EtherCAT®

The Ethernet Fieldbus.
EtherCAT - The Ethernet Fieldbus.

**EtherCAT is:**
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- EtherCAT is real time down to the I/O level
- No underlying sub-systems any more
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

• Other technologies need local I/O cycles + gateways
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

• EtherCAT: Real time down to the I/O
EtherCAT is:

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

 EtherCAT is real time down to the I/O level
- No underlying sub-systems any more
- No delays in gateways
- In- and outputs, sensors, actuators, drives, displays: \textit{everything in one system!}

© EtherCAT Technology Group, 2012
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT is faster

- **Transmission Rate:**
  - 2 x 100 Mbit/s (Fast Ethernet, Full-Duplex)

- **Update Times:**
  - 256 digital I/O in 11 µs
  - **1000 digital I/O** distributed to 100 nodes in **30 µs** = 0.03 ms
  - 200 analog I/O (16 bit) in 50 µs, 20 kHz Sampling Rate
  - **100 Servo-Axis** (each 8 Byte In + Out) in **100 µs** = 0.1 ms
  - 12000 digital I/O in 350 µs
EtherCAT is faster

- Bandwidth Usage of Ethernet for I/O and Drives:
  - Ethernet Frame: ≥ 84 Bytes incl. Preamble + IPG (interpacket gap)

  - with 4 Byte input + 4 Byte output per node:
    - 4.75% application data ratio at 0 µs reaction time/node
    - 1.9% application data ratio at 10 µs reaction time/node
EtherCAT is faster

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

**Bandwidth Usage Comparison:**
- At 4 Byte user data per node:
  - Polling / Timeslicing: ~ 2..5 %
- From 2 Bit user data per node:
  - **EtherCAT:** ~ 80..97 % (Full Duplex, 2 x 100 MBit/s)
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Functional Principle: Ethernet „on the fly“

- Analogy Fast Train:
  - “Train” (Ethernet Frame) does not stop
  - Even when watching “Train” through narrow window one sees the entire “Train”
  - “Car” (Sub-Telegram) has variable length
  - One can “extract” or “insert” single “persons” (Bits) or entire “groups” (Bytes) – even multiple groups per train
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- Efficient: Typically only one Ethernet Frame per Cycle
- Ideal Bandwidth Utilization for maximum Performance
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

**Functional Principle: Ethernet „on the fly“**

- Process data is extracted and inserted on the fly:
  - Process data size per slave almost unlimited (1 Bit…60 Kbyte, if needed using several frames)
  - Compilation of process data can change in each cycle, e.g. ultra short cycle time for axis, and longer cycles for I/O update possible
  - in addition asynchronous, event triggered communication
**Functional Principle: Ethernet „on the fly“**

- Minimal protocol overhead via implicit addressing
  - Optimized telegram structure for decentralized I/O
  - Communication completely in hardware: maximum (+ predictable!) performance
  - No switches needed if only EtherCAT devices in the network
  - Outstanding diagnostic features
  - Ethernet-compatibility maintained

- Bachelor of Science in Computer Science: A Comprehensive Guide
  - Course Overview
  - Course Objectives
  - Course Outline
  - Required Materials
  - Assessment Criteria
  - Additional Resources

**EtherCAT is:**
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

© EtherCAT Technology Group, 2012
‘Slow’ Control Systems benefit, too

Reaction time with legacy fieldbus I/O:

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

T_{mpd}: Master Processing Delay
T_{I/O}: Local I/O Update Time
(local Extension Bus + Firmware)
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

‘Slow’ Control Systems benefit, too

System Architecture with EtherCAT:

no dedicated Master Device any more

on underlying extension bus any more
‘Slow’ Control Systems benefit, too

System Architecture with EtherCAT:

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT Cycle

T_{DMA} = Time for Data Transfer from/to Ethernet Controller via Direct Memory Access: \textit{neglectible}
‘Slow’ Control Systems benefit, too

Reaction Time with EtherCAT:

- Reaction time reduced significantly with the same controller performance
- No underlying local I/O cycles and extension bus delays any more
- Due to the very simple protocol no dedicated master systems (e.g. plug-in cards) required
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Fieldbus: requires Mapping in Control System

