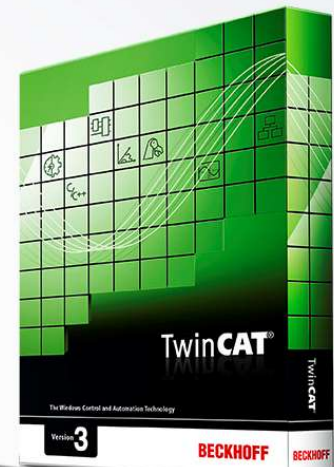
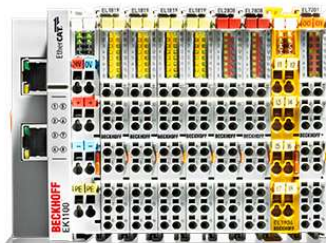


EtherCAT: Ethernet for Control Automation Technology **BECKHOFF**





1. Overview

2. Functioning Principles

3. Advantages

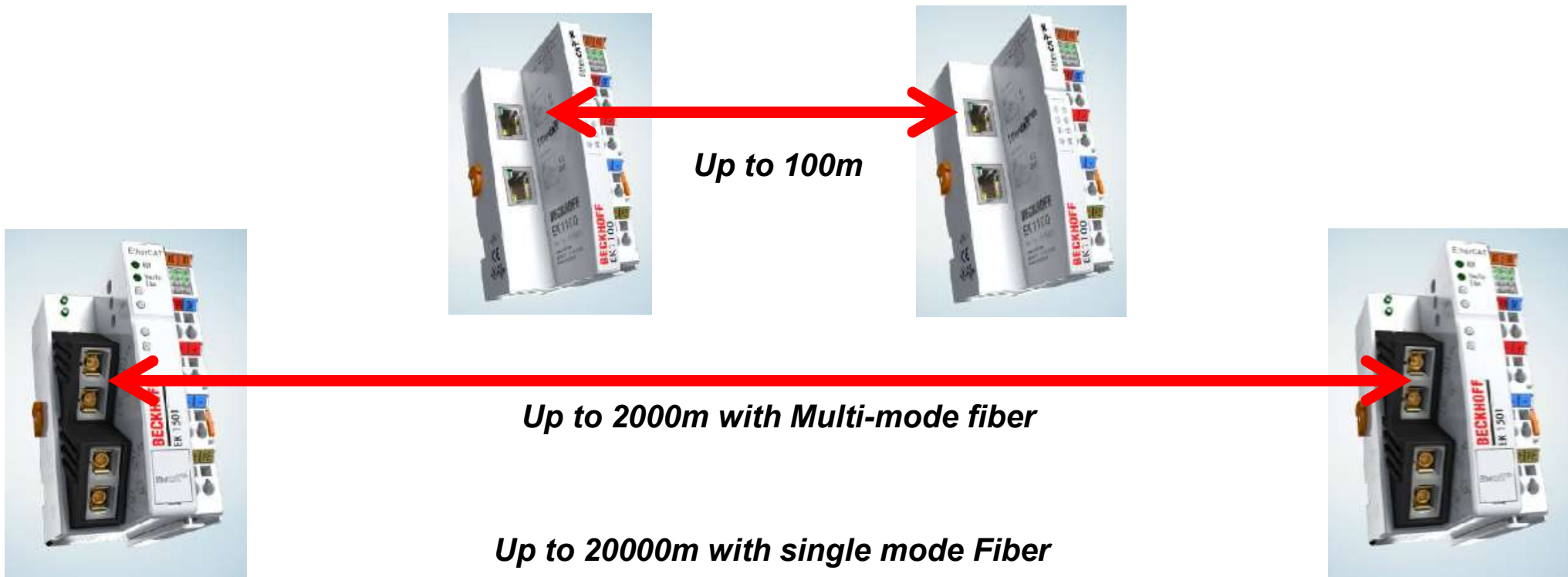
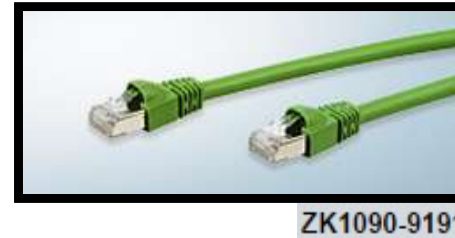
What is EtherCAT?



- EtherCAT is:
 - A Beckhoff invention from 2003
 - Managed by the Ether**CAT**[®] Technology Group
 - The fastest Industrial Ethernet based fieldbus
 - Real-Time, Deterministic, Synchronized Protocol
 - Popular
 - Largest number of members of all fieldbus organizations
 - Lots of products available

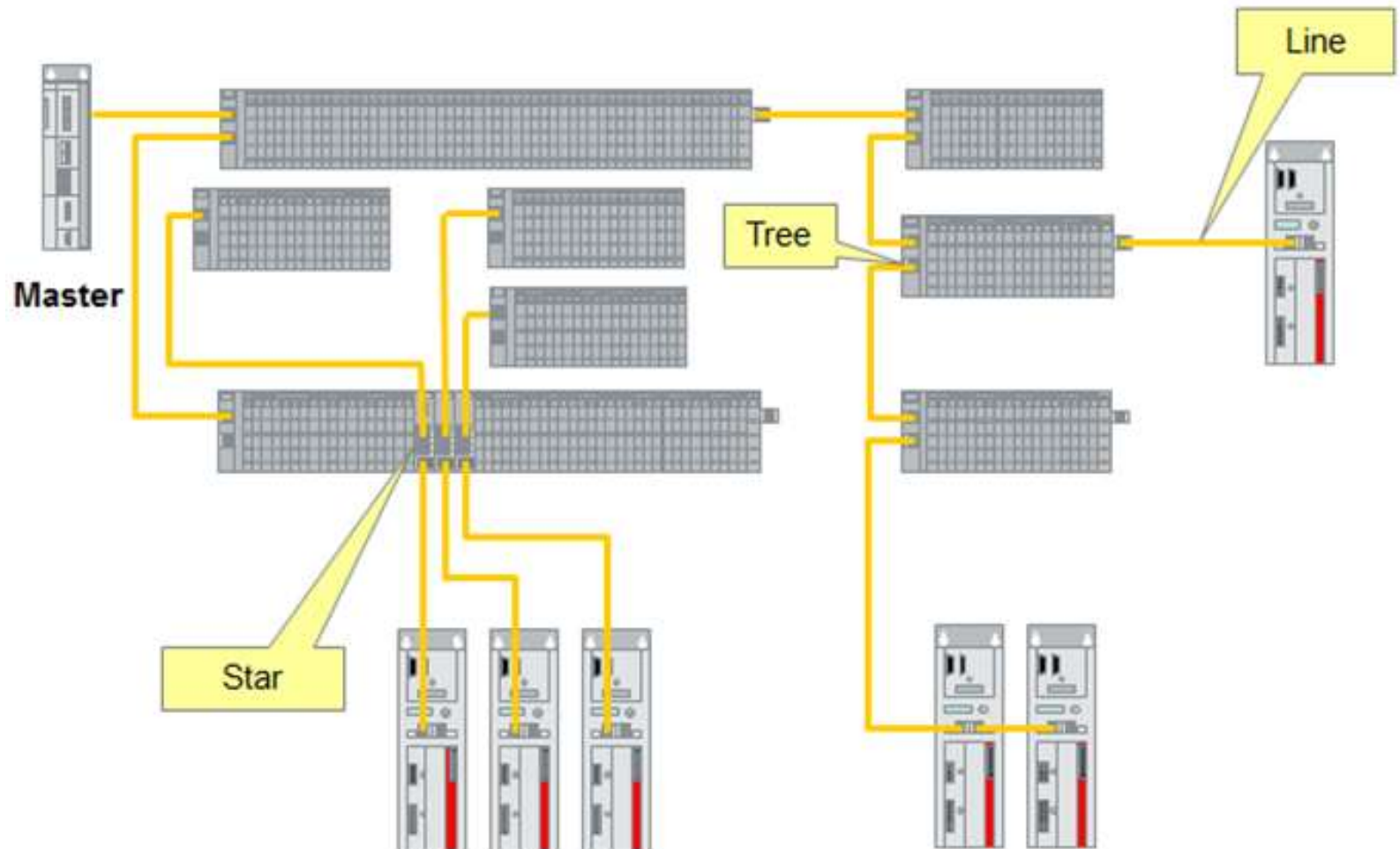
EtherCAT Basics: Wiring

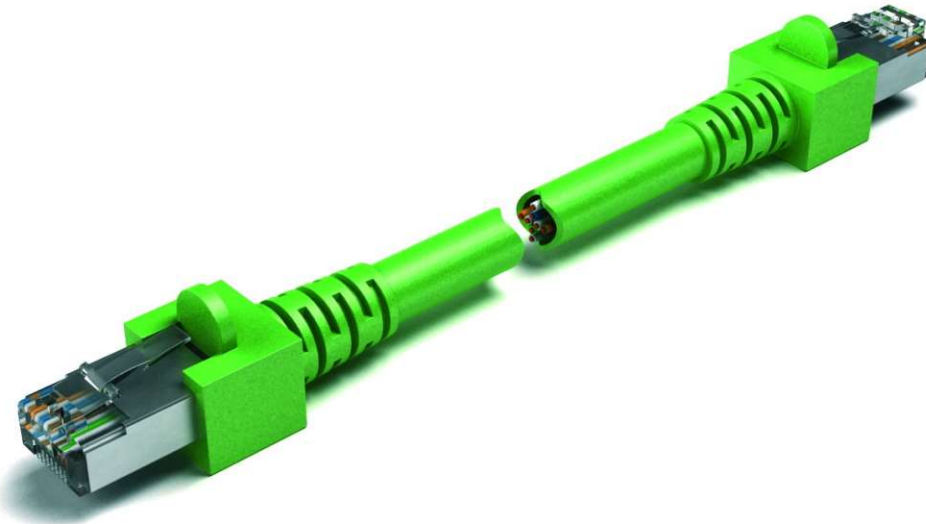
- Uses Standard Ethernet cable(CAT 5)
 - Fiber also available
- Node separation:
 - Ethernet Cable: 100m/300m
 - Fiber: 2 km/20km



