Documentation

EK1110, EK1110-0008

EtherCAT Extension

Version: 2.3
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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.

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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!

<table>
<thead>
<tr>
<th>DANGER</th>
<th>Serious risk of injury!</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Failure to follow this safety instruction directly endangers the life and health of persons.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WARNING</th>
<th>Risk of injury!</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Failure to follow this safety instruction endangers the life and health of persons.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAUTION</th>
<th>Personal injuries!</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Failure to follow this safety instruction can lead to injuries to persons.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOTE</th>
<th>Damage to environment/equipment or data loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Failure to follow this instruction can lead to environmental damage, equipment damage or data loss.</td>
</tr>
</tbody>
</table>

Tip or pointer

This symbol indicates information that contributes to better understanding.
1.3 Documentation issue status

<table>
<thead>
<tr>
<th>Version</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3</td>
<td>• Technical data added&lt;br&gt;• Update structure</td>
</tr>
<tr>
<td>2.2</td>
<td>• Technical data added&lt;br&gt;• Update structure</td>
</tr>
<tr>
<td>2.1</td>
<td>• Addenda of EK1110-0008</td>
</tr>
<tr>
<td>2.0</td>
<td>• Migration</td>
</tr>
<tr>
<td>1.4</td>
<td>• Technical data added&lt;br&gt;• Addenda chapter &quot;Installation instructions for enhanced mechanical load capacity&quot;</td>
</tr>
<tr>
<td>1.3</td>
<td>• Technical data added&lt;br&gt;• Update structure</td>
</tr>
<tr>
<td>1.2</td>
<td>• Technical data added</td>
</tr>
<tr>
<td>1.1</td>
<td>• Technical data adapted</td>
</tr>
<tr>
<td>1.0</td>
<td>• Technical data added</td>
</tr>
<tr>
<td>0.1</td>
<td>• First preliminary version</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Example</th>
<th>Family</th>
<th>Type</th>
<th>Version</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL3314-0000-0016</td>
<td>EL terminal (12 mm, non-pluggable connection level)</td>
<td>3314 (4-channel thermocouple terminal)</td>
<td>0000 (basic type)</td>
<td>0016</td>
</tr>
<tr>
<td>ES3602-0010-0017</td>
<td>ES terminal (12 mm, pluggable connection level)</td>
<td>3602 (2-channel voltage measurement)</td>
<td>0010 (high-precision version)</td>
<td>0017</td>
</tr>
<tr>
<td>CU2008-0000-0000</td>
<td>CU device</td>
<td>2008 (8-port fast ethernet switch)</td>
<td>0000 (basic type)</td>
<td>0000</td>
</tr>
</tbody>
</table>

**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 Introduction

EK1110/ EK1110-0008 EtherCAT extension

Like the E-bus end terminal, the EK1110 and accordingly the EK1110-0008 EtherCAT extension is connected to the end of the EtherCAT Terminal Block. The terminal offers the option of connecting an Ethernet cable with RJ 45 or rather M8 connector, thereby extending the EtherCAT strand electrically isolated by up to 100 m. In the EK1110 (EK1110-0008) terminal, the E-bus signals are converted on the fly to 100BASE-TX Ethernet signal representation. Power supply of both terminals to the electronics is via the E-bus. No parameterization or configuration tasks are required.

The M8 socket of the type EK1110-0008 is compatible with the EtherCAT Box modules. If Ethernet cables with adequate performance are used, e.g. ZK1090-3131-1xxx, line lengths of 100 m are possible via M8.

Connection

<table>
<thead>
<tr>
<th>Terminal point</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X1</td>
<td>Connection for EtherCAT networks (100BASE-TX Ethernet signal representation)</td>
<td>EK1110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RJ45</td>
</tr>
</tbody>
</table>
2.2 Technical data

