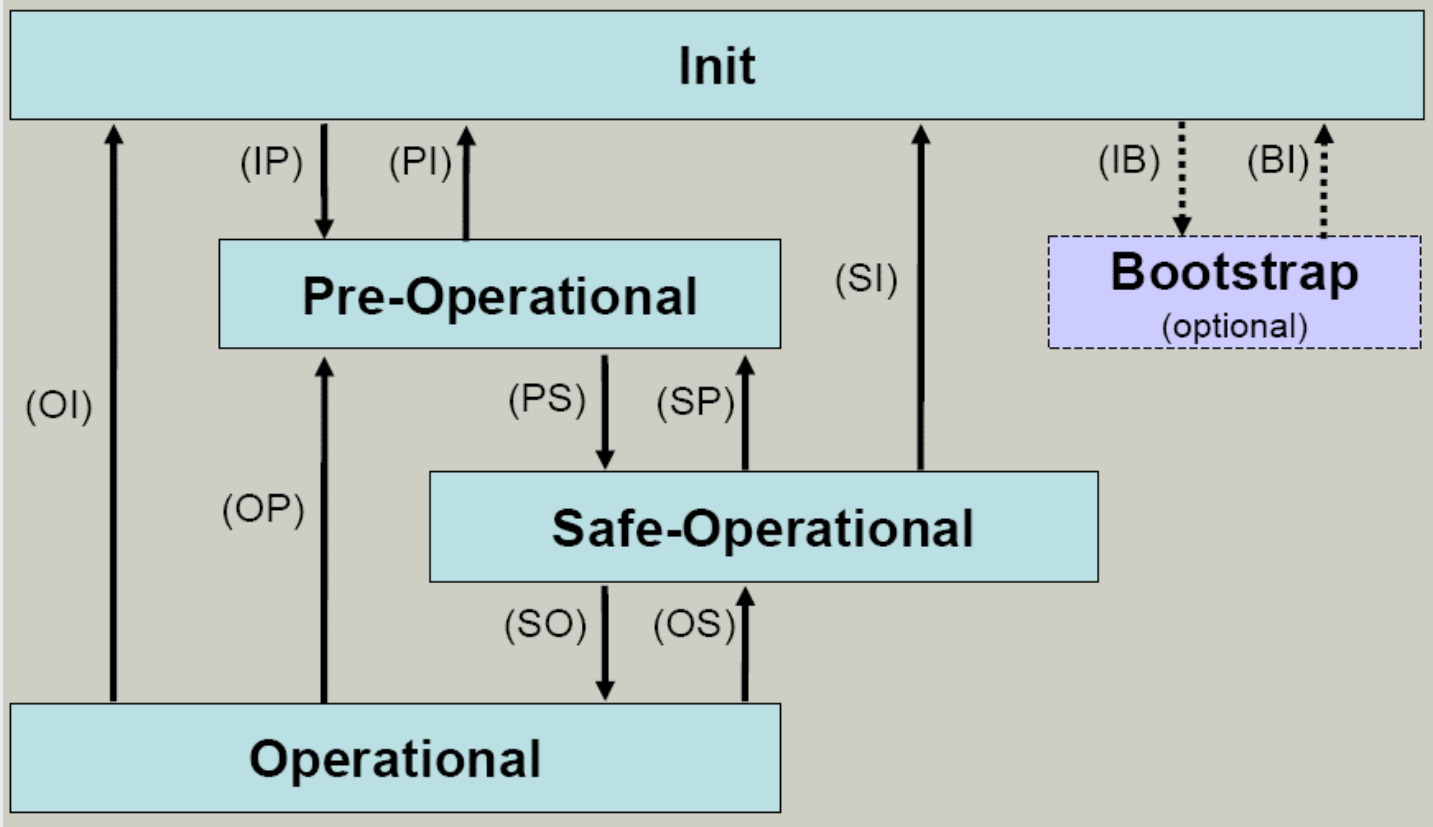
- FMMU
- mailbox
- protocols
- working counter