- Single or Hybrid of Topologies Possible:

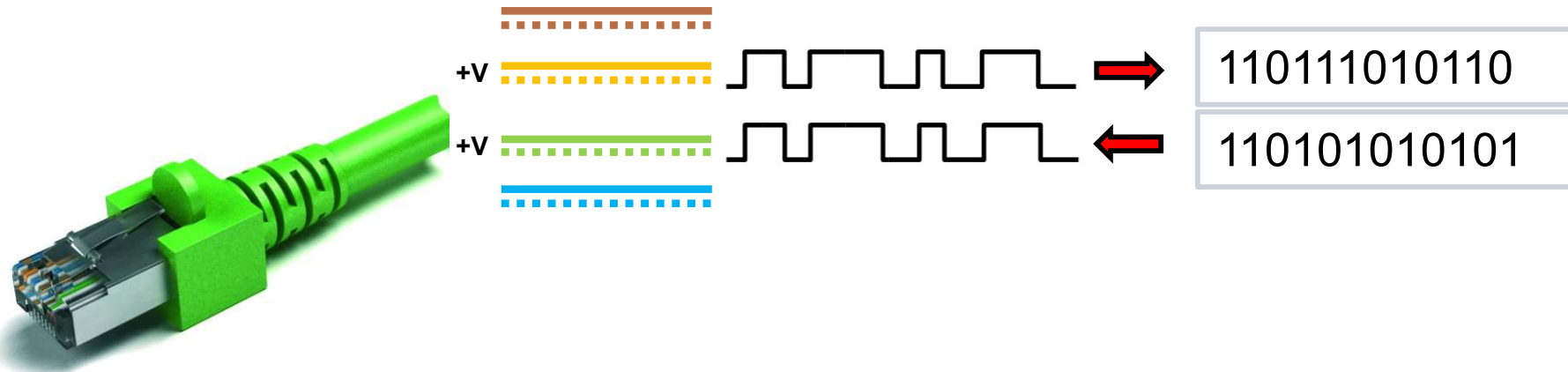
- Point-to-Point
- Ring
- Line
- Tree
- Star



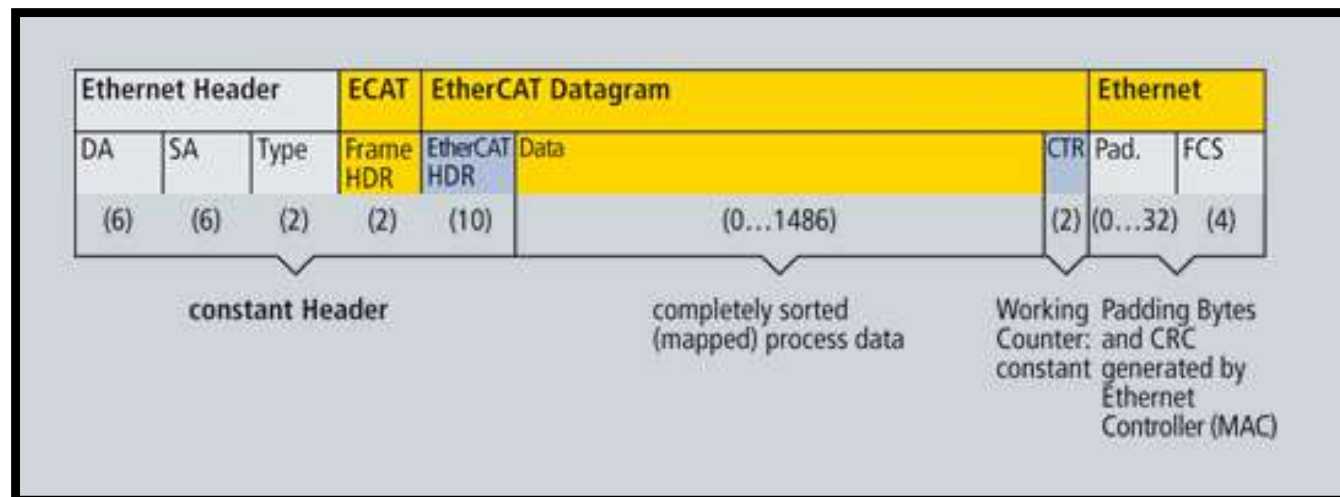


- Two twisted pairs are used for communication

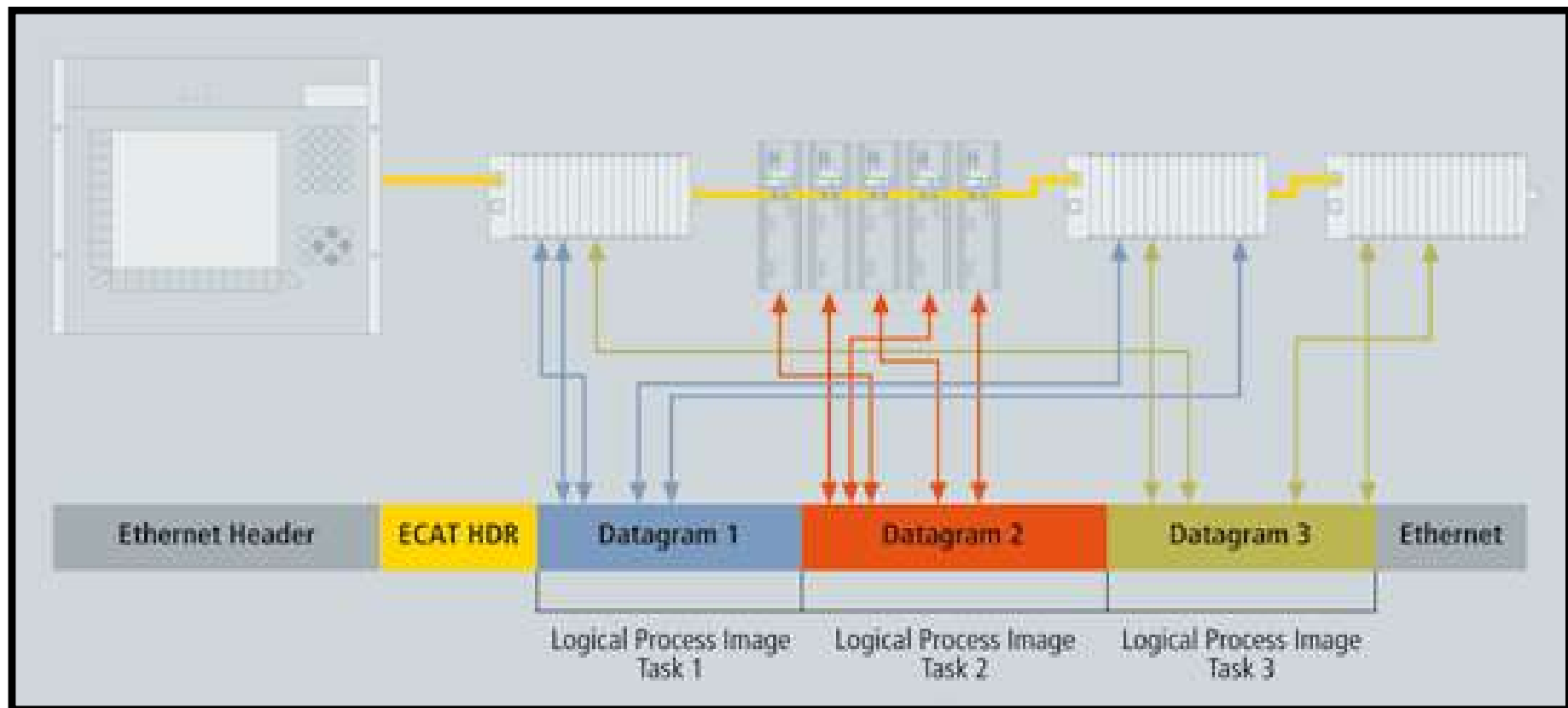




- EtherCAT uses the Ethernet frame structure to transfer data



- Hardware can be updated at different rates
- Hardware being updated at the same rate may be grouped into a datagram



Virtually Unlimited Slaves Possible

BECKHOFF

- Theoretical limit of 65,535
- Tested to 10,056
- Compare to:



– **Lightbus:** 254



– **Sercos 2:** 253



– **Profibus:** 126



– **CANopen:** 63



– **DeviceNet:** 63



EtherCAT Comparison

- Other fieldbuses use Ethernet as a base for communication



- Profinet (Profibus and Profinet International)



- EtherNET/IP (ODVA-Open DeviceNet Vendors Association)



- Modbus TCP (Modbus Organization)