<table>
<thead>
<tr>
<th>Technical data</th>
<th>EK1110</th>
<th>EK1110-0008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task in the EtherCAT system</td>
<td>Conversion of the E-bus signals to 100BASE-TX Ethernet for extension of the EtherCAT network</td>
<td></td>
</tr>
<tr>
<td>Transmission medium</td>
<td>Ethernet CAT 5 cable (shielded)</td>
<td></td>
</tr>
<tr>
<td>Cable length between two Bus Couplers</td>
<td>max. 100 m (100BASE-TX)</td>
<td></td>
</tr>
<tr>
<td>Protocol / Baud rate</td>
<td>any EtherCAT protocol / 100 Mbaud</td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td>approx. 1 µs</td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td>no address and configuration settings required</td>
<td></td>
</tr>
<tr>
<td>Bus connection</td>
<td>1 x RJ45, 1 x M8, shielded, screw type</td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td>from E-bus</td>
<td></td>
</tr>
<tr>
<td>Current consumption</td>
<td>typ. 130 mA</td>
<td></td>
</tr>
<tr>
<td>Dielectric strength</td>
<td>500 V (supply voltage/EtherCAT)</td>
<td></td>
</tr>
<tr>
<td>Dimensions (W x H x D)</td>
<td>approx. 44 mm x 100 mm x 68 mm</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>approx. 50 g</td>
<td></td>
</tr>
<tr>
<td>Permissible ambient temperature range during operation</td>
<td>-25°C ... +60°C (extended temperature range)</td>
<td></td>
</tr>
<tr>
<td>Permissible ambient temperature range during storage</td>
<td>-40°C ... + 85°C</td>
<td></td>
</tr>
<tr>
<td>Permissible relative humidity</td>
<td>95%, no condensation</td>
<td></td>
</tr>
<tr>
<td>Mounting [p. 22]</td>
<td>on 35 mm mounting rail conforms to EN 60715</td>
<td></td>
</tr>
<tr>
<td>Vibration/shock resistance</td>
<td>conforms to EN 60068-2-6 / EN 60068-2-27, see also installation instructions [p. 24] for enhanced mechanical load capacity</td>
<td></td>
</tr>
<tr>
<td>EMC immunity/emission</td>
<td>conforms to EN 61000-6-2 / EN 61000-6-4</td>
<td></td>
</tr>
<tr>
<td>Protection class</td>
<td>IP20</td>
<td></td>
</tr>
<tr>
<td>Installation position</td>
<td>variable</td>
<td></td>
</tr>
<tr>
<td>Approval</td>
<td>CE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATEX [p. 32]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cULus [p. 33]</td>
<td></td>
</tr>
</tbody>
</table>

2.3 Start

For commissioning:

- mount the EK1110 as described in the chapter Mounting and wiring [p. 20]
- configure the EK1110 in TwinCAT as described in chapter Parameterization and commissioning [p. 35].
3 Basics communication

3.1 System properties

Protocol

The EtherCAT protocol is optimized for process data and is transported directly within the Ethernet frame thanks to a special Ether-type. It may consist of several sub-telegrams, each serving a particular memory area of the logical process images that can be up to 4 gigabytes in size. The data sequence is independent of the physical order of the Ethernet terminals in the network; addressing can be in any order. Broadcast, Multicast and communication between slaves are possible. Transfer directly in the Ethernet frame is used in cases where EtherCAT components are operated in the same subnet as the control computer.

However, EtherCAT applications are not limited to a subnet: EtherCAT UDP packs the EtherCAT protocol into UDP/IP datagrams. This enables any control with Ethernet protocol stack to address EtherCAT systems. Even communication across routers into other subnets is possible. In this variant, system performance obviously depends on the real-time characteristics of the control and its Ethernet protocol implementation. The response times of the EtherCAT network itself are hardly restricted at all: the UDP datagram only has to be unpacked in the first station.

![EtherCAT Telegram Structure](image)

**Fig. 10: EtherCAT Telegram Structure**

Protocol structure: The process image allocation is freely configurable. Data are copied directly in the I/O terminal to the desired location within the process image: no additional mapping is required. The available logical address space is with very large (4 GB).
**Topology**

Line, tree or star: EtherCAT supports almost any topology. The bus or line structure known from the fieldbuses thus also becomes available for Ethernet. Particularly useful for system wiring is the combination of line and junctions or stubs. The required interfaces exist on the couplers; no additional switches are required. Naturally, the classic switch-based Ethernet star topology can also be used.

![EtherCAT Topology](image)

**Fig. 11: EtherCAT Topology**

Maximum wiring flexibility: with or without switch, line or tree topologies, can be freely selected and combined.