- Traditional fieldbus system generate physical process image
- This has to be mapped to logical process image(s)
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Fieldbus: requires Mapping in Control System

- The same applies to system with just one process image
- Resorting of process data ("Mapping") is required, too
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- Control System is unburdened, master becomes very simple
- Data is transmitted according to the application requirements: extremely fast, flexibly and efficiently
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- EtherCAT Node measures time difference between leaving and returning frame
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT Node measures time difference between leaving and returning frame
EtherCAT is:

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

**Distributed Clocks**

- Precise Synchronization (<< 1 µs!) by exact adjustment of Distributed Clocks

![Distributed Clocks Diagram](image)
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Distributed Clocks

- Long Term Scope View of two separated devices
- 300 Nodes in between, 120m Cable Length

Interrupt Node 1

Simultaneousness:
~15 ns

Interrupt Node 300

Jitter: ~ +/-20ns
Synchronization of multiple Networks

- EtherCAT networks can be coupled via EtherCAT Bridge
- Bridge provides hardware synchronization of several networks

EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

• EtherCAT networks can be coupled via EtherCAT Bridge
• Bridge provides hardware synchronization of several networks
EtherCAT is Industrial Ethernet!

- EtherCAT uses Standard Ethernet Frames: IEEE 802.3
- Alternatively via UDP/IP (if IP Routing is needed)
- no shortened frames

<table>
<thead>
<tr>
<th>Type</th>
<th>Res.</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bit</td>
<td>4 Bit</td>
<td>11 Bit</td>
</tr>
<tr>
<td>16 Bit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Or: via UDP/IP
UDP Port 0x88A4

MTU: max. 1514 Byte
EtherCAT is Industrial Ethernet!

- fully transparent for TCP/IP
- all Internet technologies (HTTP, FTP, Webserver,…)
  available without restricting the real time capabilities!
EtherCAT is Industrial Ethernet!

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- Any Ethernet Device can be connected to Switchport
- Access to Webserver with Standard Browser
EtherCAT is Industrial Ethernet!

- Virtual Ethernet Switch routes any Ethernet Frame
- From inside as well as from outside the segment
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Switchport: Any Ethernet Protocol

- Interface to any Ethernet Device or Network
- Ethernet Frames are inserted into EtherCAT Protocol:
  - ‘Ethernet over EtherCAT’
EtherCAT is Industrial Ethernet!

- Master TCP/IP Stack can provide remote Mailbox access via TCP/IP to any EtherCAT device – ideal for tools.
- No need for TCP/IP stack in each device: cost reduction

Master TCP/IP Stack provides access to Mailbox protocol

Online access to device

Switchport

Master

© EtherCAT Technology Group, 2012
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

…via Switchport

+ any Ethernet Protocol can be used
+ requires only one Ethernet Port (at IPC/Controller)
+ EtherCAT performance is not limited
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Vertical Integration (2)

...via 2. Ethernet Port

+ any Ethernet Protocol can be used
+ EtherCAT performance is not limited
- but: requires second Ethernet Port (at IPC/Controller)
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Vertical Integration (3)

…via Switch

+ any Ethernet Protocol can be used
+ requires only one Ethernet Port (at IPC/Controller)
- but: performance reduced by switch delay (and generic Ethernet traffic)
EtherCAT is:
- Faster ✔
- Synchronization ✔
- Industrial Ethernet ✔
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT wiring is more flexible

- Standard Ethernet Topology: Star
EtherCAT is:

- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT wiring is more flexible

- Flexible topologies – arbitrarily extendable
  - Topology variants like Line, Star, Tree, Daisy Chain
  - Drop Lines possible; can be used in any combination!
  - Up to 65,535 nodes for each EtherCAT segment
- Standard Ethernet cabling
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT wiring is more flexible

EtherCAT Device Protocol processed on the fly
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT Extra Large System Test

10.056 EtherCAT Nodes
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

- **Ethernet Signal Variants of EtherCAT:**
  - 100BASE-TX (up to 100 m between 2 nodes)
  - 100BASE-FX (up to 20 km between 2 nodes (single mode fibre))
  - LVDS (for modular devices)

- **Any number of physical layer changes allowed**
  
*LVDS: Low Voltage Differential Signaling according to ANSI/TIA/EIA-644, also used in IEEE 802.3ae (10 Gigabit Ethernet)
EtherCAT instead of PCI

- Protection of your investment
- smooth migration path from legacy fieldbus to EtherCAT
- seamless integration of existing fieldbus devices, e.g.:
  - AS-Interface
  - BACnet MS/TP
  - CANopen
  - CC-Link
  - ControlNet
  - DeviceNet
  - Ethernet/IP
  - FIPIO
  - Interbus
  - IO-Link
  - Lightbus
  - LonWorks
  - Modbus Plus, RTU, TCP
  - PROFIBUS
  - PROFINET IO
  - ...