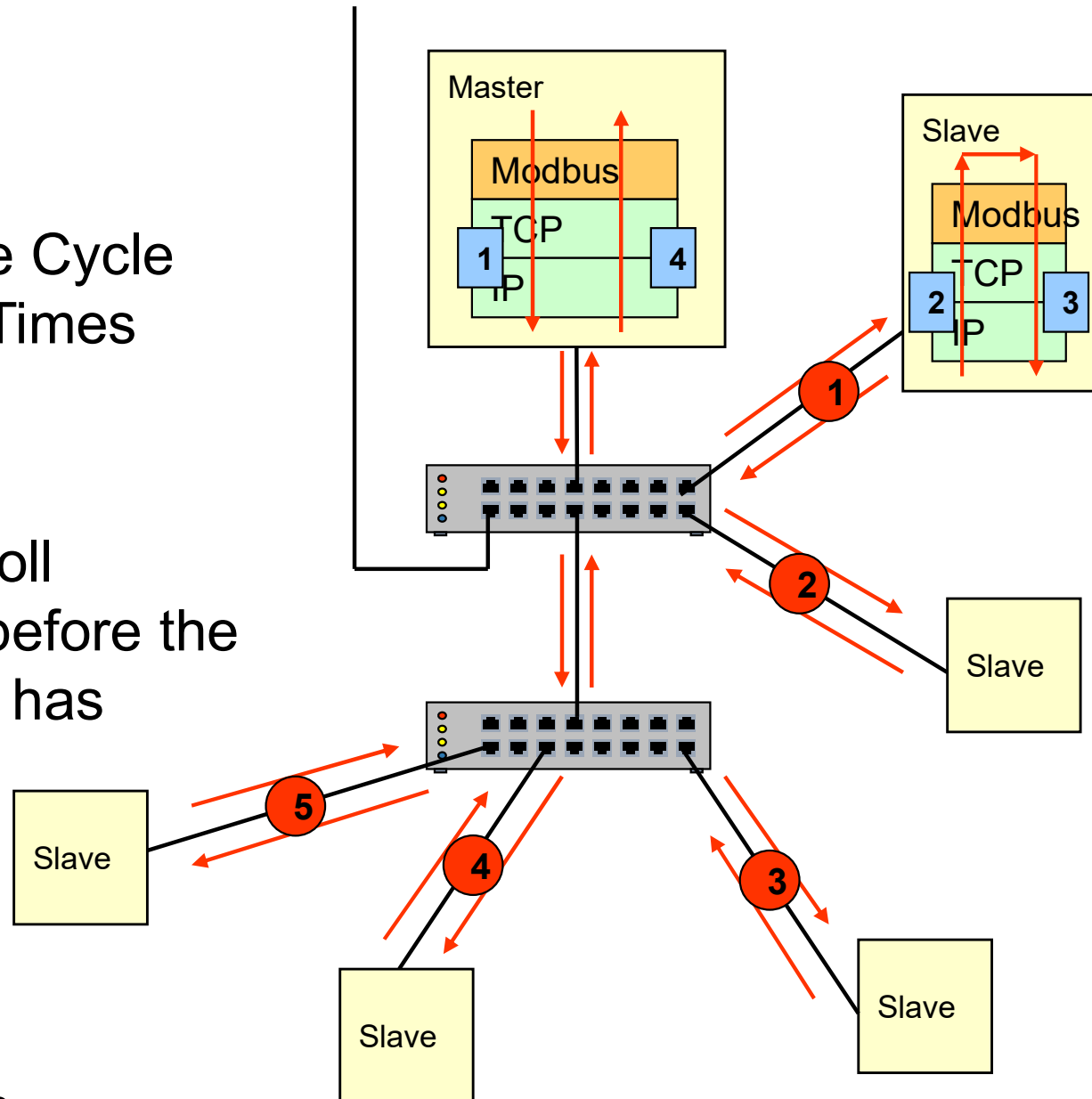


Standard Ethernet Functioning Principle

BECKHOFF

Modbus TCP Example

- Polling
- Each Request/Response Cycle passes TCP/IP Stack 4 Times
- Each Switch Delays Communication
- Depending on Master, Poll Request can be issued before the corresponding response has returned.
- Inefficiencies:
 - Switch Delays
 - Stack Delays
 - Bandwidth Utilization

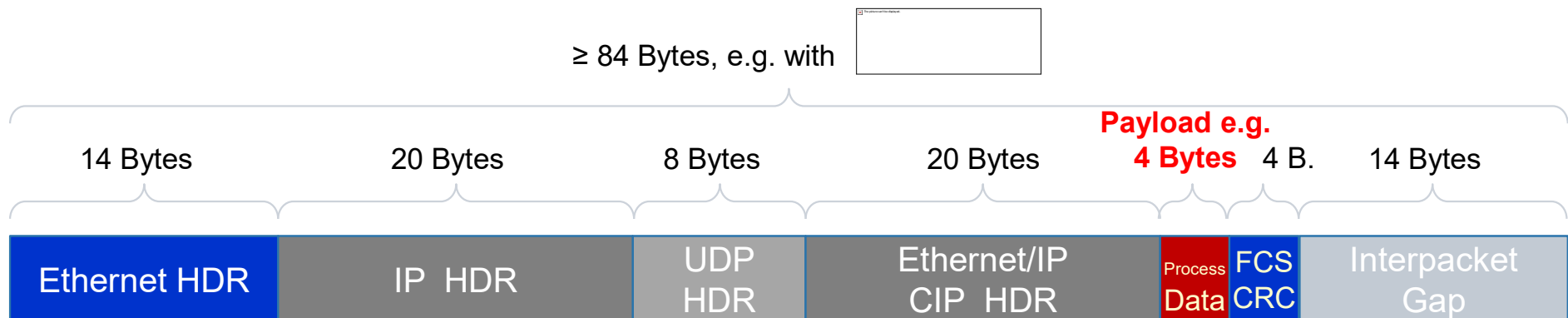
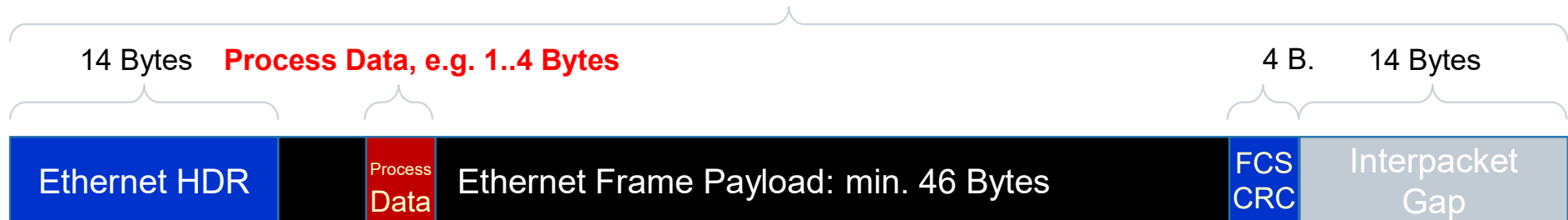


Minimum Ethernet Frame: 84 Bytes

Example: with 4 Bytes Process Data (32 I/O): $4/84 =$

4.75% Application Data Ratio

≥ 84 Bytes, regardless which Protocol



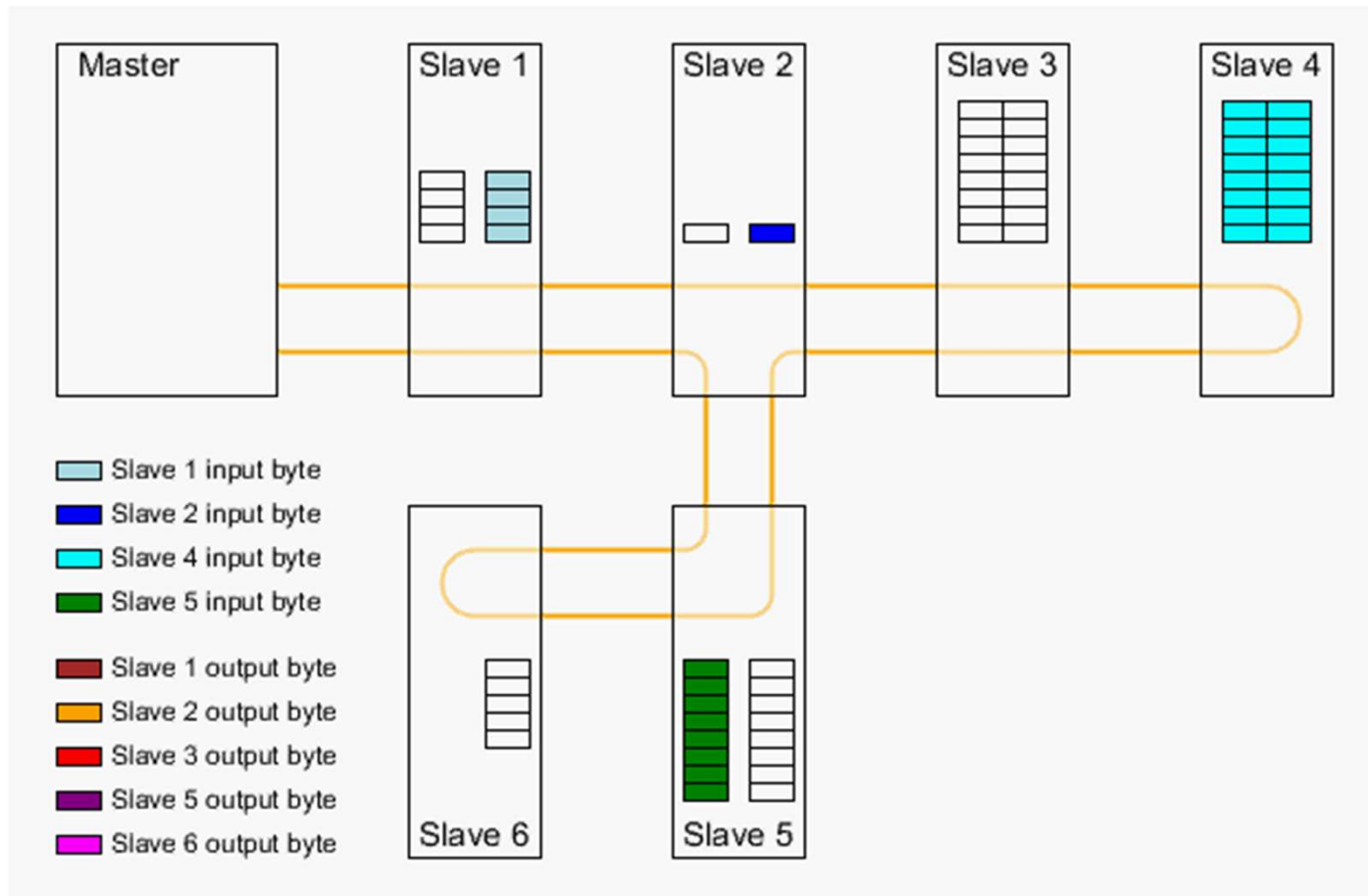
EtherCAT Improves on Standard Ethernet Inefficiencies **BECKHOFF**