Wiring flexibility is further maximized through the choice of different cables. Flexible and cost-effective standard Ethernet patch cables transfer the signals in Ethernet mode (100Base-TX). The complete bandwidth of the Ethernet network - such as different optical fibers and copper cables - can be used in combination with switches or media converters.

**Distributed Clocks**

Accurate synchronization is particularly important in cases where spatially distributed processes require simultaneous actions. This may be the case, for example, in applications where several servo axes carry out coordinated movements simultaneously.

The most powerful approach for synchronization is the accurate alignment of distributed clocks, as described in the new IEEE 1588 standard. In contrast to fully synchronous communication, where synchronization quality suffers immediately in the event of a communication fault, distributed aligned clocks have a high degree of tolerance vis-à-vis possible fault-related delays within the communication system.
With EtherCAT, the data exchange is fully based on a pure hardware machine. Since the communication utilizes a logical (and thanks to full-duplex Fast Ethernet also physical) ring structure, the mother clock can determine the run-time offset to the individual daughter clocks simply and accurately - and vice versa. The distributed clocks are adjusted based on this value, which means that a very precise network-wide timebase with a jitter of significantly less than 1 microsecond is available.

However, high-resolution distributed clocks are not only used for synchronization, but can also provide accurate information about the local timing of the data acquisition. For example, controls frequently calculate velocities from sequentially measured positions. Particularly with very short sampling times, even a small temporal jitter in the displacement measurement leads to large step changes in velocity. With EtherCAT new, extended data types are introduced as a logical extension (time stamp and oversampling data type). The local time is linked to the measured value with a resolution of up to 10 ns, which is made possible by the large bandwidth offered by Ethernet. The accuracy of a velocity calculation then no longer depends on the jitter of the communication system. It is orders of magnitude better than that of measuring techniques based on jitter-free communication.

Performance

EtherCAT reaches new dimensions in network performance. Protocol processing is purely hardware-based through an FMMU chip in the terminal and DMA access to the network card of the master. It is thus independent of protocol stack run-times, CPU performance and software implementation. The update time for 1000 I/Os is only 30 µs - including terminal cycle time. Up to 1486 bytes of process data can be exchanged with a single Ethernet frame - this is equivalent to almost 12000 digital inputs and outputs. The transfer of this data quantity only takes 300 µs.

The communication with 100 servo axes only takes 100 µs. During this time, all axes are provided with set values and control data and report their actual position and status. Distributed clocks enable the axes to be synchronized with a deviation of significantly less than 1 microsecond.

The extremely high performance of the EtherCAT technology enables control concepts that could not be realized with classic fieldbus systems. For example, the Ethernet system can now not only deal with velocity control, but also with the current control of distributed drives. The tremendous bandwidth enables status information to be transferred with each data item. With EtherCAT, a communication technology is available that matches the superior computing power of modern Industrial PCs. The bus system is no longer the bottleneck of the control concept. Distributed I/Os are recorded faster than is possible with most local I/O interfaces. The EtherCAT technology principle is scalable and not bound to the baud rate of 100 Mbaud – extension to Gbit Ethernet is possible.

Diagnostics

Experience with fieldbus systems shows that availability and commissioning times crucially depend on the diagnostic capability. Only faults that are detected quickly and accurately and which can be precisely located can be corrected quickly. Therefore, special attention was paid to exemplary diagnostic features during the development of EtherCAT.

During commissioning, the actual configuration of the I/O terminals should be checked for consistency with the specified configuration. The topology should also match the saved configuration. Due to the built-in topology recognition down to the individual terminals, this verification can not only take place during system start-up, automatic reading in of the network is also possible (configuration upload).

Bit faults during the transfer are reliably detected through evaluation of the CRC checksum: The 32 bit CRC polynomial has a minimum hamming distance of 4. Apart from breaking point detection and localization, the protocol, physical transfer behavior and topology of the EtherCAT system enable individual quality monitoring of each individual transmission segment. The automatic evaluation of the associated error counters enables precise localization of critical network sections. Gradual or changing sources of error such as EMC influences, defective push-in connectors or cable damage are detected and located, even if they do not yet overstrain the self-healing capacity of the network.