EtherCAT State Machine 1/2

- cable and connector
- LED diagnosis
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- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

‚Init' State

no process data communication

Master can write info register

‚Pre-Operational' State

no process data communication

Master configures Slave

mailbox communication

‚Safe Operational' State

mailbox communication

process data communication –> just inputs

outputs are in ‚Safe State'

EtherCAT State Machine 2/2

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
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‚Operational‘ State

process data communication in- and outputs

‚Bootstrap‘ State

optional for download of new Firmware

EtherCAT

Sync Manager

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

Prevents simultaneous access to DPRAM - data consistence

3 Buffer operation:

- always one cache free for writing
- always one cache with consistent data ready to read
- assures most actual data
- occupied threefold memory opposite to 1-cache operation
- default for process data

1 Buffer operation

- 1:1 data transmission, no lost of data
- writing site must write before reading site can write and contrary
- overflow protection
- default for mailbox data

Sync Manager

- cable and connector
- LED diagnosis
- version identification
- state machine
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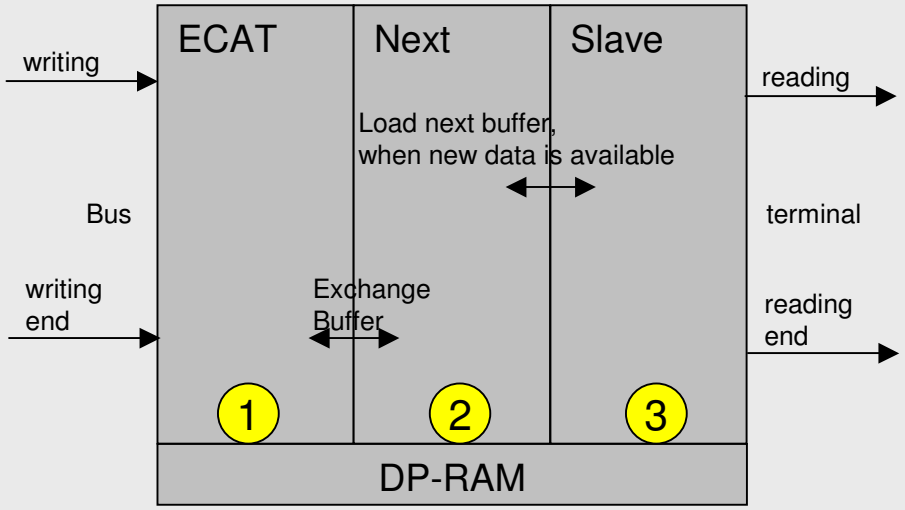
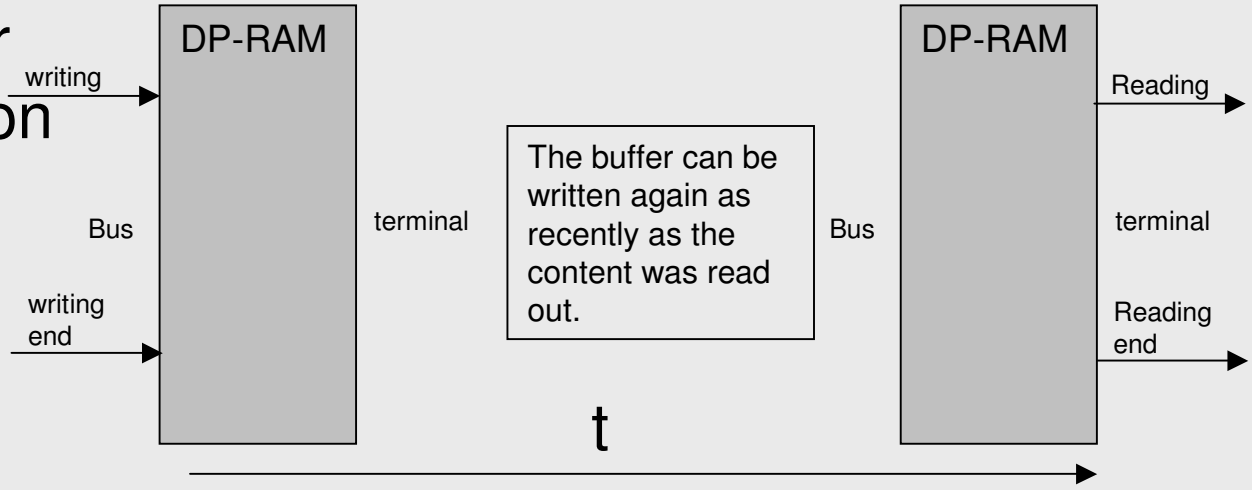
3 Buffer operation



