



- 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
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- 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

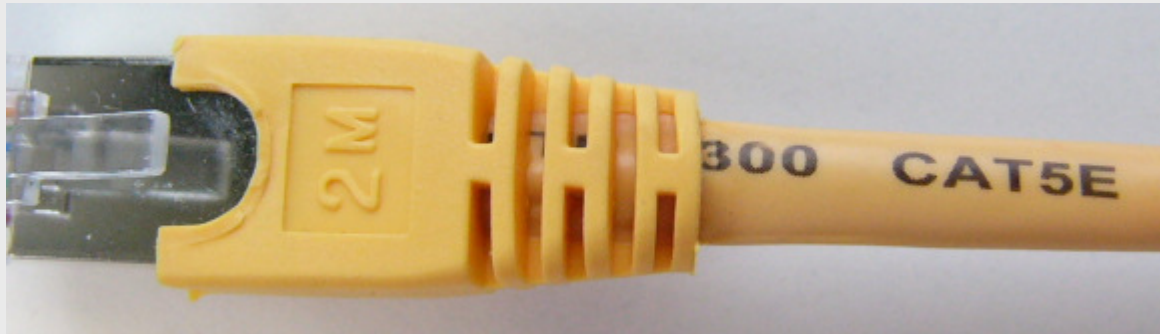
Pin M12	Pin RJ45	Wire color (EIA/TIA-T568B)	Wire color (Industrial Ethernet cable)	Signal	Description
1	1	white-orange	yellow	TD+	Transmission Data +
3	2	orange	orange	TD-	Transmission Data -
2	3	white-green	white	RD+	Receiver Data +
4	6	green	blue	RD-	Receiver Data -

* ZB90x0, Industrial Ethernet cable

Cable

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

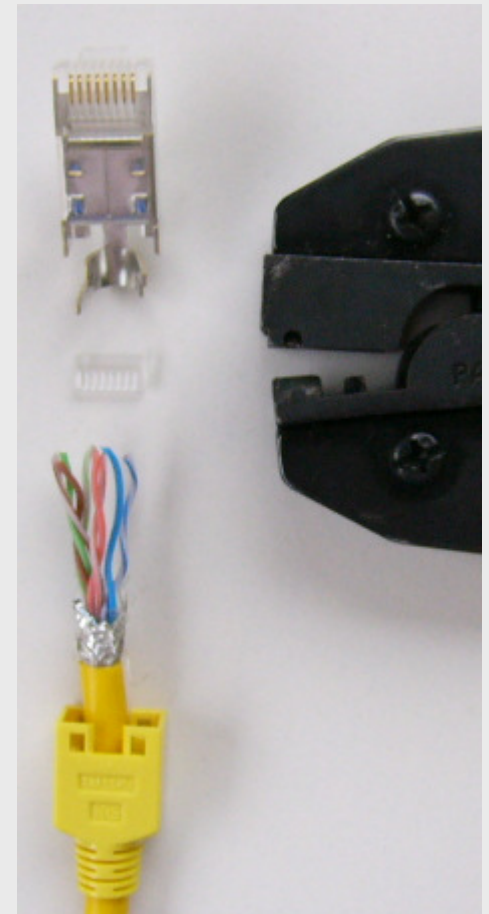
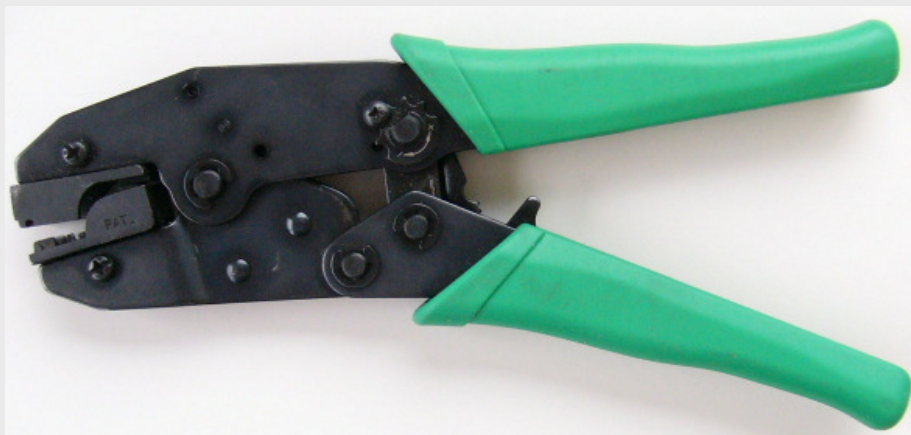


