

Industrial Ethernet Designs with MCUs- a Hands on Introduction

Class 3: Industrial Ethernet Applications

12/13/2017

Warren Miller

This Week's Agenda

- 12/11/17 An Overview of Ethernet
- 12/12/17 An Introduction to Industrial Ethernet
- 12/13/17 Industrial Ethernet Applications
- 12/14/17 Industrial Ethernet Implementations
- 12/15/17 Industrial Ethernet- an example

Course Description

- Industrial Ethernet is still a key communication technology for factory control.
- It is built on the long legacy of Ethernet, but adds significant capabilities for increasing robustness and reliability.
- This course will provide an overview of the key differences between our familiar Ethernet protocol and the Industrial version.
- A hands on example will use easily available software and development boards to dig into some of the key details of an actual Industrial Ethernet implementation. Students can optionally obtain the hardware and software to follow along with the implementation.

Today's Topics

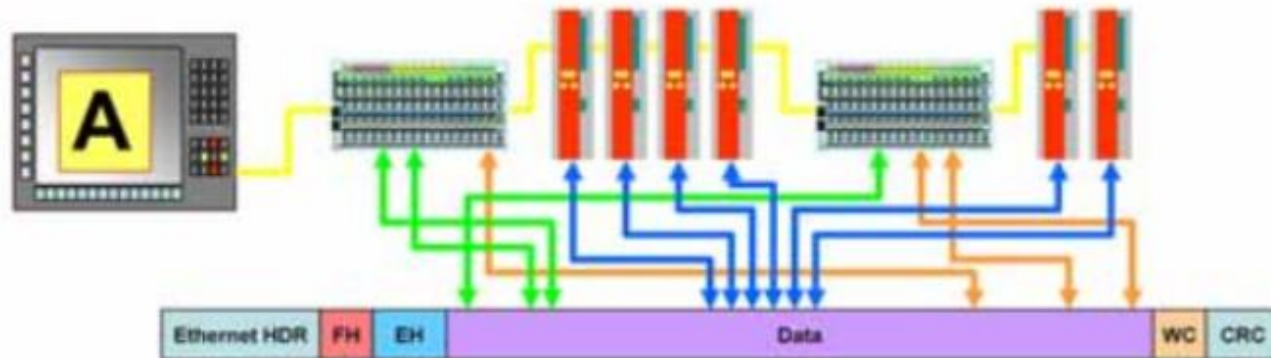
Industrial Ethernet is implemented in several different ways depending on the end application. This class will dig into one example, EtherCAT, in significant detail to illustrate how various end applications are served.

- EtherCAT in detail
- Comparisons with other implementations
- To find out more...

EtherCAT Overview

- EtherCAT is:
 - Industrial Ethernet down to the I/O Level
 - Flexible Wiring and simple Configuration
 - lower cost
 - well proven
 - an open technology
- Key Principle: Frame Processing on the Fly
- Master uses Standard Ethernet Controllers

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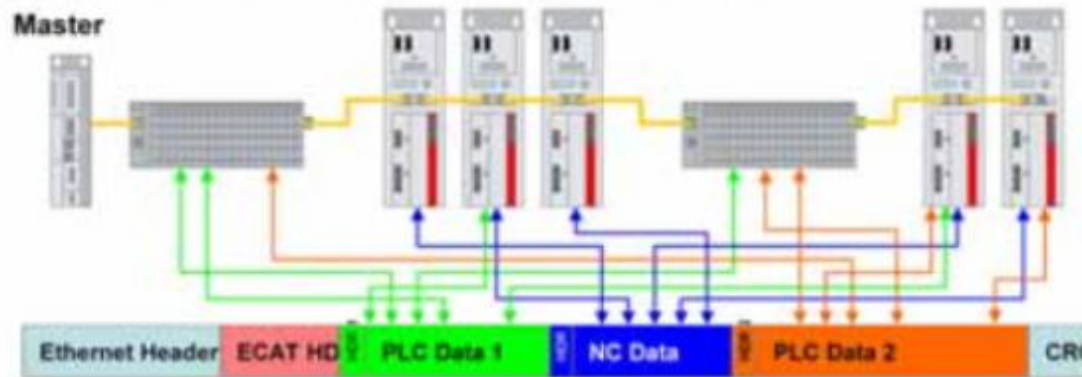