- maximum system expandability with low cost fieldbus gateways
**EtherCAT instead of PCI**

- **Update Times:**
  - Process image update-time via PCI (500 Bytes input and output data each): 400 µs
  - Process image update-time via EtherCAT (1,500 Bytes input and output data): 150 µs
EtherCAT is:
- Faster ✔
- Synchronization ✔
- Industrial Ethernet ✔
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT instead of PCI

• No Slots in Control System (IPC or PLC) required any more
• Nevertheless maximum expandability

© EtherCAT Technology Group, 2012
EtherCAT is easier to configure

**EtherCAT is:**
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

**Topology:**
- Automatic Topology Expected/Actual Comparison

**Diagnosis:**
- Diagnosis with exact Localization

- Every node constantly monitors checksum
- Bit errors are detected and localized
- Even Timing Errors (e.g. Time Window for Actual Values missed) are detected and stored locally in the chip
EtherCAT is easier to configure

- Network planning:
  - Performance independent of:
    - Slave implementation
      (no Stacks involved in Process Data Communication)
    - Topology (no Switches/Hubs)

- Addressing
  - No manual address setting required
  - No IP- or MAC-Address Handling Required
  - Addresses can be assigned automatically
  - Addresses can be kept
    - no new addressing if nodes are added
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Configuration: Classical Fieldbus Systems

1. Select + Plan Topology according to System Limitations
2. Configure Node Address at Slave Device
3. Select and Configure Baudrate, depending on:
   - Network Length + Topology
   - EMI-Environment
   - Application Requirements
4. Select Device Description Files (GSD, EDS) in Configuration Tool
5. Select and Configure Communication Parameters, such as:
   - cyclic Polling
   - event driven Communication
   - synchronized or free running
6. Allocate physical to logical Process Image (Mapping)
Configuration: EtherCAT

1. Select + Plan Topology according to System Limitations
2. Configure Node Address at Slave Device
3. Select and Configure Baudrate, depending on:
   - Network Length + Topology
   - EMI Environment
   - Application Requirements
4. Select Device Description Files (GSD, EDS) in Configuration Tool
5. Select and Configure Communication Parameters, such as:
   - cyclic Polling
   - event driven Communication
   - synchronized or free running
6. Allocate physical to logical Process Image (Mapping)
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT is lower costs (1): Engineering

- Less effort for Network planning:
  - Simplified configuration
  - Default settings will work, no network tuning
- Improved Diagnosis:
  - Faster error handling leads to less downtime
- Faster Setup:
  - No address setting required
- Implementation / Tools:
  - Standard Network Monitor Tools, e.g. MS Network Monitor or Wireshark: free of charge
  - Parser Software: free of charge
**EtherCAT is lower costs (2): Hardware**

**EtherCAT is:**
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

<table>
<thead>
<tr>
<th><strong>Master:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- no dedicated plug in card (co-processor)</td>
<td></td>
</tr>
<tr>
<td>- on-board Ethernet Port is fine</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Slave:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- low cost Slave Controller</td>
<td></td>
</tr>
<tr>
<td>- FPGA or ASIC</td>
<td></td>
</tr>
<tr>
<td>- for simple devices: no µC needed</td>
<td></td>
</tr>
<tr>
<td>- no powerful µC needed</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Infrastructure:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- no Switches/Hubs required</td>
<td></td>
</tr>
<tr>
<td>- Standard Ethernet Cabling + Connectors</td>
<td></td>
</tr>
</tbody>
</table>
EtherCAT is easier to implement