RJ45 connector crimping

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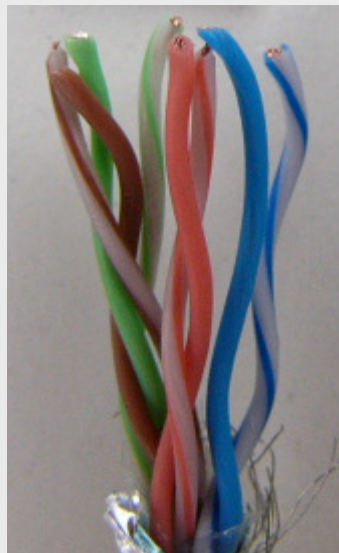
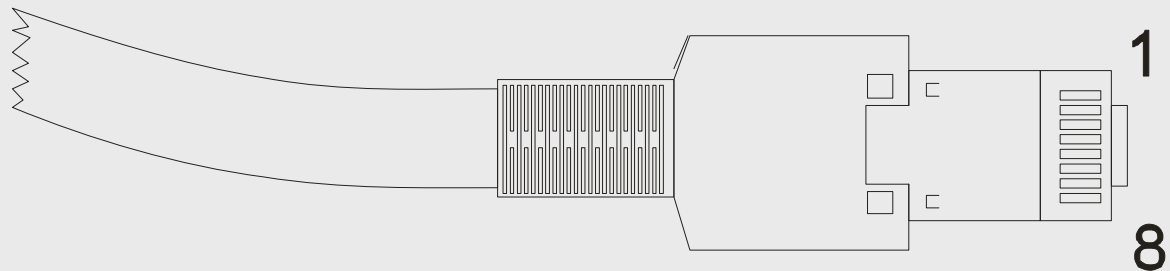
The crimping of RJ45 connectors often causes problems in industrial environments.

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



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

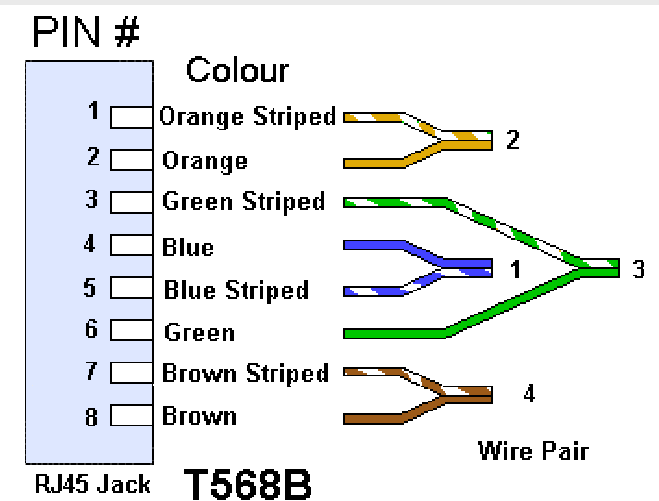
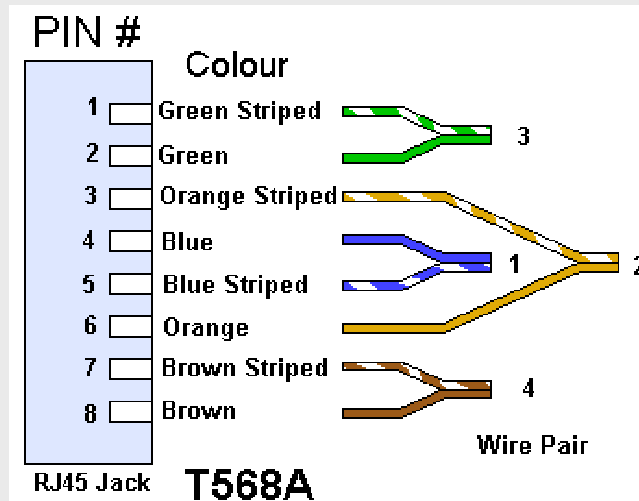
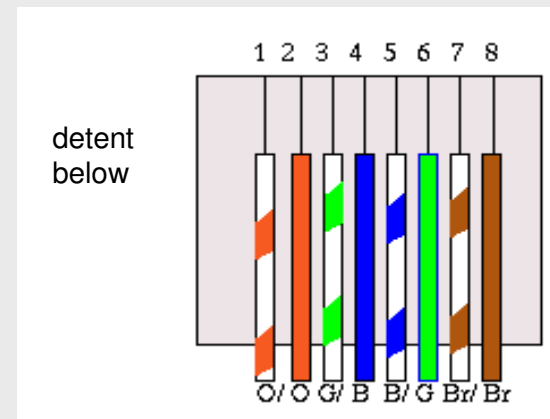
Nach EIA/TIA-T568B

