EtherCAT: what are the User benefits
- or -
Competitive Advantages
through EtherCAT
Your Goals as a Machine Builder / System Integrator

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

Employ Industrial Ethernet

Sell more Machines / Plants!

Industrial Ethernet: Just a means to achieve competitive advantages.

This is of course valid for the entire electrical equipment of the machine or plant....
Your Selling Points – or: how do you differentiate yourself from your competition

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How does the communication system / the electrical equipment influence these selling points?

- Quality
- Throughput, Efficiency
- Price
- Availability
- Energy Efficiency
- Safety
- Expandability
- Ease of Integration (into plant environment)
- Worldwide Support, …
- User Friendliness
- Suppliers Reliability, After Sales Service, …
Your Selling Point: **Quality**

*Or: how good does the machine/plant do what it was purchased for?*

- Robotics: **Repeat Accuracy**
- Plastics Machine: **low part Variety, Precision**
- Press: **Forming Quality determined by Precision in Force/Time Distribution**
- Assembly Line: **Precision**
- Woodworking Machinery: **Precision**
- Machine Tooling: **Precision**
- Semiconductor Equipment: **Process Accuracy**
- Packaging Machine: **Process Accuracy**
Crucial for **Precision**: Performance of Control- and Communication System

**Example: Robotics**

Kuka Robotics, Germany:
KR C4 Robot Controller features EtherCAT Master
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The fastest Industrial Ethernet Technology

- 1000 distributed digital I/O in 30μs
- 100 Servo-Axis every 100 μs
- EtherCAT directly to the I/O Slice, no Sub-Bus
- Optimal Usage of the Standard Ethernet Port in the Controls, no extra hardware
- Reason for this Unique Performance:
  
  The EtherCAT Functional Principle (Ethernet on the Fly)
Decisive Factors: Performance

Example: Metal Forming
Häusler AG, Switzerland:
Plate bending machines
for plates up to 450 mm thick

Michael Fabianek, Häusler AG:
“The extremely short cycle
time of EtherCAT fits
perfect with our concept.
The quicker the position
data is available to us, the
more accurate we can
control the machine. This
also leads to less
vibrations in the machine
and thus to a longer
lifetime of mechanical parts”
Also most important for **Precision:**
Synchronization Features

EtherCAT Distributed Clocks:
Synchronization with max. Precision

**Example: FPD Manufacturing**

Kleo Halbleitertechnik GmbH, Germany:
Laser lithography system for LCD screen production

Stefan Scharl, Kleo:

*“EtherCAT enables us to achieve short sampling rates, short cycle times of around 50 μs and stable real-time capability as the basis for high-precision positioning of the laser beams.”*
Also most important for **Precision**: Synchronization Features

**Example: Bowling Robot**

ARM Automation, Austin, TX: “E.A.R.L.”
(Enhanced Automated Robotic Launcher)

Joe Geisinger, CTO of ARM Automation:

*Thanks to the distributed clock function of EtherCAT, we have achieved optimum synchronization and precision. This provides the precision to coordinate the external I/O with the control and position of the drives in the sub-millisecond range: the position of the E.A.R.L. robot’s end effector is communicated to the EtherCAT drives to determine the exact time at which the ball needs to be released.*
Your Selling Point: **Throughput / Efficiency**

Or: **how fast does the machine / plant do what it was purchased for?**

- Throughput / Efficiency have direct impact on Return of Investment

- Not only machines and plants with closed loop control: Every Application with **Transitions** benefits immediately from faster control technology with EtherCAT

- Examples for Transitions:
  - Wait for cylinder end position, then…
  - Wait until part has arrived, then…
  - Wait for threshold of pressure, force, torque, weight, temperature, then….
I/O Reaction Time and Control Cycle Time

**PROFIBUS-Timing**
(synchronized, not free running!)

- **T_{resp, PROFIBUS}**
- **T_{resp}(Ø) = 2.5-3 Cycles**

**EtherCAT-Timing**

- **T_{resp}(Ø) = 1.5 Cycles**

<table>
<thead>
<tr>
<th>PLC</th>
<th>PROFIBUS</th>
<th>K-Bus</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
</table>