- **Switch Delays: Data processing in switches**
 - No switches means no switch delays.
 - Message is not routed because everyone gets it and knows where their data lies.
 - 1 microsecond forwarding delay.
- **Stack Delays: Data processing in slave**
 - EtherCAT works down to the I/O level; data is handled in hardware directly.
 - Ethernet on the fly reduces stack delays.
- **Bandwidth Utilization: Sending a frame for each communication**
 - Only one frame is generated by the master per cycle and goes to each slave directly.
 - All data for whole network is on same frame.

1. Overview

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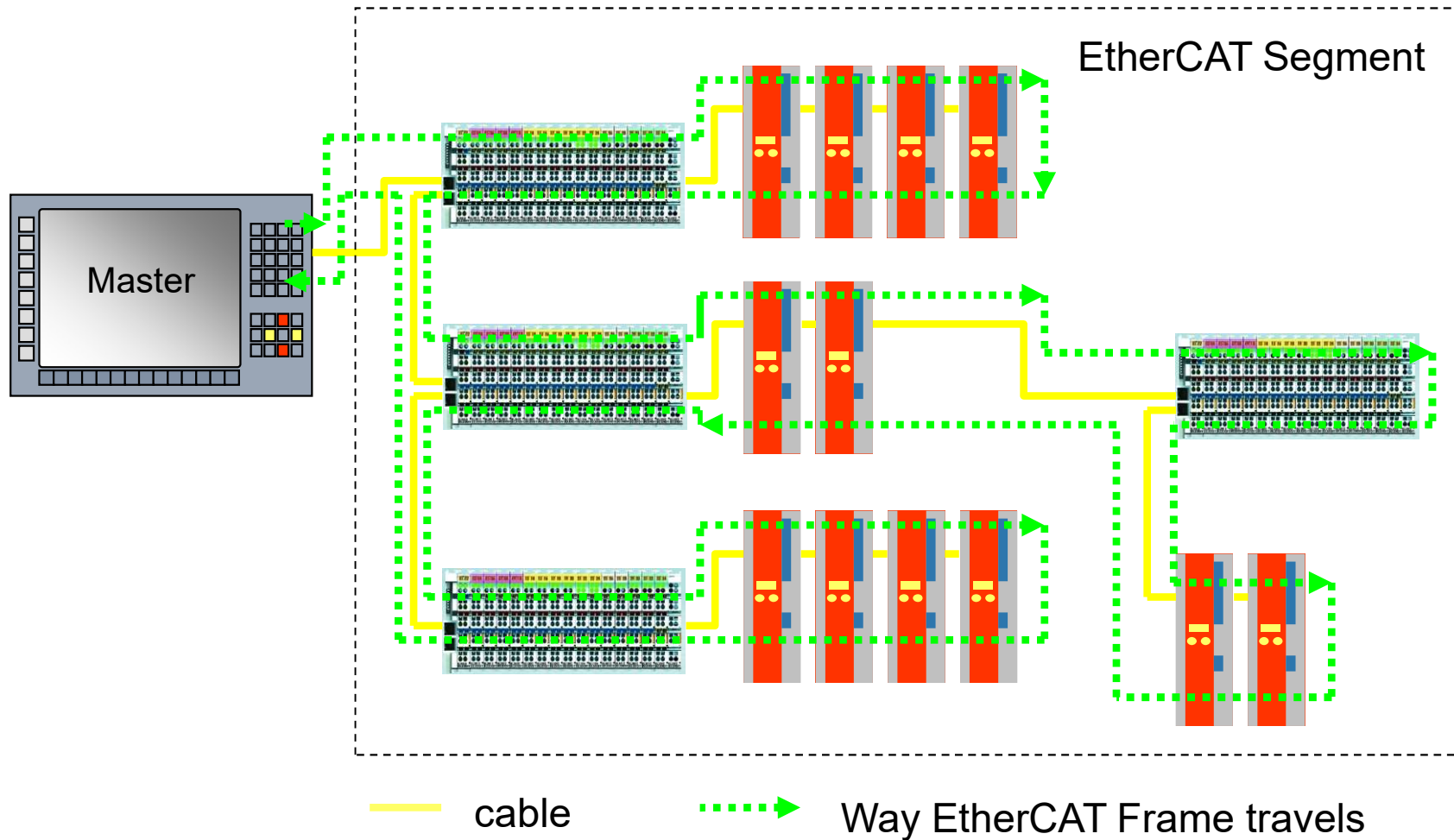
Improvements:

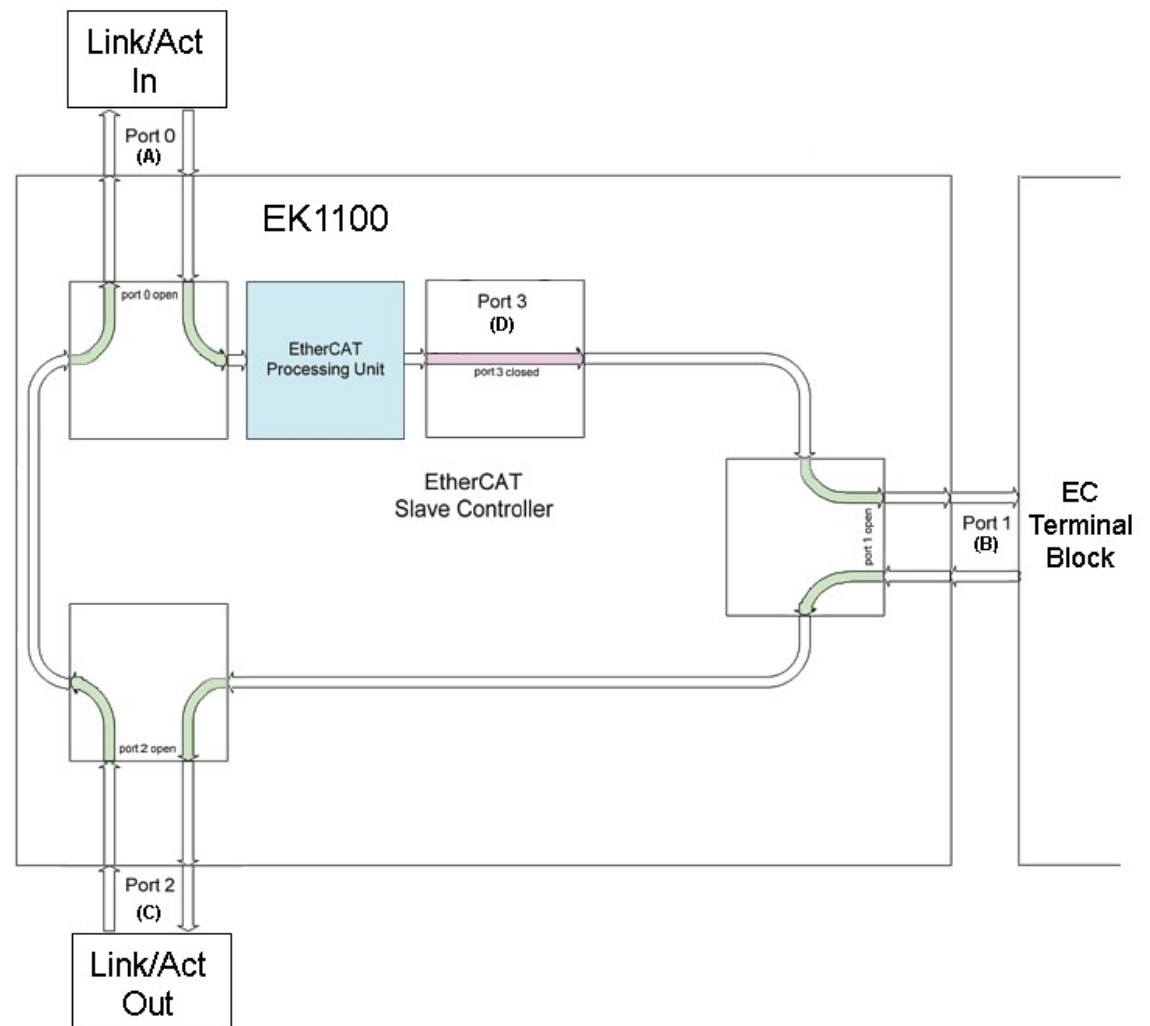
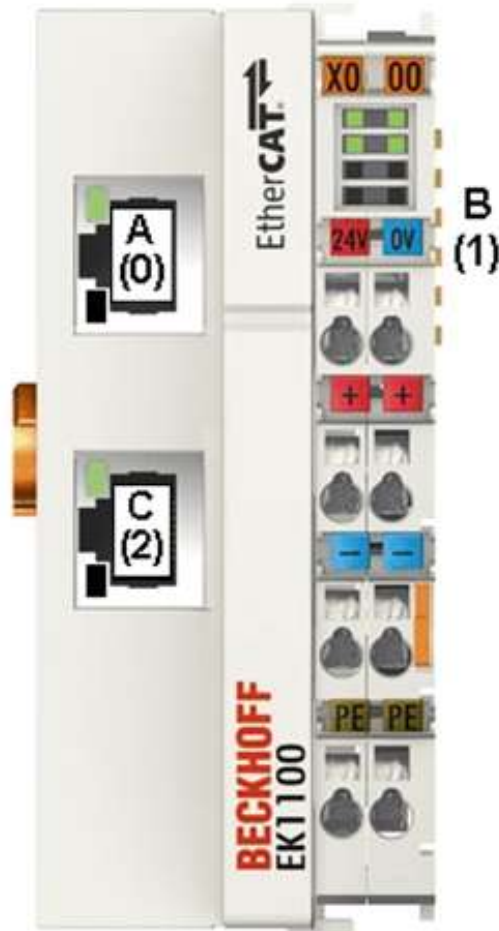
No switches