~~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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Cable standardization

- cable and connector
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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 Ring, 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

➤ cable and connector

➤ LED diagnosis

➤ version identification

➤ state machine

➤ sync manager

➤ FMMU

➤ mailbox

➤ protocols

➤ working counter

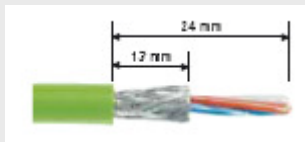
Push the housing over the cable sheath



Press data module and element together



Stripping



Remove



Form the wires



Put on upper shielding shell



Put up splicing element



Put on lower shielding shell



Put up housing



Push housing and lock it



Put the data module into the assembly tool



Tighten connection

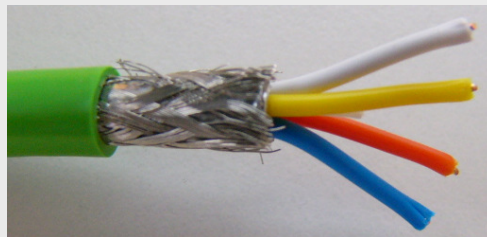


Installation for field assembly connector ZS1090-0003

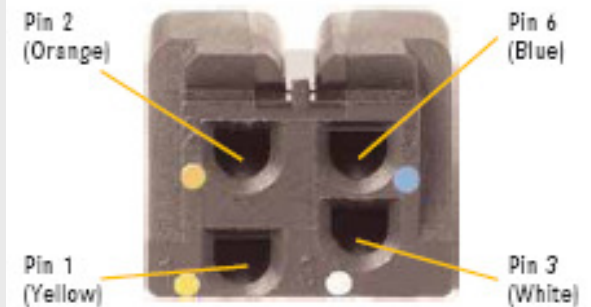
2/2

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- assembly with existing tool
- error-secure through color code
- industrial capable



Function/ Signal	EtherCAT	Wire colour		Pin No.
		EIA/TIA 568 A	EIA/TIA 568 B	
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



Link/Act LED

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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**

RUN LED

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

– **Status:**

- off:
- blinking
- single flash
- on
- flickering

INIT

Pre-Operational

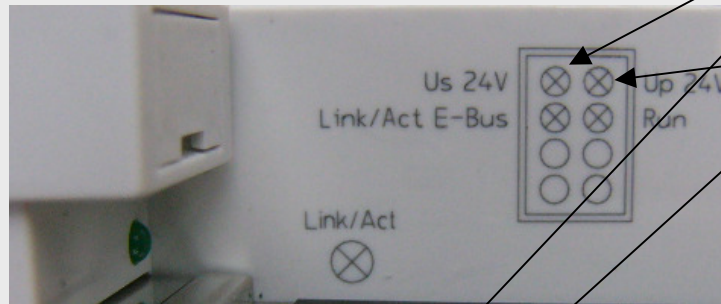
Safe-Operational

Operational

Bootstrap

LED's at the EK1100

- cable and connector
- LED diagnosis
- version identification
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power supply for bus coupler
and E-Bus

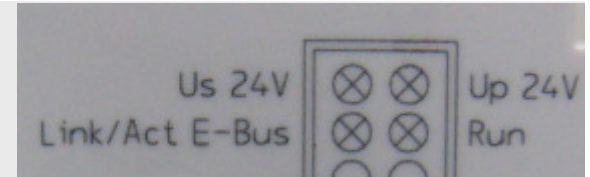
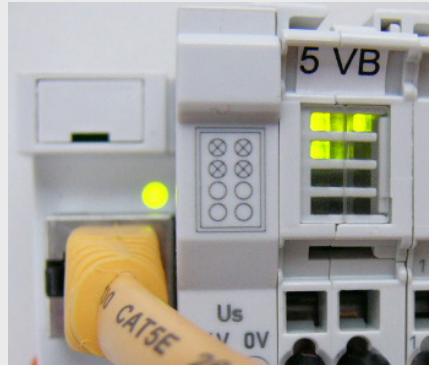
power supply for power
contacts