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EtherCAT: Ethernet On The Fly

Minimal protocol overhead via implicit addressing



- Optimized telegram structure for decentralized I/O
- Communication completely in hardware: maximum performance
- no switches needed if only EtherCAT devices in the network
- Outstanding diagnostic features
- Ethernet-compatibility maintained

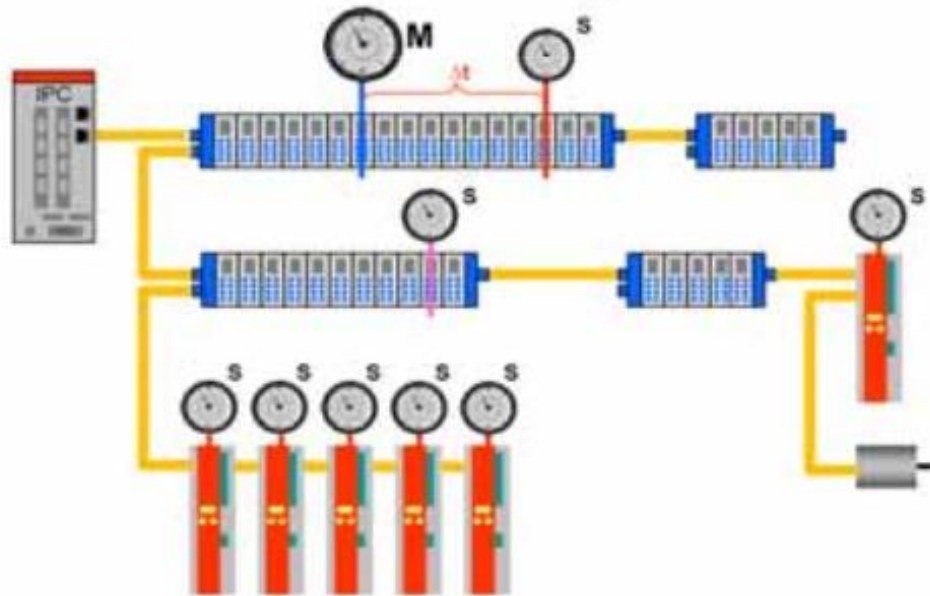
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EtherCAT Synchronization

Precise Synchronization ($\ll 1 \mu\text{s}$!) by exact adjustment of distributed clocks.

Advantage: Accuracy does not depend on master precision, small communication jitter and thus implementation in software only is acceptable and does not deteriorate synchronization

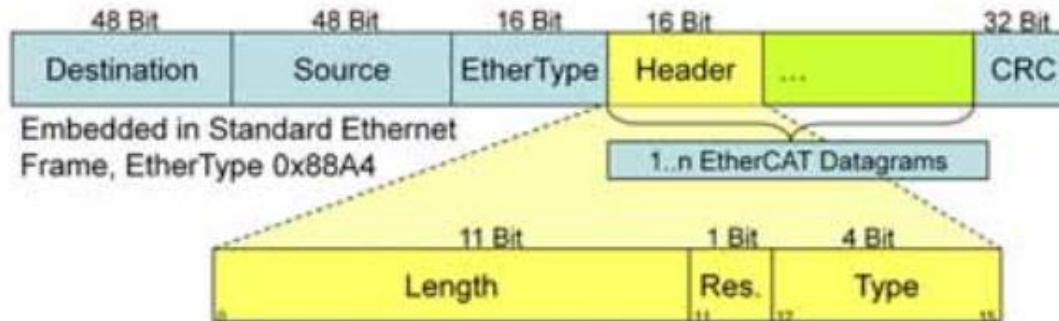


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EtherCAT Uses Ethernet Frames

- EtherCAT: only Standard Ethernet Frames (IEEE 802.3)
- Master: Ethernet MAC without co-processor or special HW
- Fully transparent for other Ethernet protocols
- Internet Technologies (TCP/IP, FTP, Web server etc.) without restricting the real time capabilities, even with 100µs cycle time – no large time gaps for rare traffic needed
- Full Tool-Access to devices at real time operation – with and without TCP/IP