Integration of standard Bus Terminals from Beckhoff

In addition to the new Bus Terminals with E-Bus connection (ELxxxx), all Bus Terminals from the familiar standard range with K-bus connection (KLxxxx) can be connected via the BK1120 or BK1250 Bus Coupler. This ensures compatibility and continuity with the existing Beckhoff Bus Terminal systems. Existing investments are protected.
3.2 EtherCAT basics

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

3.3 EtherCAT cabling – wire-bound

The cable length between two EtherCAT devices must not exceed 100 m. This results from the FastEthernet technology, which, above all for reasons of signal attenuation over the length of the cable, allows a maximum link length of $5 + 90 + 5$ m if cables with appropriate properties are used. See also the Design recommendations for the infrastructure for EtherCAT/Ethernet.

Cables and connectors

For connecting EtherCAT devices only Ethernet connections (cables + plugs) that meet the requirements of at least category 5 (Cat5) according to EN 50173 or ISO/IEC 11801 should be used. EtherCAT uses 4 wires for signal transfer.

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

<table>
<thead>
<tr>
<th>Pin</th>
<th>Color of conductor</th>
<th>Signal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yellow</td>
<td>TD +</td>
<td>Transmission Data +</td>
</tr>
<tr>
<td>2</td>
<td>orange</td>
<td>TD -</td>
<td>Transmission Data -</td>
</tr>
<tr>
<td>3</td>
<td>white</td>
<td>RD +</td>
<td>Receiver Data +</td>
</tr>
<tr>
<td>6</td>
<td>blue</td>
<td>RD -</td>
<td>Receiver Data -</td>
</tr>
</tbody>
</table>

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

Recommended cables

Suitable cables for the connection of EtherCAT devices can be found on the Beckhoff website!

E-Bus supply

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 (see details in respective device documentation).

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. 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.

Fig. 12: System manager current calculation
Malfunction possible!
The same ground potential must be used for the E-Bus supply of all EtherCAT terminals in a terminal block!

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. 13: States of the EtherCAT State Machine](image)

Init

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

Pre-Operational (Pre-Op)

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

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

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

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

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

Operational (Op)

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

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

Boot

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

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

### 3.5 CoE - Interface: notes

This device has no CoE.

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  M8 Connector Cabling

A list of the EtherCAT cable, power cable, sensor cable, Ethernet-/EtherCAT connectors and the field assembled connectors can be found at the following link: http://download.beckhoff.com/download/document/catalog/main_catalog/english/Beckhoff_EtherCAT-Box-Accessories.pdf

You can find the corresponding data sheets at the following link: http://beckhoff.de/english/fieldbus_box/data_sheets.htm?id=6903389254355

EtherCAT cable

Fig. 14: ZK1090-3131-0xxx

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

- **Recommendations about cabling**
  You may get detailed recommendations about cabling EtherCAT from the documentation "Recommendations for the design of the infrastructure for EtherCAT/Ethernet", that is available for download at www.Beckhoff.com.

EtherCAT uses 4 wires for signal transfer.
Due to automatic cable detection (auto-crossing) symmetric (1:1) or cross-over cables can be used between EtherCAT devices from Beckhoff.
## M8 Connector pin assignment

<table>
<thead>
<tr>
<th>Signal</th>
<th>Description</th>
<th>Pin (M8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx+</td>
<td>Transmit Data+</td>
<td>1</td>
</tr>
<tr>
<td>Tx-</td>
<td>Transmit Data-</td>
<td>4</td>
</tr>
<tr>
<td>Rx+</td>
<td>Receive Data+</td>
<td>2</td>
</tr>
<tr>
<td>Rx-</td>
<td>Receive Data-</td>
<td>3</td>
</tr>
<tr>
<td>Shield</td>
<td>Shielding</td>
<td>Housing</td>
</tr>
</tbody>
</table>
4.2 Nut torque for connectors

For usage of the EtherCAT connector M8 of EK1110-0008 the following have to be noticed:

M8 connectors

It is recommended to pull the M8 connectors tight with a nut torque of 0.4 Nm. When using the torque control screwdriver ZB8800 is also a max. torque of 0.5 Nm permissible.