LED's at the EK1100

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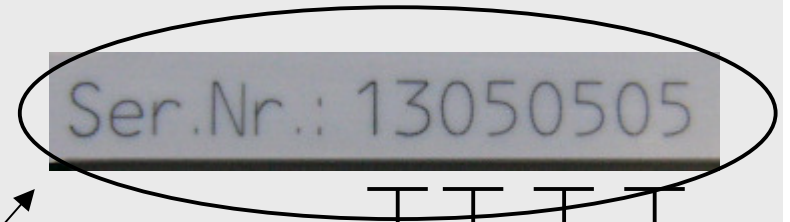
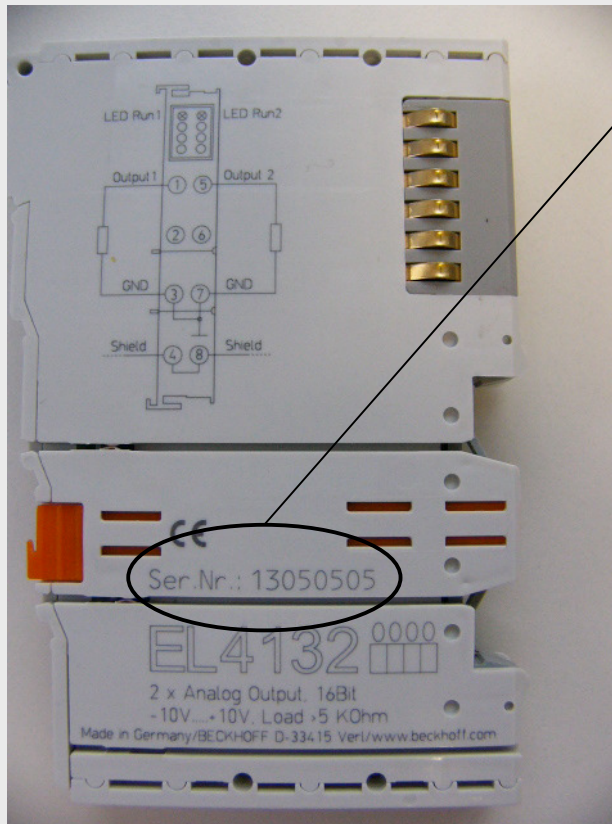
existing EtherCAT connection
over cable and E-Bus;
status EK1100 INIT

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
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week of production