- PROFIBUS-Timing (synchronized, not free running!)
- EtherCAT-Timing
Cycle Time Reduction = Efficiency Gain

Machine-Cycle Time Reduction in %
(= Gain of Machine Efficiency)

$$T_{d\%} = \frac{N_{r2} \cdot T_{c2} - N_{r1} \cdot T_{c1}}{T_t}$$

$$T_{d\%} = \text{Machine Cycle Time Reduction (\%)}$$

- $N_{r1} = \text{Ø No. of Control Cycles for I/O Reaction System 1}$
- $N_{r2} = \text{Ø No. of Control Cycles for I/O Reaction System 2}$
- $T_{c1} = \text{Control Cycle Time 1 (the shorter Cycle Time)}$
- $T_{c2} = \text{Control Cycle Time 2 (the shorter Cycle Time)}$
- $T_t = \text{Time between 2 Control Transitions}$
Cycle Time Reduction = Efficiency Gain

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E.g.: 2 Trans/sec, from 5 ms Profibus to 0,1 ms EtherCAT:
3% Efficiency Gain

![Graph](image)

with: $N_{rl} = 3$, $N_{r2} = 1.5$, $T_{c2} = 0.1$ ms
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Example: Packaging
Bosch Packaging / Beckhoff Automation, Germany: Linear Transport System for Packaging Applications

e.g. for aligning products equidistantly that arrive arbitrarily
Decisive Factors: Performance

Technical Data

Linear Motor Control Loop closed via EtherCAT:
- 96 Position Sensors (= Drive Input Channels)
- 64 Drives with 192 Coils (= Drive Output Channels)
- 31 Movers (= Objects controlled individually)

Bus Cycle Time: 250 µs
Current Control Loop: 31,25 µs
Positioning Accuracy: +/-0.25 mm @ 3m/s
Net Data Throughput: ~ 60 Mbit/s (full duplex)
Decisive Factors: Topology + Performance

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Example: Logistics and Material Handling
Numina Group, USA:
Shipping box labeling + handling system

Mark Woodworth, Numina:

"With EtherCAT we achieve the fastest realtime speeds throughout with a consistent performance, regardless of the number of I/Os."
Your Selling Point: Price and Costs

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- Device Costs
- Infrastructure Costs
- Engineering Costs
- Setup Costs
- Maintenance Costs
- License Costs
- …
Device Costs – from the Communication System Point of View

- Supplier Variety – *most important Pre-Requisite for low Prices*
  - How many Vendors support the Communication System
  - How many Master Devices are available?

- Interface Costs – *direct Influence on Device Prices*
  - How much are the Chips, how much processing power and memory is required by the Communication Technology?
  - Are there Chips from multiple Sources?

- Infrastructure Costs – *less hardware – reduced costs*
  - Cable, Connectors, Switches/Hubs, …
Supplier Variety with EtherCAT

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- Sept 2011: Over 1200 Beckhoff Implementation Kits sold to ETG Members (25% Master-Kits, 75% Slave-Kits) + Kits of other technology providers + Open/Shared Source Master

- Hannover Fair 2011: 68 Exhibitors with more than 280 different EtherCAT Devices at ETG booth

- EtherCAT Master: over 120 Vendors
- EtherCAT Servo-Drives: over 90 Vendors
- EtherCAT I/O: over 60 Vendors
- EtherCAT Gateways for 19 different Fieldbus-Systems available
- Variable Frequency Drives, Sensors, Hydraulic + Pneumatic Valves, Sensors, HMI, Control Panels, …
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Master:
- no dedicated plug in card (co-processor)
- on-board Ethernet Port is fine

Slave:
- low cost Slave Controller
- FPGA or ASIC, several suppliers
- for simple devices: no µC needed at all
- no powerful µC needed
EtherCAT Chips from Multiple Sources

ASIC
- Hilscher netX® 100/500
- Beckhoff® ET1200
- Beckhoff® ET1100
- Hilscher netX® 50