1 Buffer operation



Sync Manager

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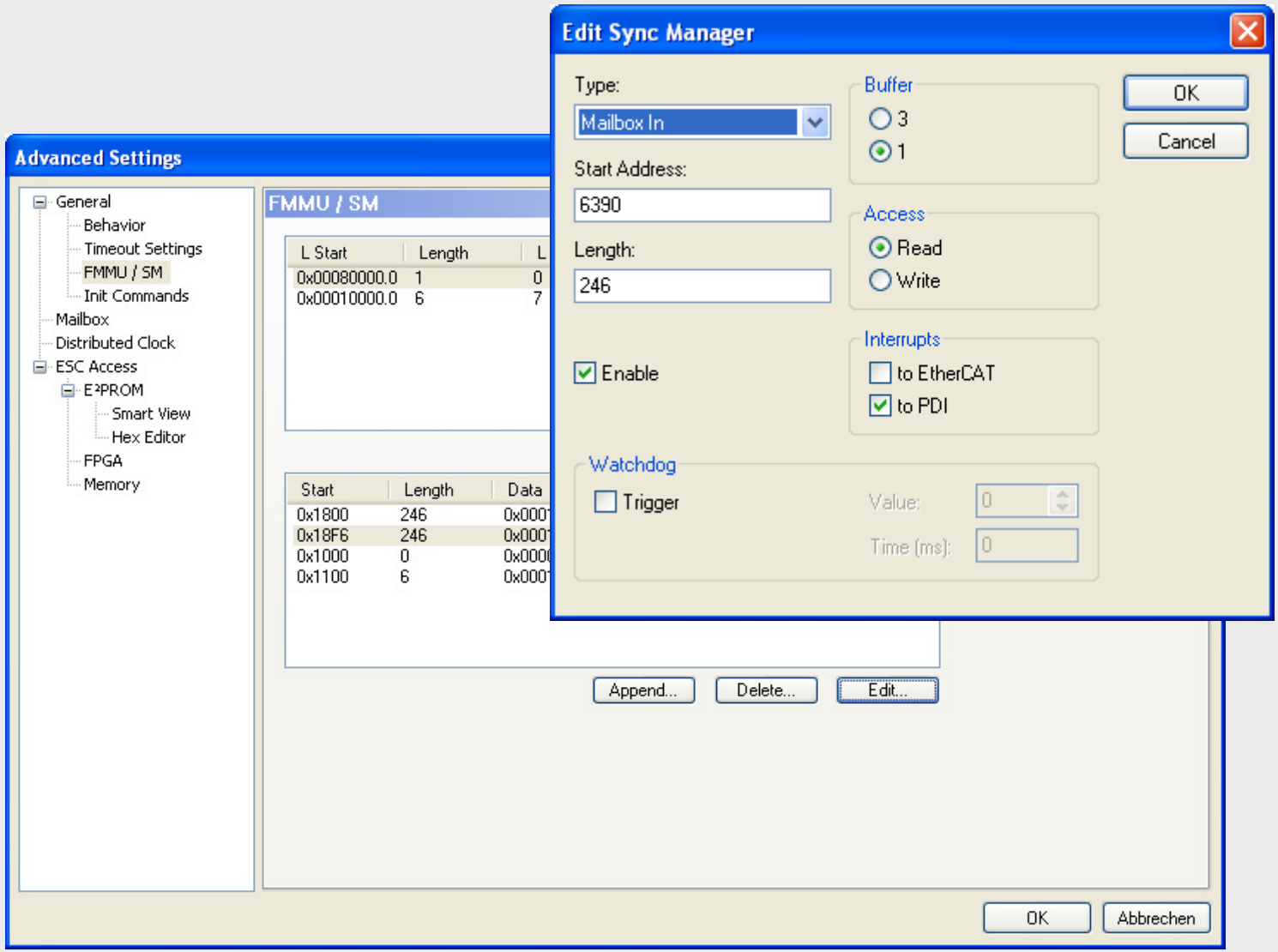