• Slave Implementation:
  – All time critical functions implemented on ASIC or FPGA
    • ESC handles Real-time Protocol in Hardware
  – Integrated Communication State Machine
  – Network Performance independent of
    • Slave-μC Performance
    • Protocol Stack
  – For usage with or without μC (Host CPU)
  – Integrated DPRAM (1…8kByte)
  – Integrated Distributed Clock Handling
  – Ultra precise interrupts to μC
EtherCAT is easier to implement: Master

- Master Implementation:
  - e.g. with Master Sample Code (Source)
  - EtherCAT Configuration Tool
  - XML Data format of ESI and ENI
EtherCAT is well proven

EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

In Series Production since 2003, outstanding Product Variety

October 2012
EtherCAT is an open technology

- Faster ✔
- Synchronization ✔
- Industrial Ethernet ✔
- Flexible Topology ✔
- Easier to configure ✔
- Cost effective ✔
- Easier to implement ✔
- Well proven ✔

- Open
- Conformance
- Safety
- Redundancy
- Versatile

**Protocol is disclosed completely:**

- EtherCAT is IEC, ISO and SEMI Standard
  (IEC 61158, IEC 61784, ISO 15745, SEMI E54.20)

**Slave Controller from several sources available**
**Slave Controller provides interoperability**
**ETG organizes Interoperabilitly Testing („Plug Fests“), Workshops and Seminars**
**Conformance Testing + Certificates**
EtherCAT is:

- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT Masters implemented on wide range of RTOS*

- eCos
- Integrity
- INtime
- Linux with RT-Preempt
- Microwave® OS-9
- MQXTM
- On Time RTOS-32
- Oracle® Solaris (SunOS)
- PikeOS
- Proconos OS
- QNX®
- Real-Time JavaTM
- RMOS
- RTKernel
- RT-Linux
- RTX
- RTXC
- RTAI Linux
- SCALE-RT
- TKernel
- VxWin® + CeWin® + RTOS32Win® + LxWin
- VxWorks®
- Windows® CE
- Windows Embedded mit IntervalZero RTX
- Windows® XP/XPE mit CoDeSys SP RTE
- Windows® XP/XPE mit TwinCAT RT-Extension
- Windows® Vista, 7
- XOberon
- XENOMAI Linux
- μC/OS-IITM

*as of July 2012
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Typical EtherCAT Device Architecture

**EtherCAT Device**

- **HTTP, FTP,…**
- **DEVICE Application**
- **TCP**
- **UDP**
- **IP**
- **Ethernet**
- **Cyclic Synchronous Communication (Implicit Addressing)**
- **Asynchronous Communication (Explicit Addressing)**
- **Parameters**
- **Mailbox**
- **Process Data**
- **EtherCAT Slave Controller**
- **EoE**
- **CoE/SoE**
- **Ethernet Physical Layer**

Device Profile Definitions

© EtherCAT Technology Group, 2012
EtherCAT is an open technology

EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

• Foundation: November 2003
• Tasks: Support, Advancement and Promotion of EtherCAT
• The worlds largest fieldbus organization
• More than 2100* member companies from 55 countries in 6 continents:
  – Device Manufacturers
  – End Users
  – Technology Providers
• Membership is open to everybody

*as of Sept 2012
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance
- Safety
- Redundancy
- Versatile

As of August 31st, 2012: 2105 Members

August 2011 – August 2012: + 380
EtherCAT Technology Group is a truly Global Organization

- Germany
- Europe (w/o Germany)
- America
- Asia

- 35 members
- > 2100 members
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

August 31st 2012: 631 Asian Members

Aug 2011 – Aug 2012: + 164!
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Members from 55* Countries, 6 Continents

*as of Sept 2012
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

How many members invest in the technology?