FPGA
- IP-Core for Altera® Cyclone™-I
- IP-Core for Altera® Cyclone™-II
- IP-Core for Altera® Cyclone™-III
- IP-Core for Altera® Cyclone™-IV
- IP-Core for Xilinx® Spartan™-3
- IP-Core for Xilinx® Spartan™-6
- IP-Core for Xilinx® Kintex™-7
- IP-Core for Altera® Stratix™-IV
- IP-Core for Altera® Stratix™-V
- IP-Core for FPGA of Intel® Atom™ E6x5C

μC, μP
- TI’s Sitara™ and other μC + μP families

October 2011
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• Infrastructure:
  - no Switches / Hubs required
  - Standard Cabling
  - 4pin Connectors
  - Option: Power over EtherCAT for Sensors
Decisive Factors: Infrastructure Costs

Example: Packaging Machines
Radiator Specialty, (NC), USA: Filling and Packaging Line

Murray Williamson, Radiator Specialty:

“One key factor to use EtherCAT was that we didn’t have to use switches: CAT-5e cabling goes right to the EtherCAT I/O Bus Couplers. We feel that it’s the most versatile network out there.”
EtherCAT Engineering Costs

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Network Planing / Engineering:
- Process data Performance independent from Stack Performance of the Devices
- Network Performance practically independent from topology (no Switches, no Hubs)
- No Network Tuning any more: Default settings will do
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Addressing:
- No manual Address Setting required
- Addresses are assigned automatically
- Addresses can be kept even when devices are added later – no re-addressing required
- No MAC Address Handling required
Setup and Maintenance Costs (II)

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- **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 License Costs

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• **Master-Device:**
  - Master-License is free of charge on principle

• **Slave-Device:**
  - For Users free of charge on principle,
    Slave-License – as with CAN – included in Chip Price
Example Configuration (e.g. Beckhoff Products)

- PLC (CX1000)
- 10 Bus Stations
- 400 DI / 400 DO
- 100 m Cable
- 11 Bus Connectors (Fieldbus)
- 21 Bus Connectors (EtherCAT)
- Inexpensive “Compact” Fieldbus Couplers

Device + Infrastructure Cost Comparison

October 2011
### Device + Infrastructure Cost Comparison

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<table>
<thead>
<tr>
<th>Example Configuration</th>
<th>List Price*</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EtherCAT</strong></td>
<td>100 %</td>
<td>-</td>
</tr>
<tr>
<td><strong>DeviceNet</strong></td>
<td>123.7 %</td>
<td>+ 23.7 %</td>
</tr>
<tr>
<td><strong>PROFINET</strong></td>
<td>121.5 %</td>
<td>+ 21.5 %</td>
</tr>
<tr>
<td><strong>CANopen</strong></td>
<td>121.9 %</td>
<td>+ 21.9 %</td>
</tr>
</tbody>
</table>

And just for reference:

| **EtherNet/IP**          | 143.7 %     | + 43.7 %   |

Ethernet/IP, Profinet: switches not taken into account

* Beckhoff Price List 01/2011
Why such significant Price Differences?

Master/Scanner Card

Bus Coupler with CPU and local extension bus master

Bus Coupler and Digital I/O: just EtherCAT Slave Controller

EtherCAT: no Master HW

T-Junction Connectors

Simple Straight Connectors

- Fieldbus Controller
- CPU
- RAM
- Flash
- Master for Local Extension Bus
- Driver

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Decisive Factors: **Performance, Costs**

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**Example: Woodworking Industry**

Control Logic, USA: Rip Optimizing Machine

Chris Aiken, Control Logic:

“Networking with EtherCAT I/O Terminals provided industry-leading performance via real-time, high-speed updates at a lower cost than I/O technologies that aren’t Ethernet-based.”
Your Selling Point: Availability

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• Condition Monitoring / Predictive Maintenance:
Detecting mechanical wear *before* it becomes a problem
avoids unplanned shutdowns due to equipment failure

• With legacy fieldbus systems:
dedicated + costly measurement system required

• With **EtherCAT**:
Vibration Analysis
with standard (Oversampling) I/O Devices
Decisive Factors: **Condition Monitoring**

**Example: Wind Energy**

No insurance without Condition Monitoring

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Your Selling Point: **Availability**