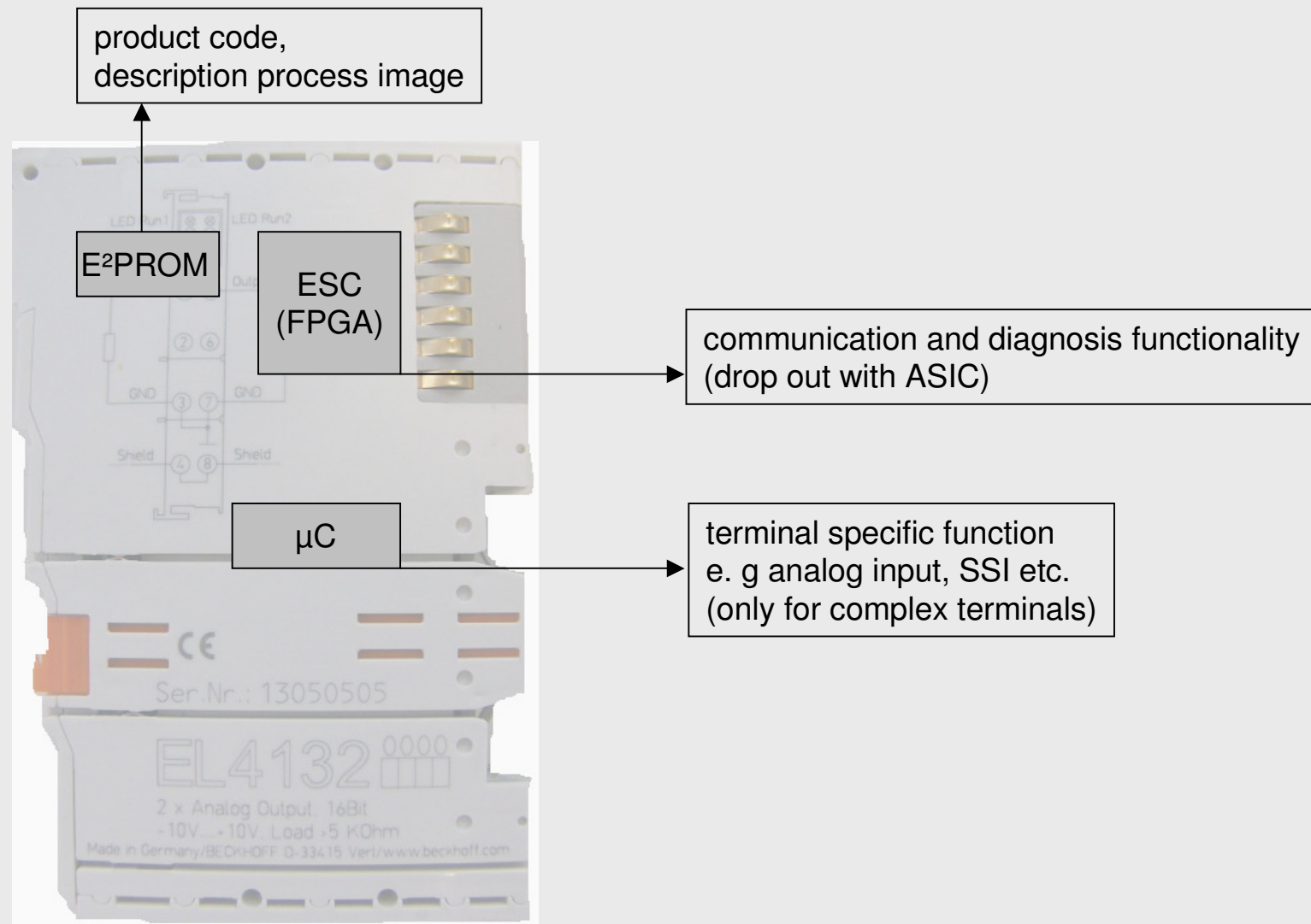
year of production

software version

hardware version

Version identification – Software

- cable and connector
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- cable and connector
- LED diagnosis
- **version identification**
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Erweiterte Einstellungen

Smart View

Config Data (evaluated from ESC)

E²PROM Size (Byte): 2048

PDI Type: SPI slave

☐ Device Emulation (state machine emulation)

SPI / 8 / 16 μ C Interface

☒ BUSY Open Drain ☒ BUSY High Active

☐ INT Open Drain ☐ INT High Active

32 Bit Interface

☒ WD Open Drain ☒ WD High Active

☐ Input Latch

Sync Signal Configuration

☐ SYNC0 Open Drain ☐ SYNC0 High Active

☐ SYNC0 Enabled ☐ SYNC0 to PDI IRQ

☐ SYNC1 Open Drain ☐ SYNC1 High Active

☐ SYNC1 Enabled ☐ SYNC1 to PDI IRQ

Impulse Length (μ s): 0

Device Identity (hex)

Vendor Id: 0x00000002

Product Code: 0x10243052

Revision No.: 0x00000000

Serial No.: 0x00000000

Product Revision: EL4132-0000-0000

Mailbox

☒ CoE ☐ SoE ☐ EoE ☒ FoE

☐ AoE

Bootstrap Configuration

Out Start/Length: 6144 244

In Start/Length: 6388 244

Standard Configuration

Out Start/Length: 6144 246

In Start/Length: 6390 246

Write E²PROM... Read E²PROM...

OK Abbrechen

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The screenshot shows the 'Erweiterte Einstellungen' (Advanced Settings) window in the Beckhoff EtherCAT configuration software. The left sidebar shows a tree view with 'Allgemein' (General) expanded, containing 'Mailbox', 'Distributed Clock', 'ESC Zugriff' (ESC Access), 'E²PROM', 'Smart View', 'Hex Editor', 'FPGA', and 'Memory'. The 'FPGA' tab is selected in the main window, showing a 'Schreibe FPGA...' (Write FPGA...) button. Below this, a sub-window is open with tabs for 'Allgemein', 'Adapter', 'EtherCAT', and 'Online'. The 'Online' tab is active, displaying a table of terminal data.