- One indicator: implementation kits sold.
- Until now, Beckhoff alone has sold over 1400 kits (78% slave kits, 22%(!) master kits)
- + there are slave implementation kits + master stacks from many other vendors*, such as

<table>
<thead>
<tr>
<th>Slave</th>
<th>Master</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beck IPC</td>
<td>acontis</td>
</tr>
<tr>
<td>Deutschmann</td>
<td>esd</td>
</tr>
<tr>
<td>EBV Elektronik</td>
<td>igH</td>
</tr>
<tr>
<td>Hilscher</td>
<td>IXXAT Automation</td>
</tr>
<tr>
<td>HMS anybus</td>
<td>Kithara</td>
</tr>
<tr>
<td>IXXAT Automation</td>
<td>Koenig-PA</td>
</tr>
<tr>
<td>koenig-pa</td>
<td>MicroSys</td>
</tr>
<tr>
<td>port</td>
<td>Profimatics</td>
</tr>
<tr>
<td>Red one</td>
<td>Sybera</td>
</tr>
<tr>
<td>Soft Servo Systems</td>
<td></td>
</tr>
<tr>
<td>ST Microelectronics</td>
<td></td>
</tr>
<tr>
<td>Terasic Technologies</td>
<td></td>
</tr>
<tr>
<td>Tetra</td>
<td></td>
</tr>
<tr>
<td>Xilinx</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

* Only those listed that have entered their offering in the EtherCAT Product Guide
ETG: Active Members

- EtherCAT is:
  - Faster ✓
  - Synchronization ✓
  - Industrial Ethernet ✓
  - Flexible Topology ✓
  - Easier to configure ✓
  - Cost effective ✓
  - Easier to implement ✓
  - Well proven ✓
  - Open
  - Conformance
  - Safety
  - Redundancy
  - Versatile

- Hannovermesse 2012: 65 Vendors with over 280 different EtherCAT Devices at ETG booth:
  - 35 different drives from 24 manufacturers jointly operating in one network
  - 25 different functional Masters in one setup, using 10 different operating systems
  - Safety devices (master + slave devices) from several manufacturers operating in one system
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open
- Conformance
- Safety
- Redundancy
- Versatile

 EtherCAT: Large Product Selection
I/O, Controller, HMI, Servo Drives, Variable Speed Drives
Sensors, Slave + Master Development Kits
Control Panels, Hydraulic Valves
and Pneumatic Valves, …
Conformance and Interoperability

EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance
- Safety
- Redundancy
- Versatile

Conformance and interoperability are very important factors for the success of a communication technology
- Conformity to the specification is an obligation to all users of the EtherCAT technology
- Therefore the **EtherCAT Conformance Test Tool (CTT)** is used
- Test Cases for the CTT are provided by the Working Group „Conformance“ within the ETG community
- The **EtherCAT Conformance Test** proves conformance with issuing a certificate after passing the test at an official **EtherCAT Test Center (ETC)**
Safety over EtherCAT

EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety
- Redundancy ✓
- Versatile

Material feeding
Muting
Two-Hand control
Protection of workspace e.g. with Laser scanner
Emergency stop
Operator Diagnosis
Safely-limited Position / Speed
Door guarding with Interlocking
Safety guard
Setup / Maintenance

© EtherCAT Technology Group, 2012

October 2012
Safety over EtherCAT: Features

- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance

Safety over EtherCAT (FSoE) defines a safety communication layer for the transportation of safety process data between Safety over EtherCAT devices.

- FSoE is an open technology within the EtherCAT Technology Group (ETG).
- The protocol is developed according to IEC 61508
  - It meets the Safety Integrity Level (SIL) 3
  - Residual Error Probability \( R(p) < 10^{-9} \)
- The protocol is approved by an independent Notified Body (TÜV)
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety
- Redundancy
- Versatile

Safety over EtherCAT: Software Architecture

EtherCAT is used as a "black channel"
It contains safety and standard information
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile ✓

• One channel communication system
  According to model A of IEC 61784-3 Annex A
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

Safety over EtherCAT: Frame Structure

EtherCAT Frame

- Ethernet Header
- EtherCAT Header
- 1. Datagram
- HDR
- Process
- FSoE Data
- FSC

FSoE Frame

The FSoE Frame is embedded as a Container in the process data of the device.
Each device detects a new FSoE Frame, if at least one Bit in the FSoE Frame is changed.
Every 2 Byte SafeData are checked by a 2 Byte CRC.
The maximum number of SafeData is therefore not restricted by the protocol.
Safety over EtherCAT: Implementation Example

- Decentralized Safety-Logic
- Standard PLC routes the safety messages
Safety over EtherCAT: Advantages