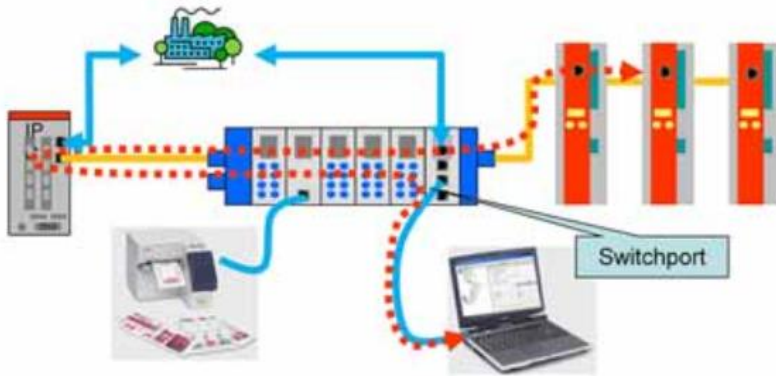


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Industrial Ethernet Technologies

EtherCAT: Connectivity

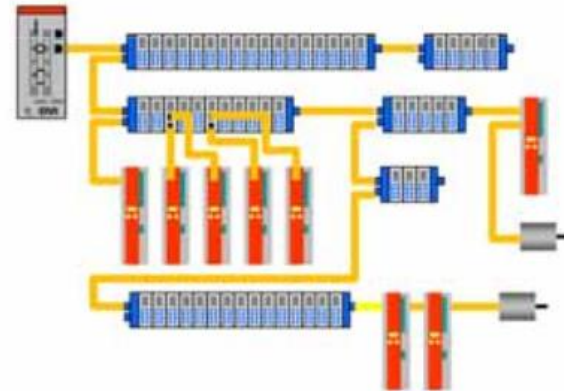
- Connection to any Ethernet device via Switchport
- Access to web server with standard browser
- Switchport can be implemented as device feature, separate device or software functionality in master
- Switchport allows for hard real time capability with parallel Ethernet communication of any kind



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- Flexible tree structures – arbitrarily extendable
- Line without limitations through cascaded switches or hubs
- 100 m between two nodes, up to 65535 nodes in one segment
- branches can be connected/removed at run time ("Hot Connect")
- Straight or crossed cables – automatic detection

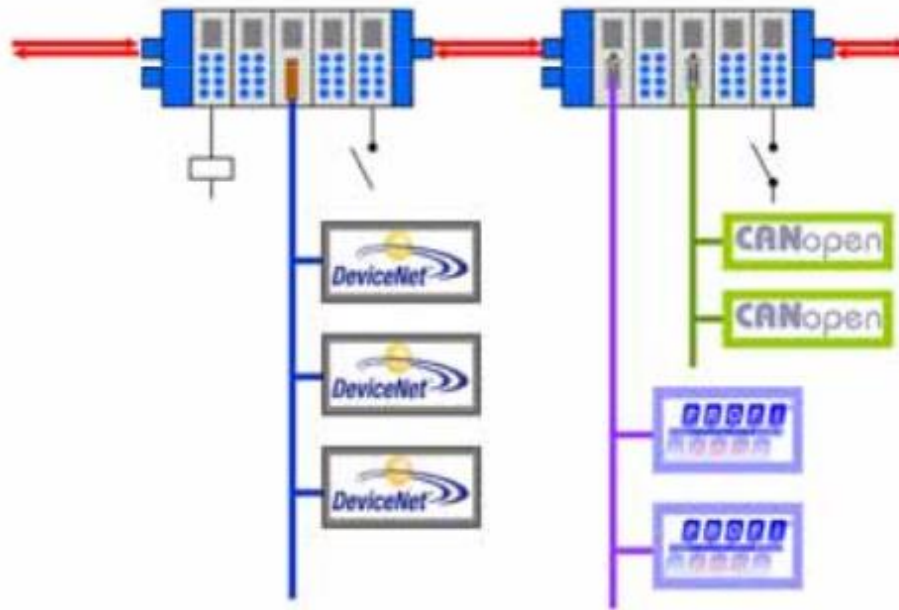


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EtherCAT: Gateways

- EtherCAT Performance allows for: EtherCAT instead of PCI
- no card slots required any more
- maximum system expandability with low cost fieldbus gateways
- seamless integration of fieldbus devices protects your investment
- smooth migration path from fieldbus to EtherCAT