No	Addr	Name	State	CRC	Reg:0002
1	1001	Klemme 1 (EK1100)	OP	192, 0	0x000B (11)
2	1002	Klemme 2 (EL3102)	OP	0, 0	0x000C (12)
3	1003	Klemme 3 (EL4132)	OP	0, 0	0x000C (12)
4	1004	Klemme 4 (EL1014)	OP	0, 0	0x0002 (2)
5	1005	Klemme 5 (EL2004)	OP	0, 0	0x0002 (2)
6	1006	Klemme 6 (EL6001)	OP	0	0x000C (12)



μC

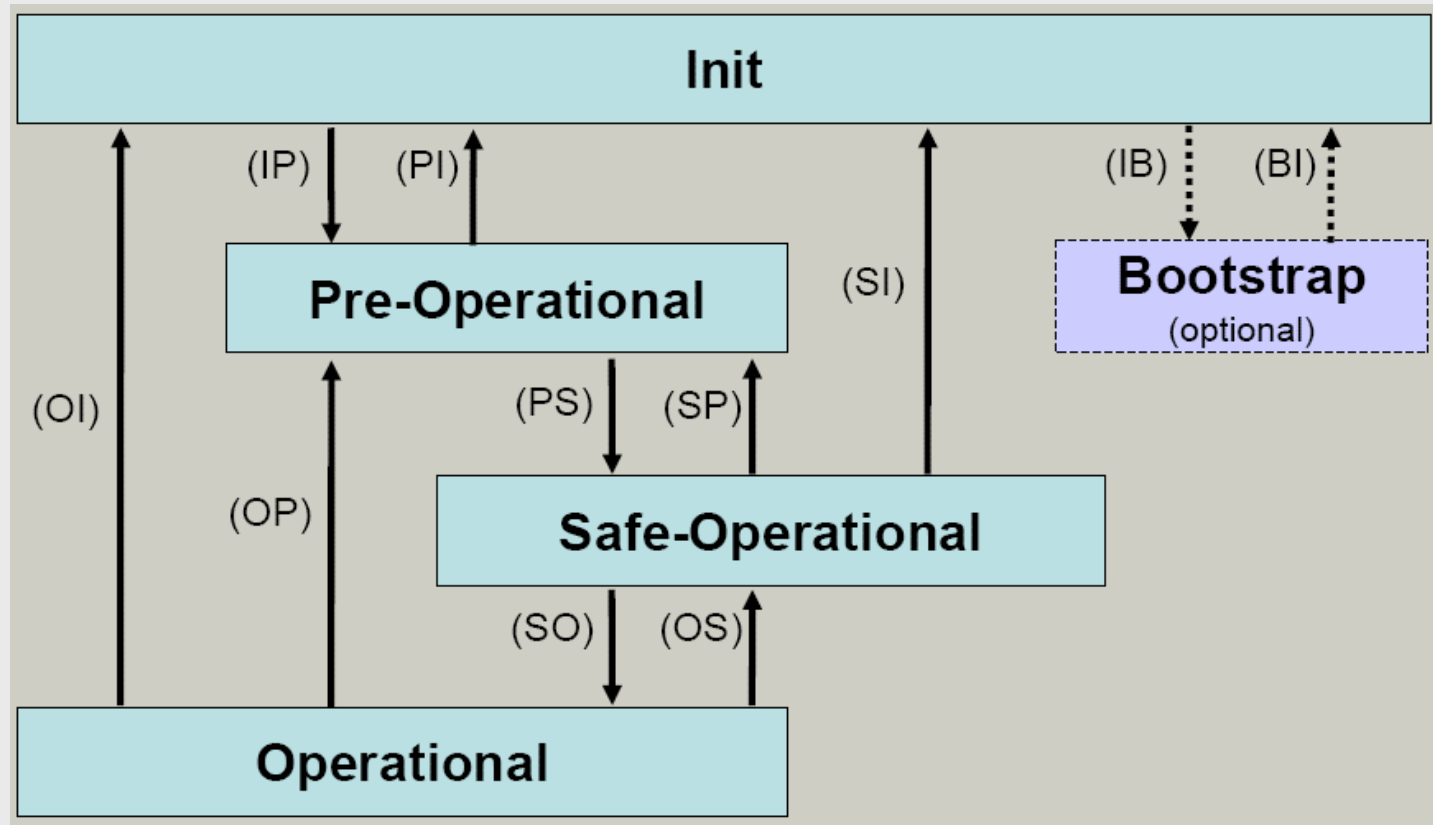
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Allgemein EtherCAT Prozess Daten Startup CoE - Online Online			
<input type="button" value="Update List"/>		<input type="checkbox"/> Auto Update	
<input type="button" value="Advanced..."/>		<input type="text" value="All Objects"/>	
Index	Name	Flags	Wert
1000	Device type	RO	0x00000000 (0)
1008	Device name	RO	EL4132-0000
1009	Hardware version	RO	V00.01
100A	Software version	RO	V00.04
+ 1011:0	Restore default parameter	RW	> 1 <