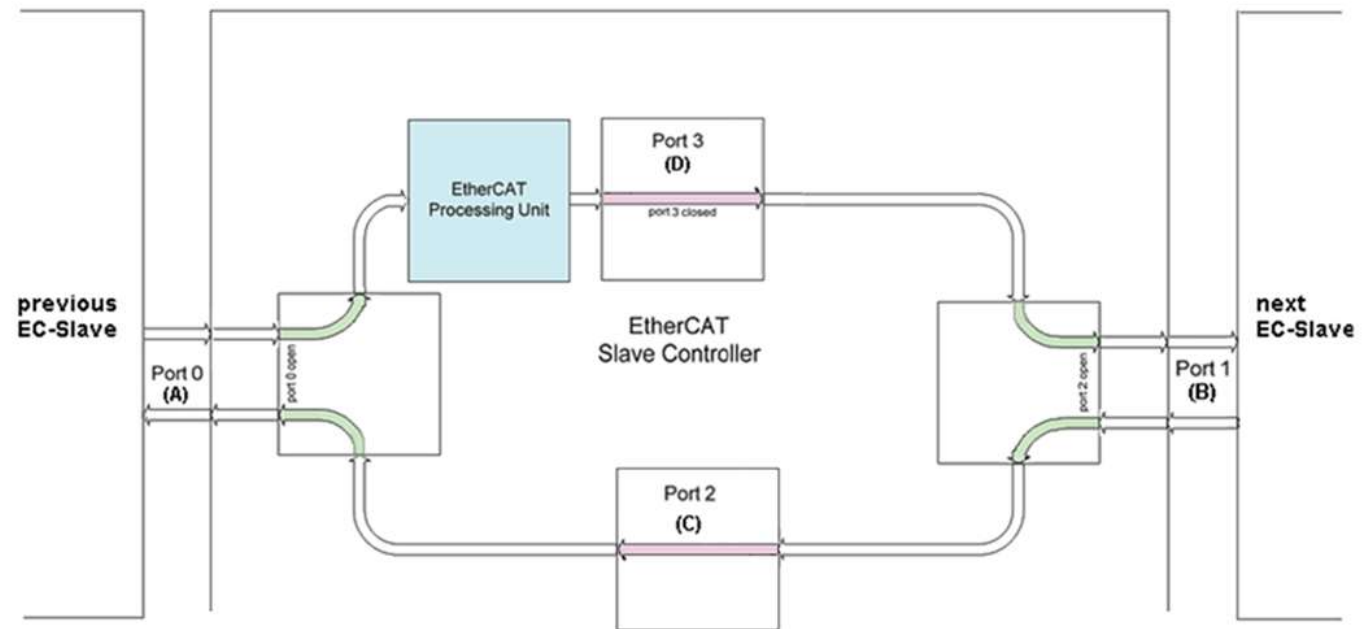
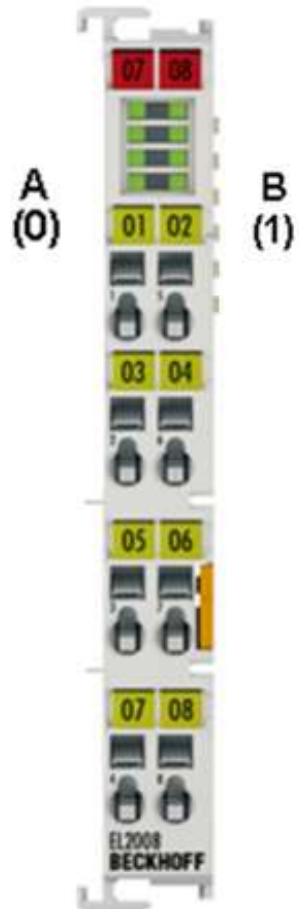
Single frame

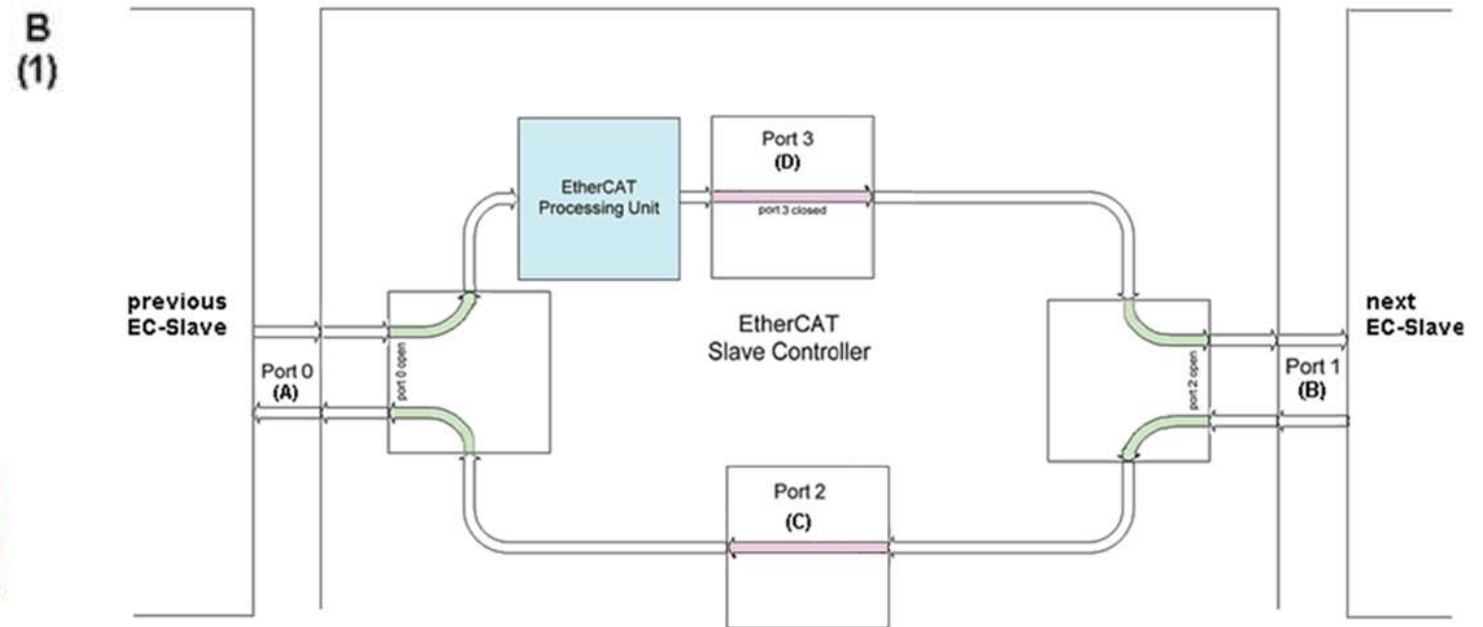
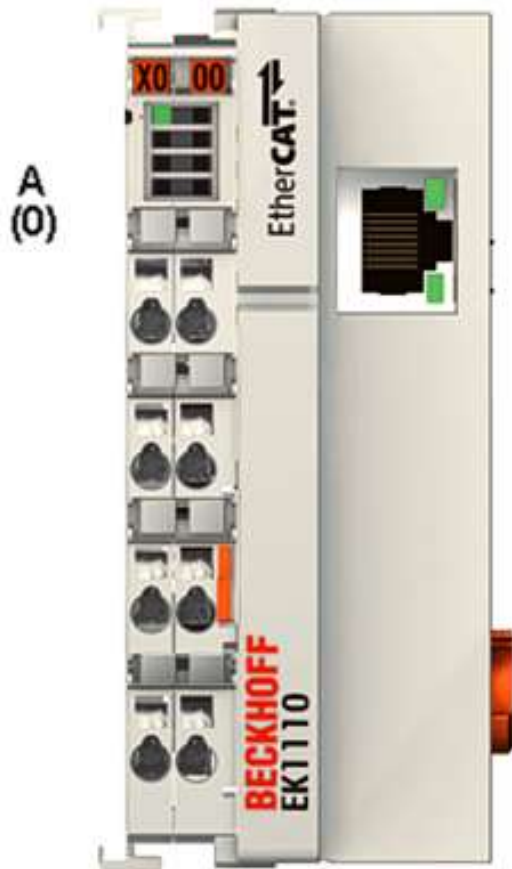
Data on the fly