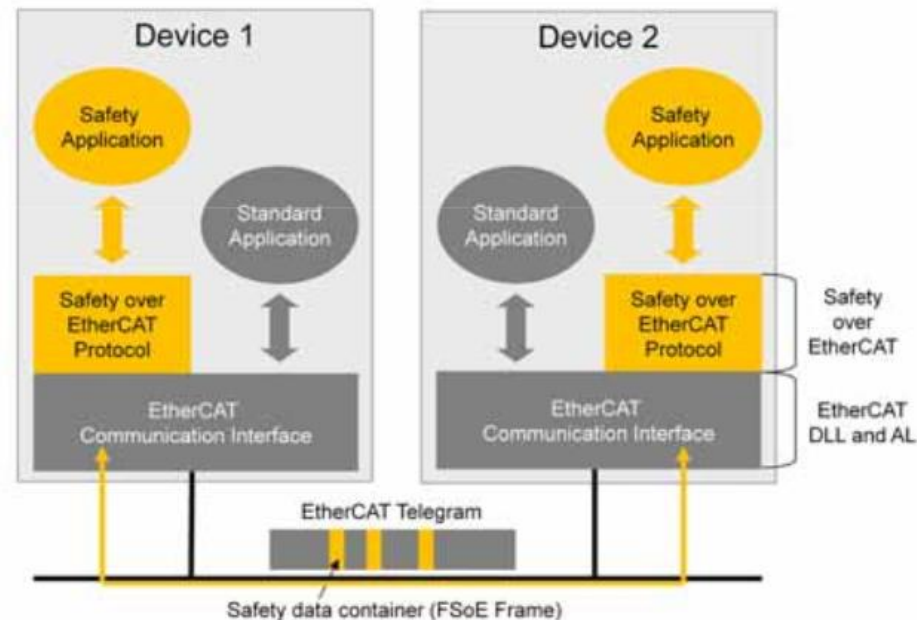
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EtherCAT: Safety

- Safety over EtherCAT is approved by TÜV
- The protocol meets Safety Integrated Level SIL 3 according to IEC 61508
- The protocol is international standard IEC 61784-3-12
- Safety over EtherCAT consequently supports a small and lean implementation
 - Suitable for functional safety I/O as well as for functional safety motion control
- The protocol is open for any communication system
 - not limited to EtherCAT
 - Routing via unsafe gateways, fieldbuses or backbones is possible, even wireless
- Safe Parameter Download at boot-up guarantees most simple device replacement
- Safety devices are available since 2005