![Fig. 15: EtherCAT Box with M8 connectors](image1)

4.3 Installation on mounting rails

<table>
<thead>
<tr>
<th>WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of electric shock and damage of device!</td>
</tr>
<tr>
<td>Bring the bus terminal system into a safe, powered down state before starting installation, disassembly or wiring of the bus terminals!</td>
</tr>
</tbody>
</table>

Assembly

![Fig. 16: Attaching on mounting rail](image2)
Mounting and wiring

The bus coupler and bus terminals are attached to commercially available 35 mm mounting rails (DIN rails according to EN 60715) by applying slight pressure:

1. First attach the fieldbus coupler to the mounting rail.  
2. The bus terminals are now attached on the right-hand side of the fieldbus coupler. Join the components with tongue and groove and push the terminals against the mounting rail, until the lock clicks onto the mounting rail.  

   If the terminals are clipped onto the mounting rail first and then pushed together without tongue and groove, the connection will not be operational! When correctly assembled, no significant gap should be visible between the housings.

---

**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 mounting rails with a height of 7.5 mm under the terminals and couplers, you should use flat mounting connections (e.g. countersunk screws or blind rivets).

---

Disassembly

![Disassembling of terminal](image)

Each terminal is secured by a lock on the mounting rail, which must be released for disassembly:

1. Pull the terminal by its orange-colored lugs approximately 1 cm away from the mounting rail. In doing so for this terminal the mounting rail lock is released automatically and you can pull the terminal out of the bus terminal block easily without excessive force.

2. Grasp the released terminal with thumb and index finger simultaneous at the upper and lower grooved housing surfaces and pull the terminal out of the bus terminal block.

---

Connections within a bus terminal block

The electric connections between the Bus Coupler and the Bus Terminals are automatically realized by joining the components:

- The six spring contacts of the K-Bus/E-Bus deal with the transfer of the data and the supply of the Bus Terminal electronics.

- The power contacts deal with the supply for the field electronics and thus represent a supply rail within the bus terminal block. The power contacts are supplied via terminals on the Bus Coupler (up to 24 V) or for higher voltages via power feed terminals.
Power Contacts

During the design of a bus terminal block, the pin assignment of the individual Bus Terminals must be taken account of, since some types (e.g. analog Bus Terminals or digital 4-channel Bus Terminals) do not or not fully loop through the power contacts. Power Feed Terminals (KL91xx, KL92xx or EL91xx, EL92xx) interrupt the power contacts and thus represent the start of a new supply rail.

PE power contact

The power contact labeled PE can be used as a protective earth. For safety reasons this contact mates first when plugging together, and can ground short-circuit currents of up to 125 A.

NOTE

Possible damage of the device

Note that, for reasons of electromagnetic compatibility, the PE contacts are capacitatively coupled to the mounting rail. This may lead to incorrect results during insulation testing or to damage on the terminal (e.g. disruptive discharge to the PE line during insulation testing of a consumer with a nominal voltage of 230 V). For insulation testing, disconnect the PE supply line at the Bus Coupler or the Power Feed Terminal! In order to decouple further feed points for testing, these Power Feed Terminals can be released and pulled at least 10 mm from the group of terminals.

WARNING

Risk of electric shock!
The PE power contact must not be used for other potentials!

4.4 Installation instructions for enhanced mechanical load capacity

WARNING

Risk of injury through electric shock and damage to the device!
Bring the Bus Terminal system into a safe, de-energized state before starting mounting, disassembly or wiring of the Bus Terminals!
Additional checks

The terminals have undergone the following additional tests:

<table>
<thead>
<tr>
<th>Verification</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration</td>
<td>10 frequency runs in 3 axes</td>
</tr>
<tr>
<td></td>
<td>6 Hz &lt; f &lt; 60 Hz displacement 0.35 mm, constant amplitude</td>
</tr>
<tr>
<td></td>
<td>60.1 Hz &lt; f &lt; 500 Hz acceleration 5 g, constant amplitude</td>
</tr>
<tr>
<td>Shocks</td>
<td>1000 shocks in each direction, in 3 axes</td>
</tr>
<tr>
<td></td>
<td>25 g, 6 ms</td>
</tr>
</tbody>
</table>