- Fully integrated solution:
  - safe and standard communication in one channel
- Reduction of fieldbuses and interfaces
- Central configuration, diagnosis and maintenance for safe and 'unsafe' I/O in one tool
- Safety application makes full use of EtherCAT advantages:
  - Short reaction times
  - Almost unlimited number of nodes
  - Large network extensions
  - Cable redundancy options
  - High Flexibility with Hot Connect
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile

 EtherCAT Master
RX Unit
TX Unit
RX
TX
MAC 1
RX
TX

Without Redundancy: Normal Operation

EtherCAT Master
RX Unit
TX Unit
RX
TX
MAC 1
RX
TX

Slave 1
RX
TX
RX
TX

Slave 2
RX
TX
RX
TX

Slave N
RX
TX
RX
TX

...
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile

Without Redundancy: Cable Failure
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile
EtherCAT is:
- Faster ✔
- Synchronization ✔
- Industrial Ethernet ✔
- Flexible Topology ✔
- Easier to configure ✔
- Cost effective ✔
- Easier to implement ✔
- Well proven ✔
- Open ✔
- Conformance ✔
- Safety ✔
- Redundancy ✔
- Versatile

With Redundancy: Normal Operation

EtherCAT Master
RX Unit
TX Unit
MAC 1
RX
TX
MAC 2
RX
TX

Slave 1
RX
TX
TX
RX

Slave 2
RX
TX
TX
RX

Slave N
RX
TX
TX
RX

Only 2nd Ethernet Port required – no special Interface Card

October 2012
© EtherCAT Technology Group, 2012
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile

With Redundancy: Cable Failure

Switchover time: < 15µs
EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile

With Redundancy: Node or Cable Failure
 EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy
- Versatile

- Cabling redundancy
  - 2nd Ethernet port needed on master side only
- Hot Swap of devices
- Hot Connect of network segments
- Master Redundancy with Hot Stand By

EtherCAT: High availability

Cabling redundancy:
- 2nd Ethernet port needed on master side only

- Hot Swap of devices
- Hot Connect of network segments
- Master Redundancy with Hot Stand By

Master

Hot Connect
Group
EtherCAT: versatile system architecture

- Master to Slave
- Slave to Slave
- Master to Master

EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

© EtherCAT Technology Group, 2012
EtherCAT is:
- Faster
- Synchronization
- Industrial Ethernet
- Flexible Topology
- Easier to configure
- Cost effective
- Easier to implement
- Well proven
- Open
- Conformance
- Safety
- Redundancy
- Versatile

EtherCAT Device Protocol processed on the fly
EtherCAT Automation Protocol: Application

October 2012
EtherCAT and Wireless Communication

- EtherCAT is:
  - Faster ✓
  - Synchronization ✓
  - Industrial Ethernet ✓
  - Flexible Topology ✓
  - Easier to configure ✓
  - Cost effective ✓
  - Easier to implement ✓
  - Well proven ✓
  - Open ✓
  - Conformance ✓
  - Safety ✓
  - Redundancy ✓
  - Versatile ✓

- Wireless Devices can be connected via Switchport
- Wireless segment does not slow down EtherCAT communication
- Protocol: EtherCAT Automation Protocol
  - Pushed and/or Polled Process Data Exchange
- Wireless Segment transparent for Master Device

```
Master

Switchport

Master sees process data of underlying system as local I/O data
```

Wireless Devices can be connected via Switchport
Wireless segment does not slow down EtherCAT communication
Protocol: EtherCAT Automation Protocol
  - Pushed and/or Polled Process Data Exchange
Wireless Segment transparent for Master Device

© EtherCAT Technology Group, 2012
EtherCAT - The Ethernet Fieldbus.

Why go for something slower, just because it is more expensive?
EtherCAT - The Ethernet Fieldbus.

EtherCAT is:
- Faster ✓
- Synchronization ✓
- Industrial Ethernet ✓
- Flexible Topology ✓
- Easier to configure ✓
- Cost effective ✓
- Easier to implement ✓
- Well proven ✓
- Open ✓
- Conformance ✓
- Safety ✓
- Redundancy ✓
- Versatile ✓

Please visit www.ethercat.org
for more information

EtherCAT Technology Group
ETG Headquarters
Ostendstr. 196
90482 Nuremberg, Germany
Phone: +49 911 54056 20
info@ethercat.org