- Black channel approach with safety and non-safety data on the same bus



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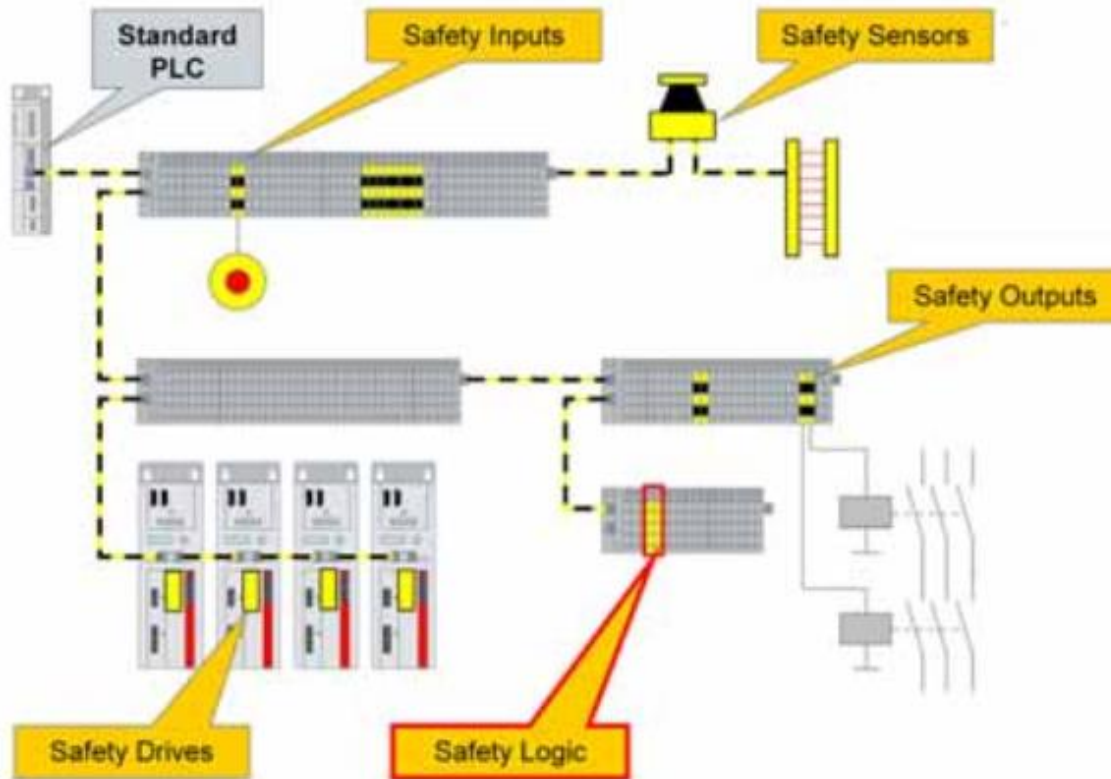
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EtherCAT: Safety Example

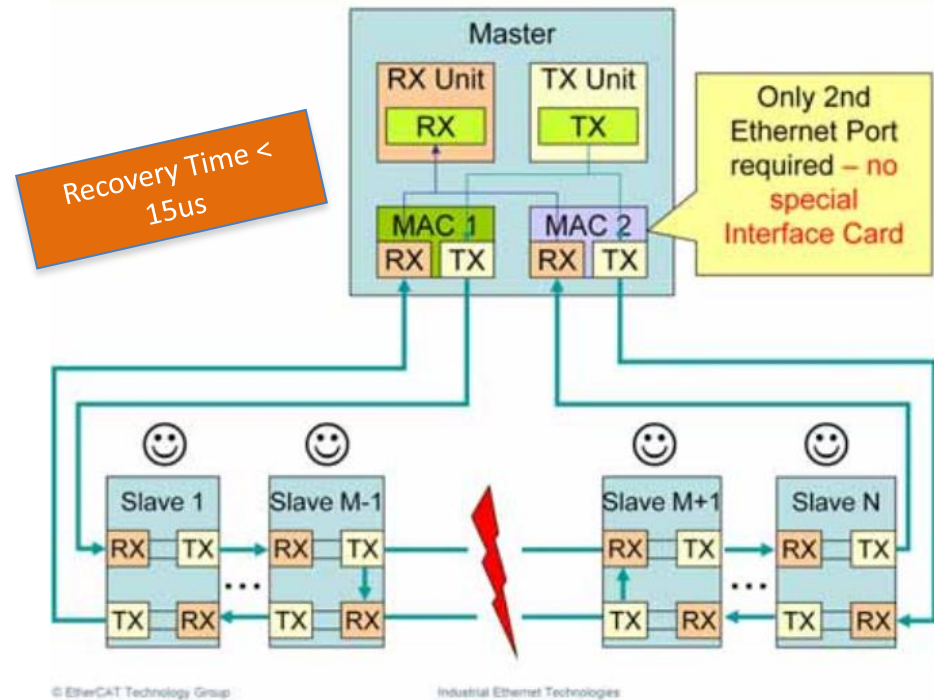
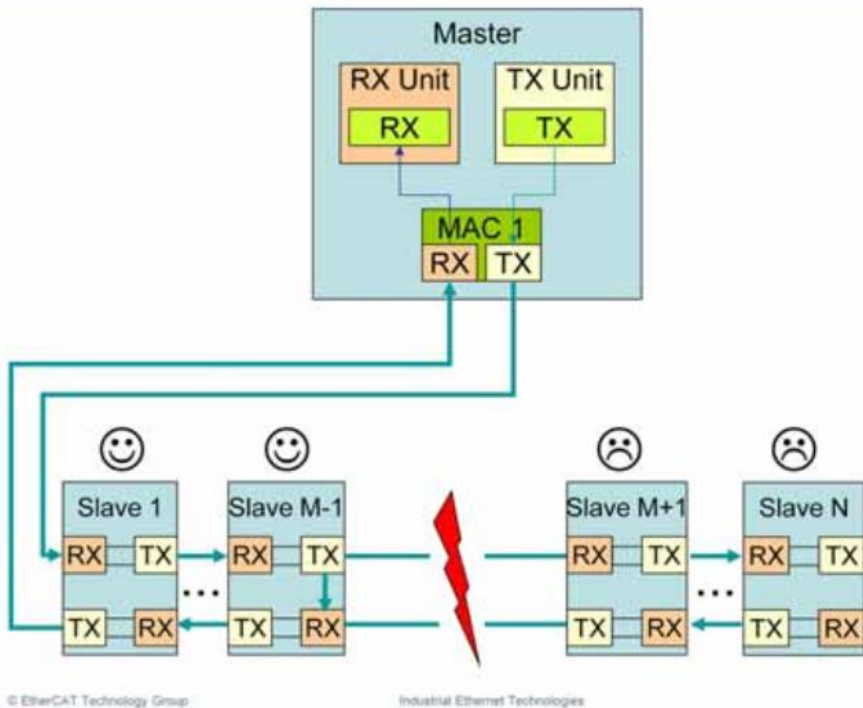
- Decentralized Safety-Logic
- Standard PLC routes the safety messages