Additional installation instructions

For terminals with enhanced mechanical load capacity, the following additional installation instructions apply:

- The enhanced mechanical load capacity is valid for all permissible installation positions
- Use a mounting rail according to EN 60715 TH35-15
- Fix the terminal segment on both sides of the mounting rail with a mechanical fixture, e.g. an earth terminal or reinforced end clamp
- The maximum total extension of the terminal segment (without coupler) is:
  - 64 terminals (12 mm mounting with) or 32 terminals (24 mm mounting with)
- Avoid deformation, twisting, crushing and bending of the mounting rail during edging and installation of the rail
- The mounting points of the mounting rail must be set at 5 cm intervals
- Use countersunk head screws to fasten the mounting rail
- The free length between the strain relief and the wire connection should be kept as short as possible. A distance of approx. 10 cm should be maintained to the cable duct.

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. 19: 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.
4.6 Connection system

**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!

Overview

The Bus Terminal system offers different connection options for optimum adaptation to the respective application:

- The terminals of KLxxxx and ELxxxx series with standard wiring include electronics and connection level in a single enclosure.
- The terminals of KSxxxx and ESxxxx series feature a pluggable connection level and enable steady wiring while replacing.
- The High Density Terminals (HD Terminals) include electronics and connection level in a single enclosure and have advanced packaging density.

**Standard wiring**

The terminals of KLxxxx and ELxxxx series have been tried and tested for years. They feature integrated screwless spring force technology for fast and simple assembly.
Pluggable wiring

Fig. 22: Pluggable wiring

The terminals of KSxxxx and ESxxxx series feature a pluggable connection level. The assembly and wiring procedure for the KS series is the same as for the KLxxxx and ELxxxx series. The KS/ES series terminals enable the complete wiring to be removed as a plug connector from the top of the housing for servicing. The lower section can be removed from the terminal block by pulling the unlocking tab. Insert the new component and plug in the connector with the wiring. This reduces the installation time and eliminates the risk of wires being mixed up.

The familiar dimensions of the terminal only had to be changed slightly. The new connector adds about 3 mm. The maximum height of the terminal remains unchanged.

A tab for strain relief of the cable simplifies assembly in many applications and prevents tangling of individual connection wires when the connector is removed.

Conductor cross sections between 0.08 mm$^2$ and 2.5 mm$^2$ can continue to be used with the proven spring force technology.

The overview and nomenclature of the product names for KSxxxx and ESxxxx series has been retained as known from KLxxxx and ELxxxx series.

High Density Terminals (HD Terminals)

Fig. 23: High Density Terminals

The Bus Terminals from these series with 16 connection points are distinguished by a particularly compact design, as the packaging density is twice as large as that of the standard 12 mm Bus Terminals. Massive conductors and conductors with a wire end sleeve can be inserted directly into the spring loaded terminal point without tools.

- **Wiring HD Terminals**
  The High Density (HD) Terminals of the KLx8xx and ELx8xx series doesn't support steady wiring.

- **Ultrasonically "bonded" (ultrasonically welded) conductors**
  It is also possible to connect the Standard and High Density Terminals with ultrasonically "bonded" (ultrasonically welded) conductors. In this case, please note the tables concerning the wire-size width [29] below!
Mounting and wiring

Wiring

Terminals for standard wiring ELxxxx/KLxxxx and for pluggable wiring ESxxxx/KSxxxx

![Diagram of terminal connection]

Fig. 24: Mounting a cable on a terminal connection

Up to eight connections enable the connection of solid or finely stranded cables to the Bus Terminals. The terminals are implemented in spring force technology. Connect the cables as follows:

1. Open a spring-loaded terminal by slightly pushing with a screwdriver or a rod into the square opening above the terminal.
2. The wire can now be inserted into the round terminal opening without any force.
3. The terminal closes automatically when the pressure is released, holding the wire securely and permanently.