EtherCAT

FMMU – Field bus Memory Management Unit

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

Translation of the logical address (within the telegram) into the physical address (within the node).

Mapping of the local addresses into the global EtherCAT address space (4 GByte)

- **integrated within the EtherCAT Slave Controller**
- **bit addressing possible**
- **minimal overhead**

Advantage: no copying within the controller, as the I/O‘s are prearanged in the process image

-> performance benefit

EtherCAT

Mailbox

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

For acyclic exchange of parameter data between Master and Slave
For configuration of the process image

EtherCAT

Protocols

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

ADS over EtherCAT (AoE)

ADS messages over EtherCAT

Ethernet over EtherCAT (EoE)

standard Ethernet frames over EtherCAT

CANopen over EtherCAT (CoE)

standard access to the object dictionary

File Access over EtherCAT (FoE)

for the download of new Firmware

Servo Profile (Sercos) over EtherCAT (SoE)

standard access to the Sercos identifier

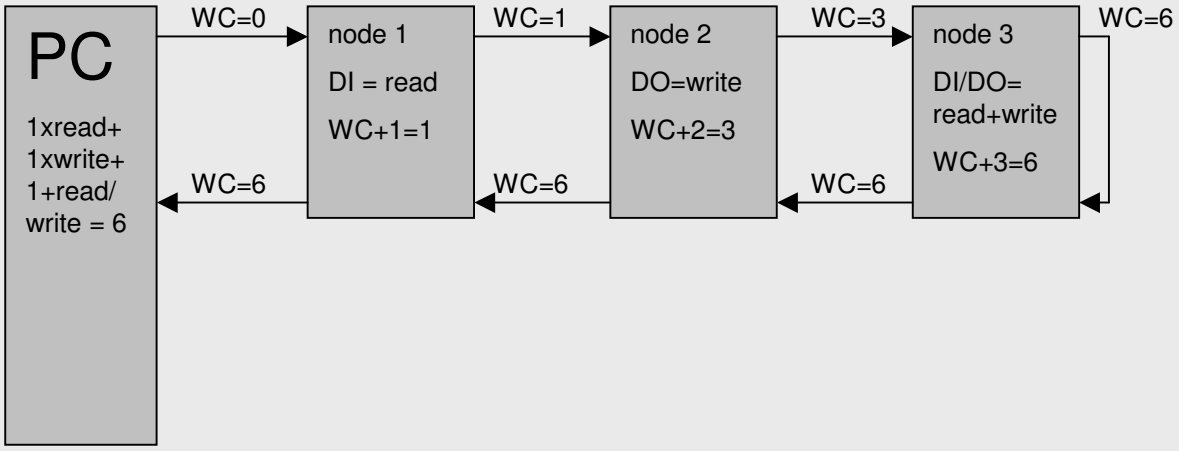
Working Counter

- cable and connector
- LED diagnosis
- version identification
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter

Every EtherCAT telegram ends with a 16 bit Working Counter.

Every Slave Controller in communication who is completing the command (reading/writing) increases the working counter.

The Master compares the received Working Counter with the calculated Working Counter. Through this it can be determined if all commands have been completed.



EtherCAT

Working Counter

- cable and connector
- LED diagnosis
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- mailbox
- protocols
- working counter