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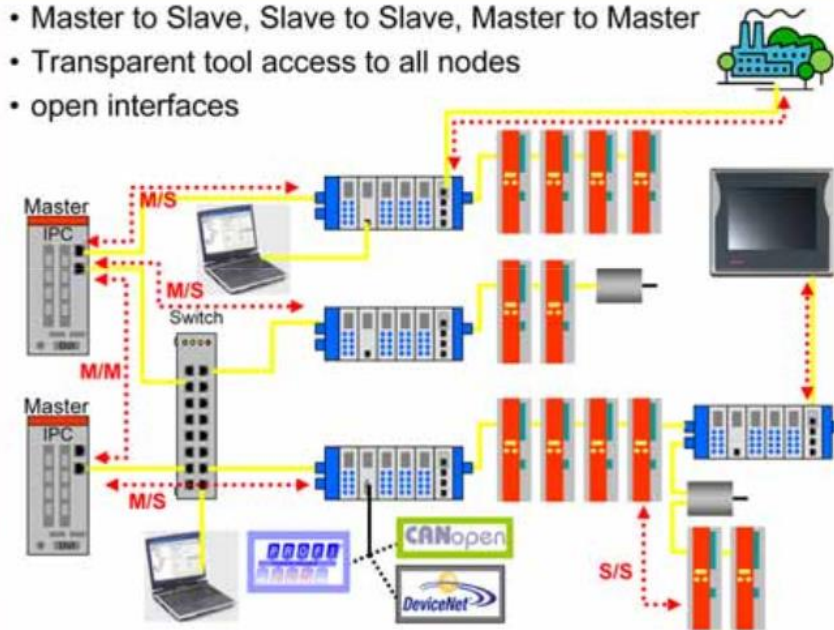
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EtherCAT: Redundancy