<table>
<thead>
<tr>
<th>Terminal housing</th>
<th>ELxxxx, KLxxxx</th>
<th>ESxxxx, KSxxxx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire size width</td>
<td>0.08 ... 2.5 mm²</td>
<td>0.08 ... 2.5 mm²</td>
</tr>
<tr>
<td>Wire stripping length</td>
<td>8 ... 9 mm</td>
<td>9 ... 10 mm</td>
</tr>
</tbody>
</table>

High Density Terminals ELx8xx, KLx8xx (HD)

The conductors of the HD Terminals are connected without tools for single-wire conductors using the direct plug-in technique, i.e. after stripping the wire is simply plugged into the contact point. The cables are released, as usual, using the contact release with the aid of a screwdriver. See the following table for the suitable wire size width.

<table>
<thead>
<tr>
<th>Terminal housing</th>
<th>High Density Housing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire size width (conductors with a wire end sleeve)</td>
<td>0.14 ... 0.75 mm²</td>
</tr>
<tr>
<td>Wire size width (single core wires)</td>
<td>0.08 ... 1.5 mm²</td>
</tr>
<tr>
<td>Wire size width (fine-wire conductors)</td>
<td>0.25 ... 1.5 mm²</td>
</tr>
<tr>
<td>Wire size width (ultrasonically “bonded” conductors)</td>
<td>only 1.5 mm² (see notice [28])</td>
</tr>
<tr>
<td>Wire stripping length</td>
<td>8 ... 9 mm</td>
</tr>
</tbody>
</table>
Shielding

Analog sensors and actors should always be connected with shielded, twisted paired wires.

4.7 Positioning of passive Terminals

Hint for positioning of passive terminals in the bus terminal block

EtherCAT Terminals (ELxxx / ESxxx), 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. 25: Correct positioning

Fig. 26: Incorrect positioning
4.8 **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
- II 3G KEMA 10ATEX0075 X Ex nC IIC T4 Gc  Ta: 0 … 55°C
4.9 ATEX - Special conditions (extended temperature range)

⚠️ WARNING

Observe the special conditions for the intended use of Beckhoff fieldbus components with extended temperature range (ET) 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 -25 to 60°C for the use of Beckhoff fieldbus components with extended temperature range (ET) 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 extended temperature range (ET) certified for potentially explosive areas bear the following marking:

II 3G KEMA 10ATEX0075 X Ex nA IIC T4 Gc Ta: -25 … 60°C

or

II 3G KEMA 10ATEX0075 X Ex nC IIC T4 Gc Ta: -25 … 60°C
4.10 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!

4.11 UL notice

<table>
<thead>
<tr>
<th>Application</th>
<th>Beckhoff EtherCAT modules are intended for use with Beckhoff's UL Listed EtherCAT System only.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination</td>
<td>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).</td>
</tr>
<tr>
<td>For devices with Ethernet connectors</td>
<td>Not for connection to telecommunication circuits.</td>
</tr>
</tbody>
</table>

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:

![UL508](image)

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:

![UL508 Limited Consumption](image)

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<sub>dc</sub> 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.
5 Commissioning

5.1 EK1110 - Configuration by means of the TwinCAT System Manager

TwinCAT tree

Enter the EK1110/ EK1110-0008 as an EtherCAT (Direct mode) device in the TwinCAT System Manager in Config mode under Devices. Any Terminals already connected to the network can also be read. This will cause all the Bus Couplers with Bus Terminals and their configurations to be loaded. You can then adapt these to meet your requirements.

Fig. 27: TwinCAT tree EK1110/ EK1110-0008

Online status (Info Data)

State, "Online" tab

Indicates the online status of the terminal.

Fig. 28: State, "Online" tab
<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x___1</td>
<td>Slave in 'INIT' state</td>
</tr>
<tr>
<td>0x___2</td>
<td>Slave in 'PREOP' state</td>
</tr>
<tr>
<td>0x___3</td>
<td>Slave in 'BOOT' state</td>
</tr>
<tr>
<td>0x___4</td>
<td>Slave in 'SAFEOP' state</td>
</tr>
<tr>
<td>0x___8</td>
<td>Slave in 'OP' state</td>
</tr>
<tr>
<td>0x001_</td>
<td>Slave signals error</td>
</tr>
<tr>
<td>0x002_</td>
<td>Invalid vendorId, productCode... read</td>
</tr>
<tr>
<td>0x004_</td>
<td>Initialization error occurred</td>
</tr>
<tr>
<td>0x010_</td>
<td>Slave not present</td>
</tr>
<tr>
<td>0x020_</td>
<td>Slave signals link error</td>
</tr>
<tr>
<td>0x040_</td>
<td>Slave signals missing link</td>
</tr>
<tr>
<td>0x080_</td>
<td>Slave signals unexpected link</td>
</tr>
<tr>
<td>0x100_</td>
<td>Communication port A</td>
</tr>
<tr>
<td>0x200_</td>
<td>Communication port B</td>
</tr>
<tr>
<td>0x400_</td>
<td>Communication port C</td>
</tr>
<tr>
<td>0x800_</td>
<td>Communication port D</td>
</tr>
</tbody>
</table>
6 Error handling and diagnostics