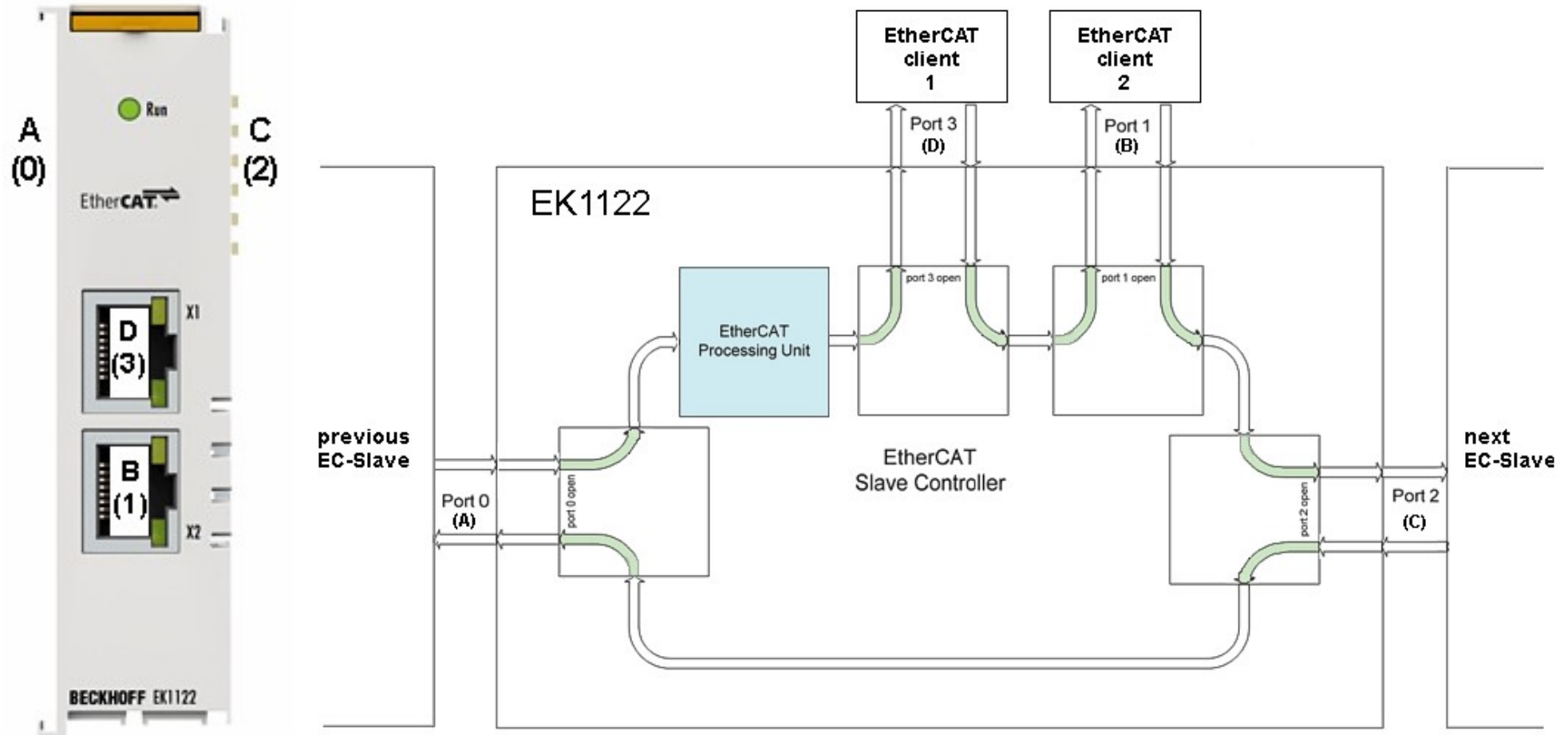
EtherCAT has Internal Ring Topology





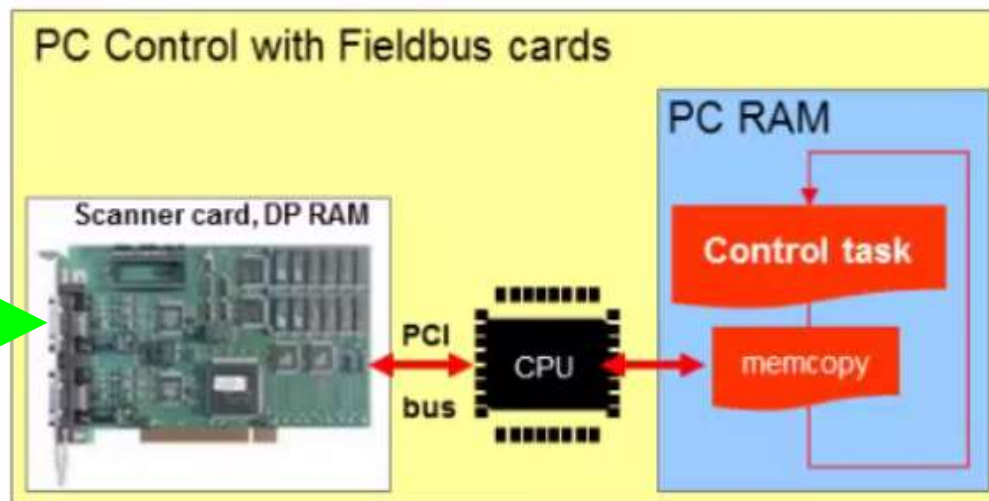




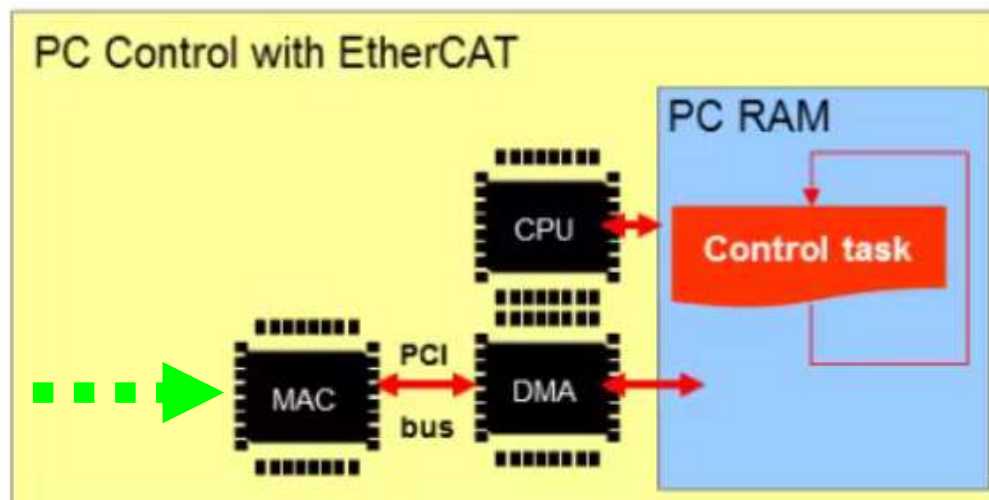
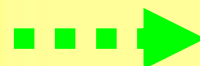


Speed Gained Using Direct Memory Addressing (DMA) BECKHOFF

- Fieldbus cards:
up to 30% of
CPU time for
data copying

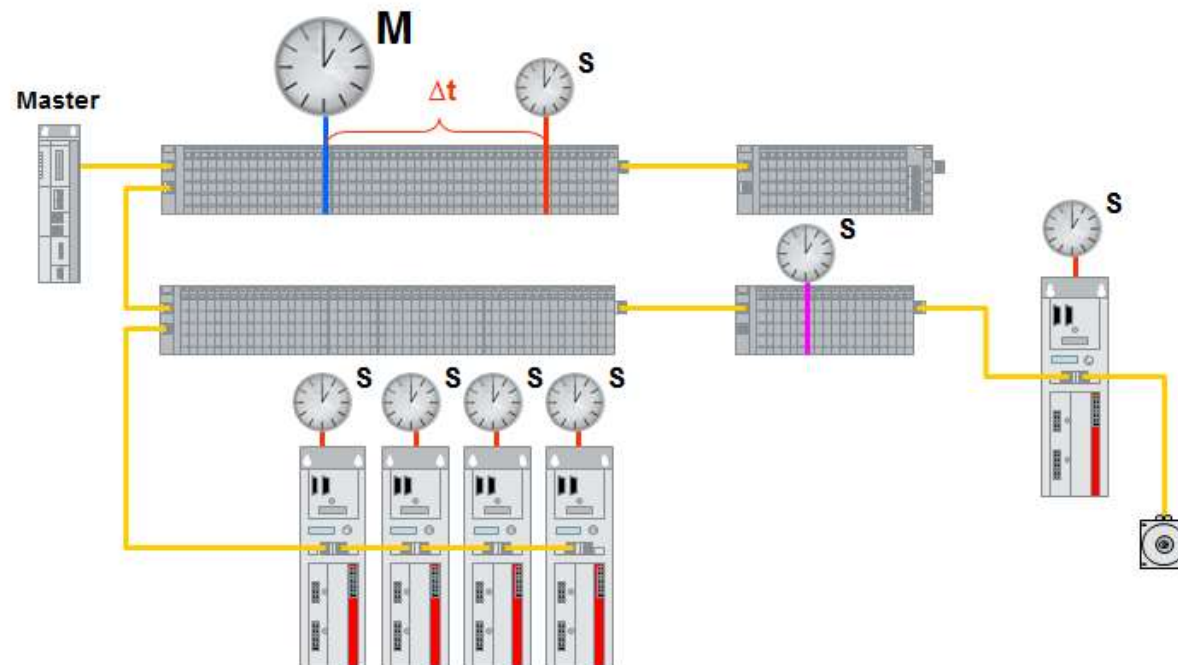


- EtherCAT:
MAC is PCI Bus
master, data is
provided by DMA
directly to PC RAM:
CPU relieved,
more performance