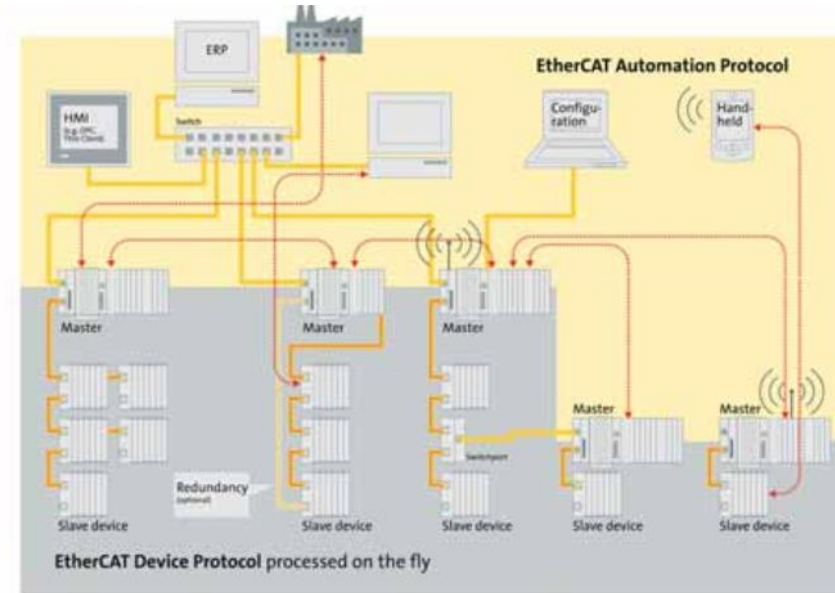
EtherCAT: Implementations

- Master to Slave, Slave to Slave, Master to Master
- Transparent tool access to all nodes
- open interfaces



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EtherCAT: Summary

- EtherCAT provides:
 - Superior Performance
 - Line, Ring, Tree, Drop Line, Star Topology
 - Master/Slave, Master/Master and Slave/Slave communication
 - Integrated Functional Safety: Safety over EtherCAT
 - TCP/IP without cycle time limitations
 - Simple configuration – no manual address setting
 - Comprehensive diagnosis functionality
 - Redundancy
 - Support of CANopen* and SERCOS* Drive Profiles
- EtherCAT is:
 - Open technology, worldwide supported, IEC standard
 - Low cost and simple to implement



- Classification
- PROFINET
- EtherNet/IP
- CC-Link IE
- Sercos III
- Powerlink
- Modbus/TCP
- **EtherCAT**
- Summary

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*CANopen is a trademark of CIA e.V.; SERCOS interface™ is a trademark of SI e.V.

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[https://www.ethercat.org/download/documents/Industrial Ethernet Technologies.pdf](https://www.ethercat.org/download/documents/Industrial_Ethernet_Technologies.pdf)

RTE Technology Comparisons



Performance	Modbus /TCP	Ethernet /IP	ProfiNet RT	Power-link	ProfiNet IRT	CC-Link IE	Sercos III	EtherCAT
Cycle Time	--	--	-	○	+	○	+	++
Synchronicity	--	-- + (CIP sync)	--	- ○ (with special interface hw)	+	+	+	++
Throughput of IP Data	++	++	++	○ (half duplex)	+	--	-	○

Topology + Wiring	Modbus /TCP	Ethernet /IP	ProfiNet RT	Power-link	ProfiNet IRT	CC-Link IE	Sercos III	EtherCAT
Topology Flexibility	--	-	-	+	+	-- (Control) + (Field)	-	++
Line Structure	--	-	-	○ (10)	○ (~25)	-- (Control) + (Field)	+ (511)	++ (65535)
COTS Infrastructure Components (Switch, Router, Connector etc.)	++	+	○	○ (no Switch)	--	-- (Control) + (Field)	-	+

Features	Modbus /TCP	Ethernet /IP	ProfiNet RT	Power-link	ProfiNet IRT	CC-Link IE	Sercos III	EtherCAT
Slave to Slave Communication	✓	✓	✓	✓	✓	✓	✓	✓
TCP/IP & other Internet Technologies supported	✓	✓	✓	✓	✓	-/✓	✓	✓
Cable Redundancy	(switches with spanning tree)	✓	✓	✓	✓	✓	✓	✓
Safety	-	✓	✓	✓	✓	✓	✓	✓

➤ Classification

➤ PROFINET

➤ EtherNet/IP

➤ CC-Link IE

➤ Sercos III

➤ Powerlink

➤ Modbus/TCP

➤ EtherCAT

➤ Summary

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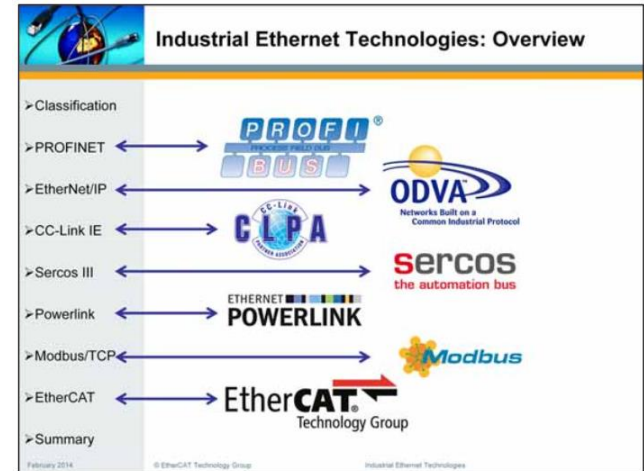
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Conclusion