6.1 Diagnostic LED

Fig. 29: EK1110/ EK1110-0008

LEDs for fieldbus diagnostics

<table>
<thead>
<tr>
<th>LED</th>
<th>Display</th>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINK / ACT (X1)</td>
<td>green</td>
<td>off</td>
<td>- no connection on the EtherCAT strand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>on</td>
<td>linked EtherCAT device connected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>flashing</td>
<td>active Communication with EtherCAT device</td>
</tr>
</tbody>
</table>

LED diagnostics EtherCAT State Machine

<table>
<thead>
<tr>
<th>LED</th>
<th>Color</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN</td>
<td>green</td>
<td>This LED indicates the terminal’s operating state:</td>
</tr>
<tr>
<td></td>
<td>off</td>
<td>State of the EtherCAT State Machine: INIT = initialization of the terminal</td>
</tr>
<tr>
<td></td>
<td>flashing uniformly</td>
<td>State of the EtherCAT State Machine: PREOP = function for mailbox communication and different standard-settings set</td>
</tr>
<tr>
<td></td>
<td>flashing slowly</td>
<td>State of the EtherCAT State Machine: SAFEOP = verification of the sync manager channels and the distributed clocks. Outputs remain in safe state</td>
</tr>
<tr>
<td></td>
<td>on</td>
<td>State of the EtherCAT State Machine: OP = normal operating state; mailbox and process data communication is possible</td>
</tr>
<tr>
<td></td>
<td>flashing rapidly</td>
<td>State of the EtherCAT State Machine: BOOTSTRAP = function for terminal firmware updates</td>
</tr>
</tbody>
</table>
7 Appendix

7.1 EtherCAT AL Status Codes

For detailed information please refer to the EtherCAT system description.

7.2 Firmware compatibility

The EK1110 has no firmware.

7.3 Firmware Update EL/ES/EM/EPxxxxx

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 (https://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.

7.3.1 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. 30: 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.

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

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

**Fig. 32: Configuration is identical**

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

Fig. 33: *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

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.

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.
7.3.2 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: \textit{KK YY FF HH}

- \textit{KK} - week of production (CW, calendar week)
- \textit{YY} - year of production
- \textit{FF} - firmware version
- \textit{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 \textit{CoE Online} (CAN over EtherCAT).

\textbf{CoE Online and Offline CoE}

Two CoE directories are available:

- \textbf{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.
- \textbf{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. \textit{Display of EL3204 firmware version} the firmware version of the selected EL3204 is shown as 03 in CoE entry 0x100A.

![Fig. 36: Display of EL3204 firmware version](image)

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 \textit{Online} option in Advanced Settings (B) and double-clicking on \textit{AllObjects}.
7.3.3 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. 37: 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

[Diagram showing EtherCAT configuration]

• 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.

[Image of Microsoft Visual Studio function succeeded]

• 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.

7.3.4 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. 38: FPGA firmware version definition

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

![Context menu Properties]

Fig. 39: 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.
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:

![TwinCAT System Manager Interface](image)

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

![Advanced Settings Dialog](image)
• Select the file (*.rbf) with the new FPGA firmware, and transfer it to the EtherCAT device:

![Image of file selection dialog]

• 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!

### 7.3.5 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.

![Image of firmware update dialog]

**Fig. 41: Multiple selection and firmware update**

Select the required slaves and carry out the firmware update in BOOTSTRAP mode as described above.
7.4 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.

Beckhoff’s branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

The addresses of Beckhoff’s branch offices and representatives round the world can be found on her internet pages: http://www.beckhoff.com

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