EtherCAT in practice

Michael Jost
Beckhoff
### Cable

**Requirements:**

- **Category 5 / class D cable**
- EtherCAT uses 4 poles
- symmetrical assignment 1:1 (no cross-cable is needed)
- max. length 100m

**Wire color**: (EIA/TIA-568B)

<table>
<thead>
<tr>
<th>Pin M12</th>
<th>Pin RJ45</th>
<th>Wire color</th>
<th>Wire color</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>white-orange</td>
<td>yellow</td>
<td>TD+</td>
<td>Transmission Data +</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>orange</td>
<td>orange</td>
<td>TD-</td>
<td>Transmission Data -</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>white-green</td>
<td>white</td>
<td>RD+</td>
<td>Receiver Data +</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>green</td>
<td>blue</td>
<td>RD-</td>
<td>Receiver Data -</td>
</tr>
</tbody>
</table>

* ZB90x0, Industrial Ethernet cable
Cable

Standard patch cable (min. CAT5) can be used for internal wirings in control cabinets.
RJ45 connector crimping

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

-电缆和连接器
-LED诊断
-版本识别
-状态机
-同步管理器
-FMMU
-邮箱
-协议
-工作计数器

正常分配

<table>
<thead>
<tr>
<th>Pin</th>
<th>white-orange</th>
<th>orange</th>
<th>white-green</th>
<th>blue</th>
<th>white-blue</th>
<th>green</th>
<th>white-brown</th>
<th>brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</table>

翻转分配

<table>
<thead>
<tr>
<th>Pin</th>
<th>white-green</th>
<th>green</th>
<th>white-orange</th>
<th>blue</th>
<th>white-blue</th>
<th>orange</th>
<th>white-brown</th>
<th>brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>4</td>
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</tr>
</tbody>
</table>

Nach EIA/TIA-T568B
PIN assignment standard RJ45 connector

- Cable and connector
- LED diagnosis
- Version identification
- State machine
- Sync manager
- FMMU
- Mailbox
- Protocols
- Working counter

Detent below:

- PIN #1: Green Striped
- PIN #2: Green
- PIN #3: Orange Striped
- PIN #4: Blue
- PIN #5: Blue Striped
- PIN #6: Orange
- PIN #7: Brown Striped
- PIN #8: Brown

RJ45 Jack T568A

PIN #1: Orange Striped
PIN #2: Orange
PIN #3: Green Striped
PIN #4: Blue
PIN #5: Blue Striped
PIN #6: Green
PIN #7: Brown Striped
PIN #8: Brown

RJ45 Jack T568B

Wire Pair

EtherCAT in practice 6
Cable standardization

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.

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

*Electronic Industries Alliance / Telecommunications Industry Association
### Installation for field assembly connector ZS1090-0003

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Push the housing over the cable sheath</td>
</tr>
<tr>
<td>2</td>
<td>Press data module and element together</td>
</tr>
<tr>
<td>3</td>
<td>Stripping</td>
</tr>
<tr>
<td>4</td>
<td>Remove</td>
</tr>
<tr>
<td>5</td>
<td>Form the wires</td>
</tr>
<tr>
<td>6</td>
<td>Put on upper shielding shell</td>
</tr>
<tr>
<td>7</td>
<td>Put up splicing element</td>
</tr>
<tr>
<td>8</td>
<td>Put on lower shielding shell</td>
</tr>
<tr>
<td>9</td>
<td>Put up housing</td>
</tr>
<tr>
<td>10</td>
<td>Push housing and lock it</td>
</tr>
<tr>
<td>11</td>
<td>Put the data module into the assembly tool</td>
</tr>
<tr>
<td>12</td>
<td>Tighten connection</td>
</tr>
</tbody>
</table>
Installation for field assembly connector ZS1090-0003

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

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

- 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

- Ser.Nr.: 13050505

- Week of production
- Year of production
- Software version
- Hardware version

- cable and connector
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- protocols
- working counter
Version identification – Software

- cable and connector
- LED diagnosis
- version identification
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- product code, description process image
- E²PROM
- ESC (FPGA)
- µC
- communication and diagnosis functionality (drop out with ASIC)
- terminal specific function e.g. analog input, SSI etc. (only for complex terminals)
- cable and connector
- LED diagnosis
- **version identification**
- state machine
- sync manager
- FMMU
- mailbox
- protocols
- working counter
cable and connector
LED diagnosis
version identification
state machine
sync manager
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EtherCAT in practice
µC

- cable and connector
- LED diagnosis
- version identification
- state machine
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- protocols
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10/02/2009 EtherCAT in practice
EtherCAT State Machine

- cable and connector
- LED diagnosis
- version identification
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- protocols
- working counter

EtherCAT State Machine Diagram:

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

States and Transitions:
- (SI) to Bootstrap (optional)
- (IP) to (PI)
- (OI) to (OP)
- (PS) to (SP)
- (SO) to (OS)
EtherCAT State Machine

‘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

- 'Operational' State
  process data communication in- and outputs

- 'Bootstrap' State
  optional for download of new Firmware
Sync Manager

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

3 Buffer operation

1 Buffer operation

The buffer can be written again as recently as the content was read out.
Sync Manager

- Cable and connector
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FMMU – Field bus Memory Management Unit

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

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

- 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
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.