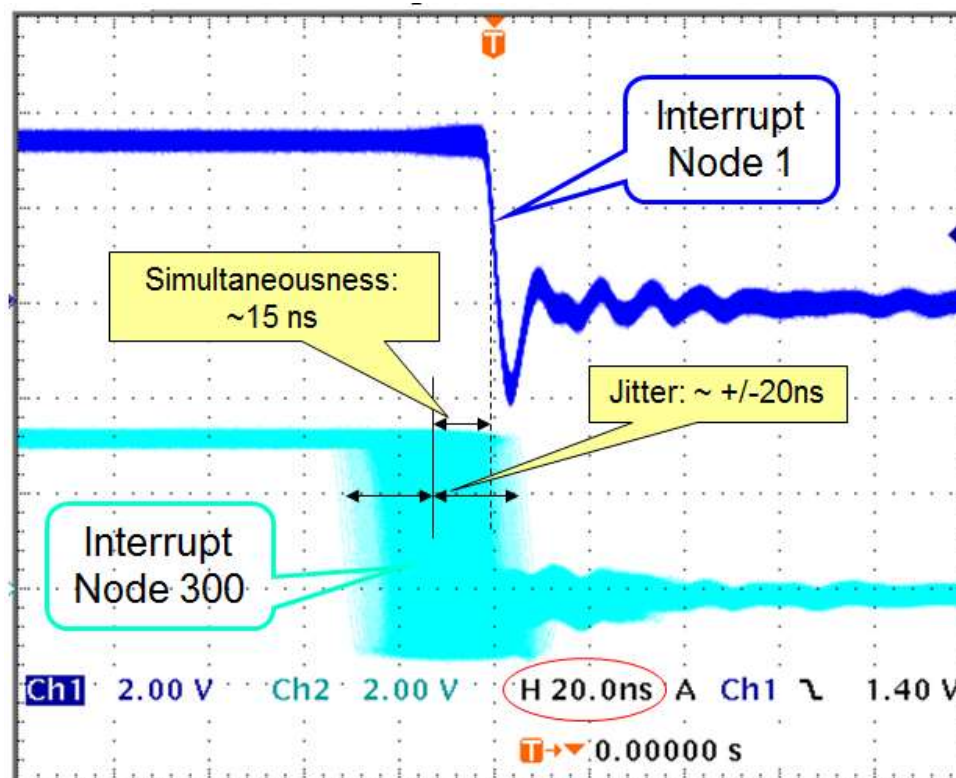


Distributed Clocks (DC) Functionality

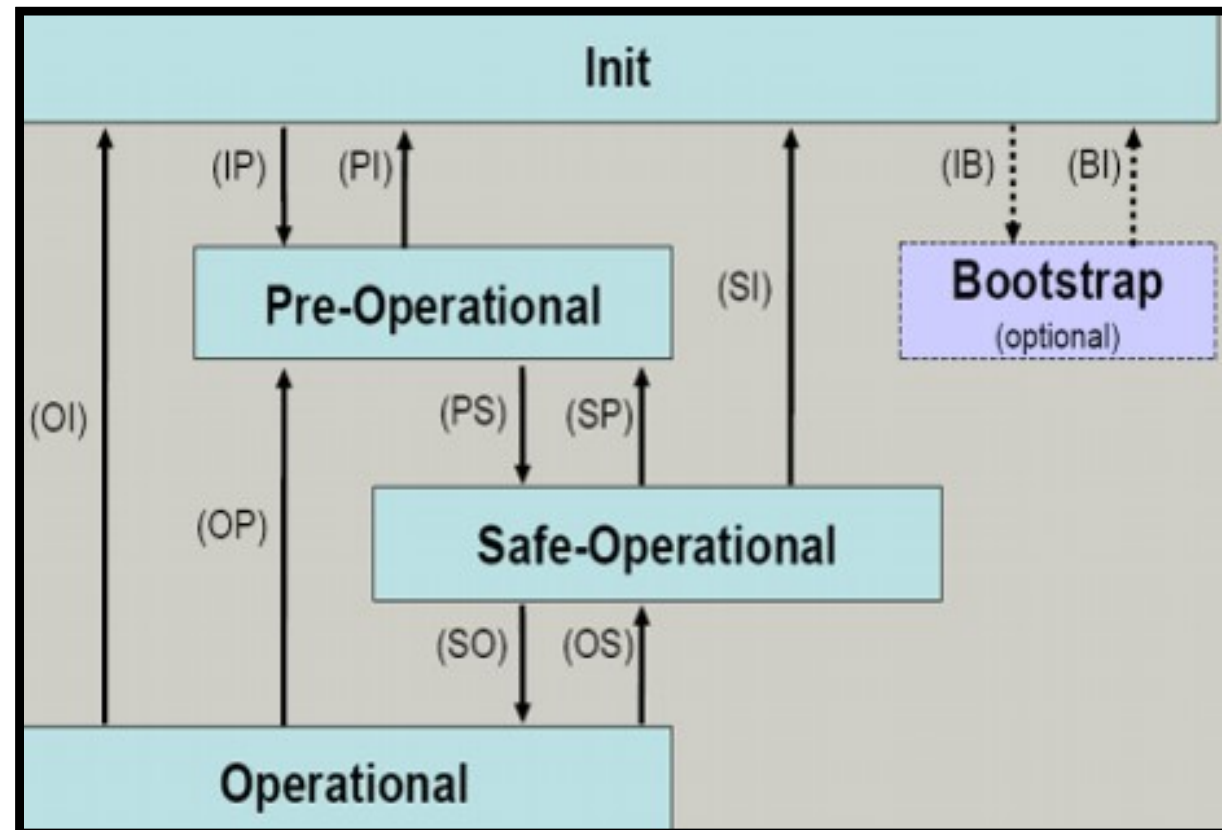
- A Sequence of Events Synchronizes the Clocks
 - The EtherCAT master sets all clocks equal to itself
 - Multiple telegrams are sent to read the EtherCAT slave times out and back
 - The EtherCAT master calculates propagation delay
 - This delay gets stored in each DC slave to adjust the local clock time.



- EtherCAT synchronizes clocks to system accuracy of $< 100\text{ns}$
- Example:
 - Long term scope view of two separated devices, synchronized
 - 300 nodes in between, 120m cable length



- **Initiate**: No communication is occurring with the slave
- **Pre-Operational**: Mailbox Communication is used to setup slave parameters
- **Safe-Operational**: Cyclic Inputs are exchanged between master and slave
- **Operational**: Cyclic Outputs are exchanged between master and slave



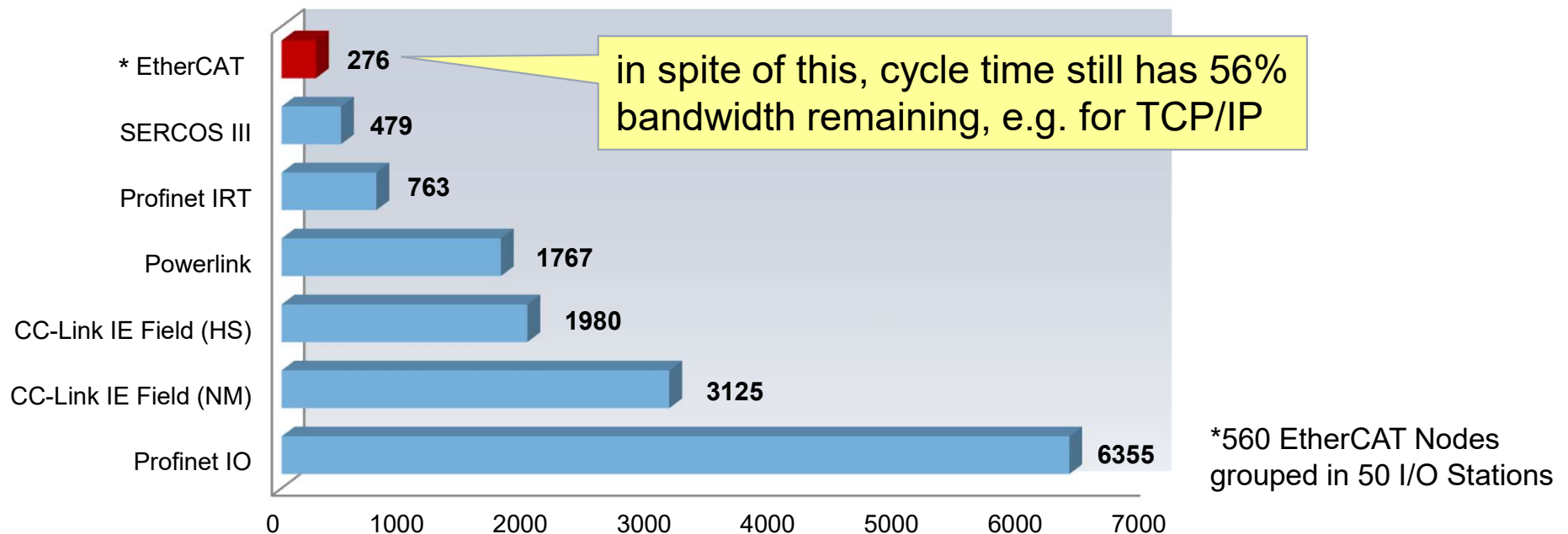


1. Overview
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- 3. Advantages**

EtherCAT Has Faster Bus Update Rates

- 40 Axes (each 20 Byte Input- and Output-Data)
- 2000 Digital + 200 Analog I/O Channels
- 500 meter Bus Length