- Availability of electrical components: Best Availability is achieved if there are less active devices: *what is not there cannot fail*

- EtherCAT uses neither active Infrastructure Components such as Switches or Hubs… nor their power supplies…

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Your Selling Point: **Availability**

- Important for high Availability of your plant: outstanding Diagnosis and (Remote)-Maintenance Capabilities

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Access via TCP/IP also to Slave Devices without own TCP/IP Stack

Internet

Web-server
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In Addition: EtherCAT High Availability Options

- Cable Redundancy
- Hot Connect of Devices and Network Segments
- Device Exchange during Operation
Decisive Factors: High Availability + Topology

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Example: Theatre Stage Control System
TTS GmbH, Germany
Schauspielhaus Nuremberg

TTS project manager Frank Kremer: “EtherCAT, encompasses the most important characteristics for us: real-time capability, high bandwidth, cable redundancy and impressive diagnostic properties.”
Decisive Factors: High Availability + Topology

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Example: Snow Blower Control
Berchtold, Austria:
  Systems of up to 1000 snow makers,
  Using redundant fiber optics
Your Selling Point: Energy Efficiency

Or: how energy efficient does the machine/plant do what it was purchased for?

A super fast communication and control system alone does not provide good energy efficiency…..

… but is a pre-requisite for the energetic Optimization of the Processes.
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Your Selling Point: Functional Safety
Safety over EtherCAT Demo @ SPS/IPC/Drives

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Functional Safety network-network Communication

Beckhoff Controller

Beckhoff Safety Logic

Beckhoff + Baumüller Safety I/O

Beckhoff Safety Drive

Baumüller Safety Controller

Beckhoff + Baumüller Safety I/O

Baumüller Safety Drive

Functional Safety intra-network Communication
Decisive Factors: Functional Safety

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Example: Tire Testing System
Seichter: Tire Uniformity Tester

Johann Klassen, Seichter:

“EtherCAT makes the machine more streamlined, faster and more precise.

Thanks to EtherCAT, networking additional emergency stops can be installed at a later stage as required.”
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Decisive Factors: **Performance, Safety**

**Example: Material Handling**
C. Gunnarssons, Sweden, Board handling plant

- 130 Axis
- 1200 I/O Points
- 80 Safety over EtherCAT devices
Your Selling Point: Expandability

- Flexible tree structures – 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
**Expandability: Protection of your Investment**

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

- maximum system expandability with low cost fieldbus gateways
Decisive Factors: **Fieldbus Integration, Topology**

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**Example: Logistics**
Constructor Finland Oy, Finland, Automated Warehousing

EtherCAT I/O with EtherCAT/DeviceNet Gateway and DeviceNet Inverters
Decisive Factors: **Fieldbus Integration**, Performance

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**Example: Robotics**
DLR, Germany: Rollin Justin
Your Selling Point: **Ease of Integration**
Consistant Solution from the MES to the Sensor

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

EtherCAT is:
Your Selling Point: **Ease of Integration**

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- Interface to any Ethernet Device or Network
- Ethernet Frames are inserted into EtherCAT Protocol:
  - ‘Ethernet over EtherCAT’
Your Selling Point:
Worldwide Acceptance + Support

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Decisive Factors: **Worldwide Availability**

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**Example: Plastics Industry**

Sumitomo Demag, Germany: IntElect Injection Molding Machine

Dr.-Ing. Etienne Nitidem, Sumitomo Demag:

*Due to the wide deployment of the technology at any time support for the development tasks by various service providers both in Germany and Japan was available. Besides the system features that were achieved, the development time line was met with the choice for EtherCAT.*
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Selecting EtherCAT leads to competitive advantages with respect to:

- Quality – high Performance leads to high Precision
- Throughput, Efficiency – Benefits also for sequential Tasks
- Price – due to large Supplier Variety and low Costs
- Availability – Diagnosis Features, Remote Maintenance, High Availability Options
- Safety – Safety over EtherCAT-Devices are available
- Expandability – due to flexible Topology and Fieldbus-Gateways
- Ease of Integration – EtherCAT is Industrial Ethernet
- World Wide Support – EtherCAT is accepted globally