Allgemein EtherCAT Prozess Daten Startup CoE - Online Online			
Status Maschine			
<input type="button" value="Init"/>	<input type="button" value="Bootstrap"/>	Aktueller Status:	<input type="text" value="OP"/>
<input type="button" value="Pre-Op"/>	<input type="button" value="Safe-Op"/>	Anforderter Status:	<input type="text" value="OP"/>
<input type="button" value="Op"/>	<input type="button" value="Fehler löschen"/>		
DLL Status			
Port A:	<input type="text" value="Carrier / Open"/>		
Port B:	<input type="text" value="Carrier / Open"/>		
Port C:	<input type="text" value="No Carrier / Closed"/>		
Port D:	<input type="text" value="No Carrier / Closed"/>		
File Access over EtherCAT			
<input type="button" value="Download..."/>	<input type="button" value="Upload..."/>		

EtherCAT State Machine

- cable and connector
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„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“

- cable and connector
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‚Operational‘ State

process data communication in- and outputs

‚Bootstrap‘ State

optional for download of new Firmware

Sync Manager

- cable and connector
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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

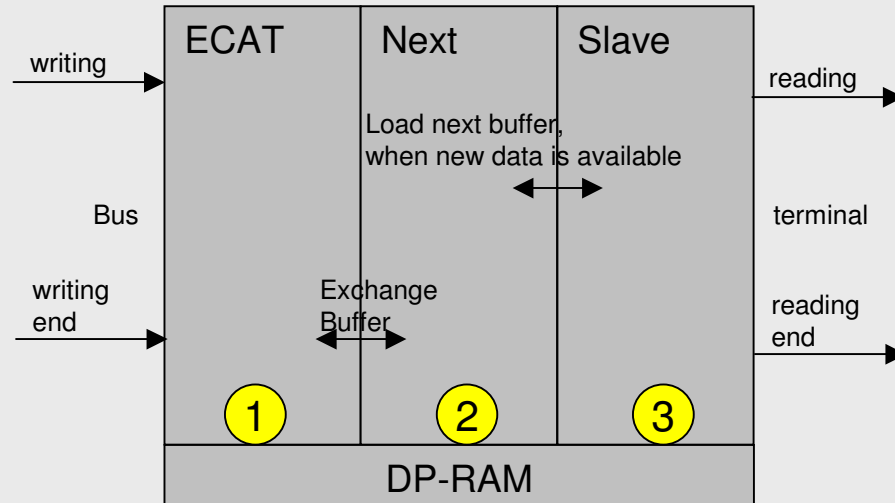
1 Buffer operation

- 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

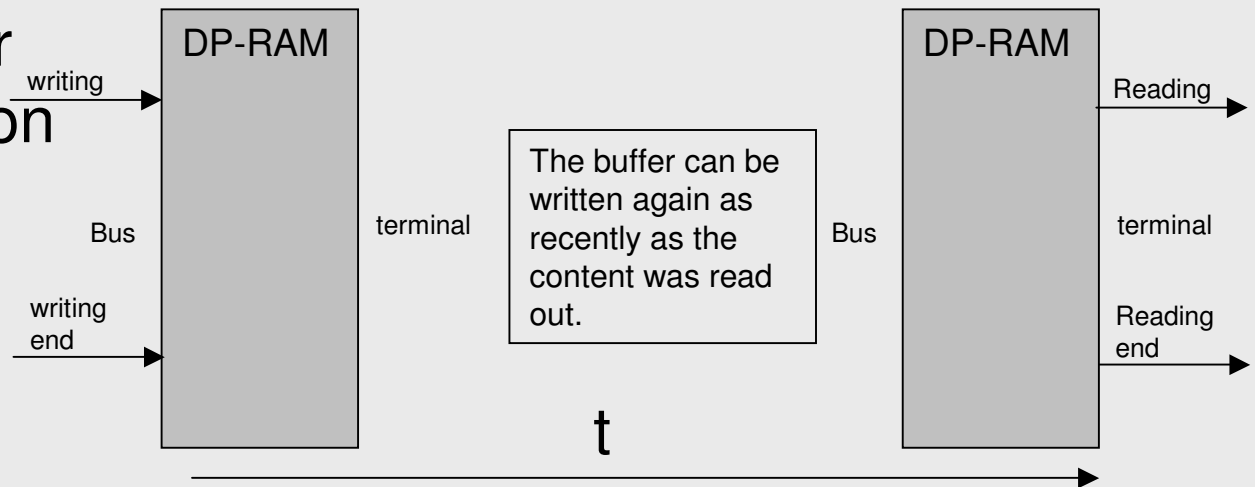
Sync Manager

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



1 Buffer operation



Sync Manager

- cable and connector
- LED diagnosis
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Advanced Settings