Performance EtherCAT: **Cycle Time = 276 μ s** at 44 % Bus Load



- **EtherNet/IP not shown due to graph limitations: 10,000-25,000 μ s** (Multiple-master required)

EtherCAT has Faster Stack Processing Times

BECKHOFF

- Stack performances of the Ethernet technologies differ substantially, due to the different complexity of the stacks
- Softing, a German specialist for fieldbus technology published the following comparison of the stack delay times* :



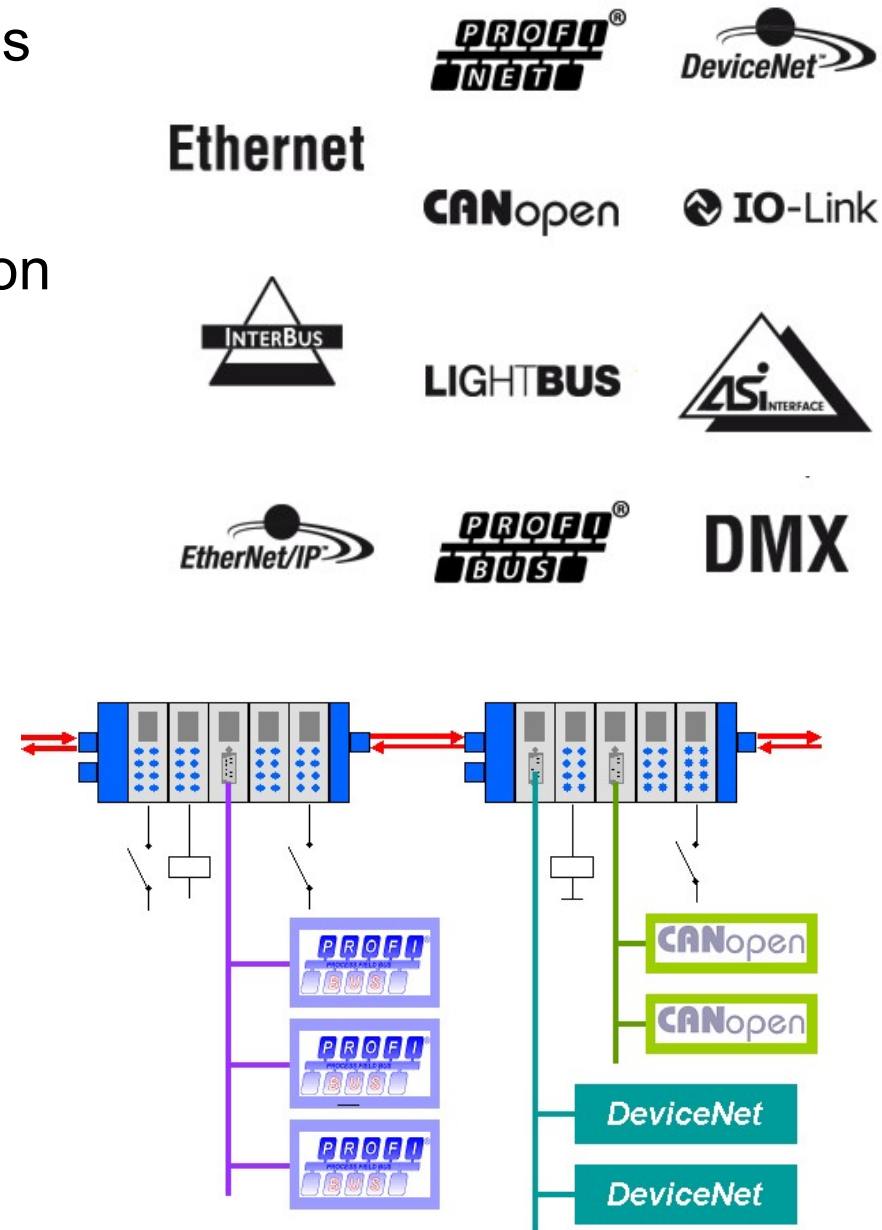
Stack Time	Profinet IO	Ethernet/IP	EtherCAT
Average	0.58 ms	1.89 ms	0.11 ms
Max:	0.74 ms	2.96 ms	0.18 ms
Min:	0.54 ms	1.23 ms	0.05 ms

- All three protocols were implemented on the same hardware (interface board with FPGA + Softcore CPU) and by the same team, so they are indeed comparable

Fieldbuses Easily Integrate with EtherCAT

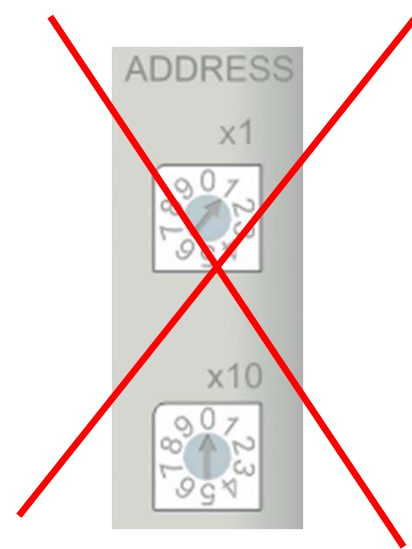
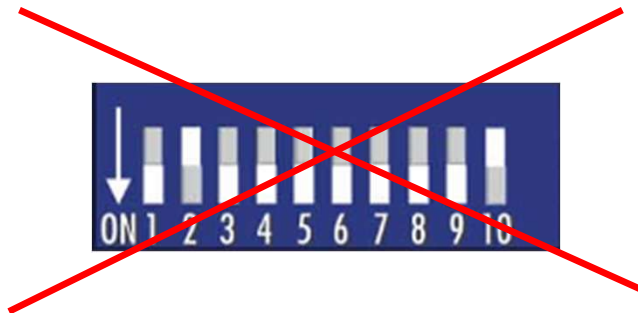
BECKHOFF

- EtherCAT slaves are available which pass data between EtherCAT and other fieldbuses.
- This hardware can be a master or slave on the connecting fieldbus
- Machine Retrofits using EtherCAT have benefits
 - **Save money**
 - EtherCAT parts, cables inexpensive
 - Reuse expensive hardware
 - **Improved Communication:**
 - Faster transfer rates on EtherCAT
 - Reduced noise and faster data on existing fieldbus cable
 - Reduced CPU load
 - **Ease of troubleshooting**



Setup and Maintenance is Easy with Auto-Addressing **BECKHOFF**

- Addressing is automatic
- No re-addressing is required for device replacement
- No MAC address handling required





EtherCAT Advantages

EtherCAT Master Suppliers are Plentiful

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BECKHOFF



(Vendors that ship or have announced EtherCAT master devices as of 03/2013. Not all products shipping yet)

- ABB
- Ackermann
- ACS Motion Control
- Addi-Data
- Adlink
- AFT Fahrzeugtechnik
- Algo System
- Amoy Dynamics
- Anca
- AutomationX
- B&R
- Balluff
- Baumüller
- BBH
- Beckhoff
- Belden
- Berghof
- Brunner Elektronik
- Bosch Rexroth
- CEC
- CREVIS
- CSM
- Deif
- Dina Elektronik
- dSPACE
- Eckelmann
- esd
- Festo
- Gantner
- GE Intelligent Platforms
- Gefran
- Grossenbacher
- HBM
- Helmholz
- IDS
- Imc/Additive
- IXXAT
- Jäger Messtechnik
- Jumo
- KEB
- KEBA
- Keyence
- kk-electronic
- Knestel
- Kolektor Synatec
- Kollmorgen
- Kuhnke
- Lenze
- M-System
- MaVi
- Messung
- MicroControl
- Microinnovations/Eaton
- Mikrap
- MKS Instruments
- MKT Systemtechnik
- MSC
- MTT
- Murrelektronik
- M-System
- National Instruments
- Omron
- Panasonic SUNX
- Power Instruments
- Prima Electro
- Schaeffler Engineering
- Schweitzer Engineering Laboratories / SEL
- SEW Eurodrive
- SIPRO
- Shanghai Xinhua
- SHF
- SMC
- Sontheim
- Industrie Elektronik
- TETRA
- TexComputer
- TR Elektronik
- Turck
- Unidor
- Unitro
- VIPA
- Wachendorff
- Wago



- **Fieldbuses are typically the bottleneck in a control system**
 - Fieldbus reaction time is typically 3-5 times longer than controller cycle*
- **Implementing EtherCAT Results in**
 - A faster control system
 - Deterministic control
 - Real-Time control
 - Synchronized control



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