EtherCAT Features

EtherCAT Implementations

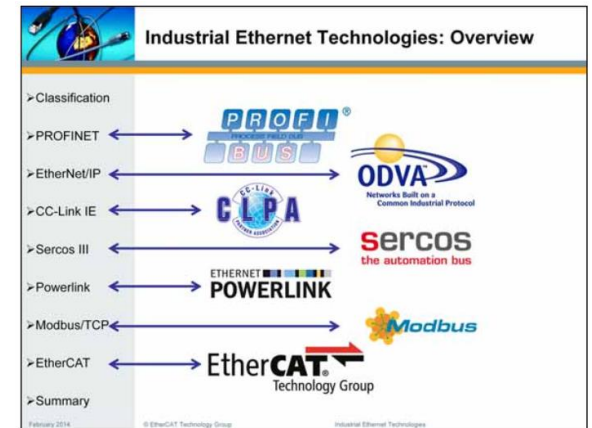
EtherCAT Comparisons



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Cycle Time	--	--	-	○	+	○	+	++
Synchronicity	--	+	--	-	+	+	+	++
Throughput of IP Data	++	++	++	○	+	--	-	○

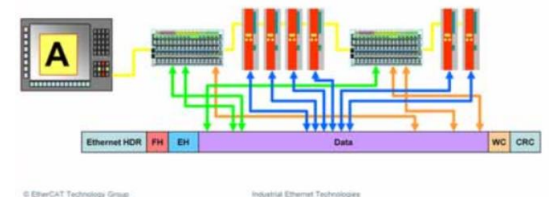
Class Resources

- Industrial Ethernet Overview- TI
- <http://www.ti.com/lit/wp/spry254/spry254.pdf>
- Video of Industrial IoT Presentation- Renesas
- https://www.youtube.com/watch?v=gphJtw0pluo&list=PLgUXqPkOStPum60jqifNt7IDY9_0a0_rX&index=14
- Technology Overview- EtherCAT Org
- [https://www.ethercat.org/download/documents/Industrial Ethernet Technologies.pdf](https://www.ethercat.org/download/documents/Industrial_Ethernet_Technologies.pdf)



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- <http://www.ti.com/lit/wp/spry254/spry254.pdf>

Industrial Communications Kit

- <https://www.digikey.com/en/product-highlight/t/texas-instruments/industrial-communications-engine-using-tis-am3359>

EtherCAT Article

- <https://www.digikey.com/en/articles/techzone/2015/aug/mcus-and-ethercat-gear-up-for-the-industrial-internet-of-things>

Connectivity and Control Systems- TI

- https://dkc1.digikey.com/IE/en/TOD/Texas_Instruments/Connectivity-Control-Systems/Connectivity-Control-Systems.html

Embedded Ethernet- MicroChip

- <https://dkc1.digikey.com/IE/en/TOD/microchip/EmbeddedEthernet/EmbeddedEthernet.html>

- https://dkc1.digikey.com/IE/en/TOD/Microchip/Ethernet_Controller_Solution/Ethernet_Controller_Solution.html

Introduction to Industrial Ethernet

- http://www.bb-elec.com/Learning-Center/All-White-Papers/Ethernet/Introduction-to-Industrial-Ethernet/AnIntroductionToIndustrialEthernet-WP12B-R1_1112.pdf

Additional Resources

- <http://www.ti.com/lit/wp/spry254/spry254.pdf>
- https://www.ethercat.org/download/documents/Industrial_Ethernet_Technologies.pdf
- https://www.youtube.com/watch?v=gphJtw0pluo&list=PLgUXqPkOStPum60jqifNt7IDY9_0a0_rX&index=14

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