- General
 - Behavior
 - Timeout Settings
 - FMMU / SM**
 - Init Commands
- Mailbox
- Distributed Clock
- ESC Access
 - E²PROM**
 - Smart View
 - Hex Editor
 - FPGA
 - Memory

FMMU / SM

L Start	Length	L
0x00080000.0	1	0
0x00010000.0	6	7

Start	Length	Data
0x1800	246	0x000
0x18F6	246	0x000
0x1000	0	0x000
0x1100	6	0x000

Edit Sync Manager

Type: Mailbox In

Start Address: 6390

Length: 246

☒ Enable

Buffer: ☐ 3 ☒ 1

Access: ☒ Read ☐ Write

Interrupts: ☐ to EtherCAT ☒ to PDI

Watchdog: ☐ Trigger Value: 0 Time (ms): 0

Append... Delete... Edit...

OK Abbrechen

FMMU – Field bus Memory Management Unit

- cable and connector
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- 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 prearranged in the process image

-> performance benefit



Mailbox

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



Protocols

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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

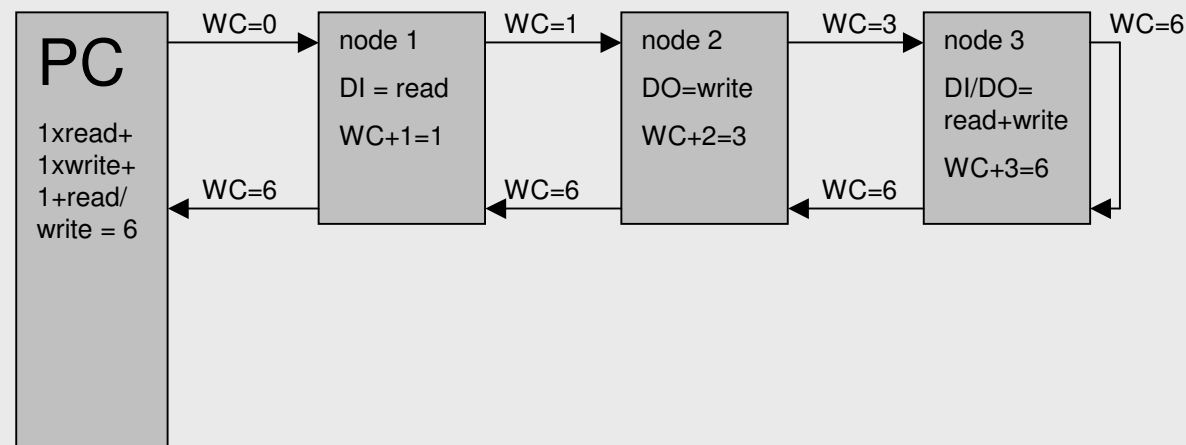
Working Counter

- cable and connector
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- **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.





Working Counter

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The screenshot displays the Beckhoff EtherCAT configuration software interface. The left pane shows a tree view of the configuration for seven channels (Klemme 1 to 7). The right pane shows a table of the configuration data, including Frame, Command, Address, Length, and Working Counter (WC) values. A red box highlights the 'working counter' option in the left pane. An arrow points from the 'WC=8' label in the left pane to the 'WC' column in the table.

Frame	Cmd	Addr	Len	WC
0	LRW	0x00010000	16	8
0	LRD	0x00080000	1	3 (Mailbox)
0	BRD	0x01300000	2	6 (State)

Nummer	Boxbezeichnung	Adresse
1	Klemme 1 (EK1100)	1001
2	Klemme 2 (EL1012)	1002
3	Klemme 3 (EL3102)	1003
4	Klemme 4 (EL2032)	1004
5	Klemme 5 (EL5001)	1005
6	Klemme 6 (EL4132)	1006
7	Klemme 7 (EL9010)	