BECKHOFF

EtherCAT Seminar

EtherCAT Technology Basics for Developers

Handout

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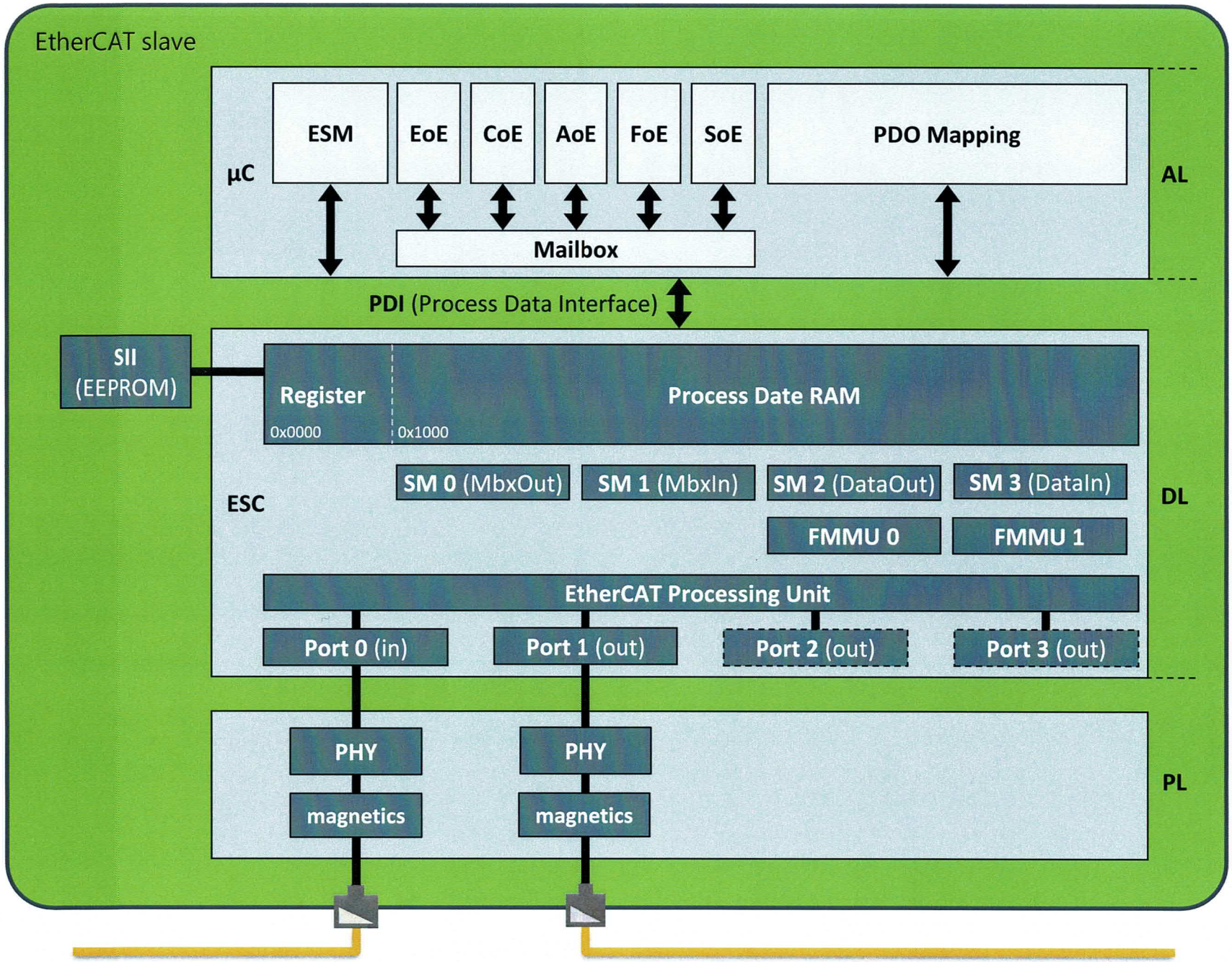
EtherCAT slave
µC
ESM
EoE
CoE
AoE
FoE
SoE
PDO Mapping
Mailbox
AL
PDI (Process Data Interface)
SII
(EEPROM)
Register
0x0000
0x1000
Process Date RAM
ESC
SM 0 (MbxOut)
SM 1 (MbxIn)
SM 2 (DataOut)
SM 3 (DataIn)
FMMU 0
FMMU 1
DL
EtherCAT Processing Unit
Port 0 (in)
Port 1 (out)
Port 2 (out)
Port 3 (out)
PHY
magnetics
PHY
magnetics
PL

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EtherCAT Communication

Communication Principles

1812

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Agenda

- Introduction
- ESI: Device Description
- Configuration Tool
- EtherCAT Master
- Physical Layer
- Data Link Layer
  - EtherCAT Slave Controller
  - Distributed Clocks
- Application Layer
  - State Machine
  - Mailbox Protocols
  - Process Data
- Device Profiles
- Synchronization Modes
- SII: Slave Information Interface
- Diagnosis
- Standards & Implementation

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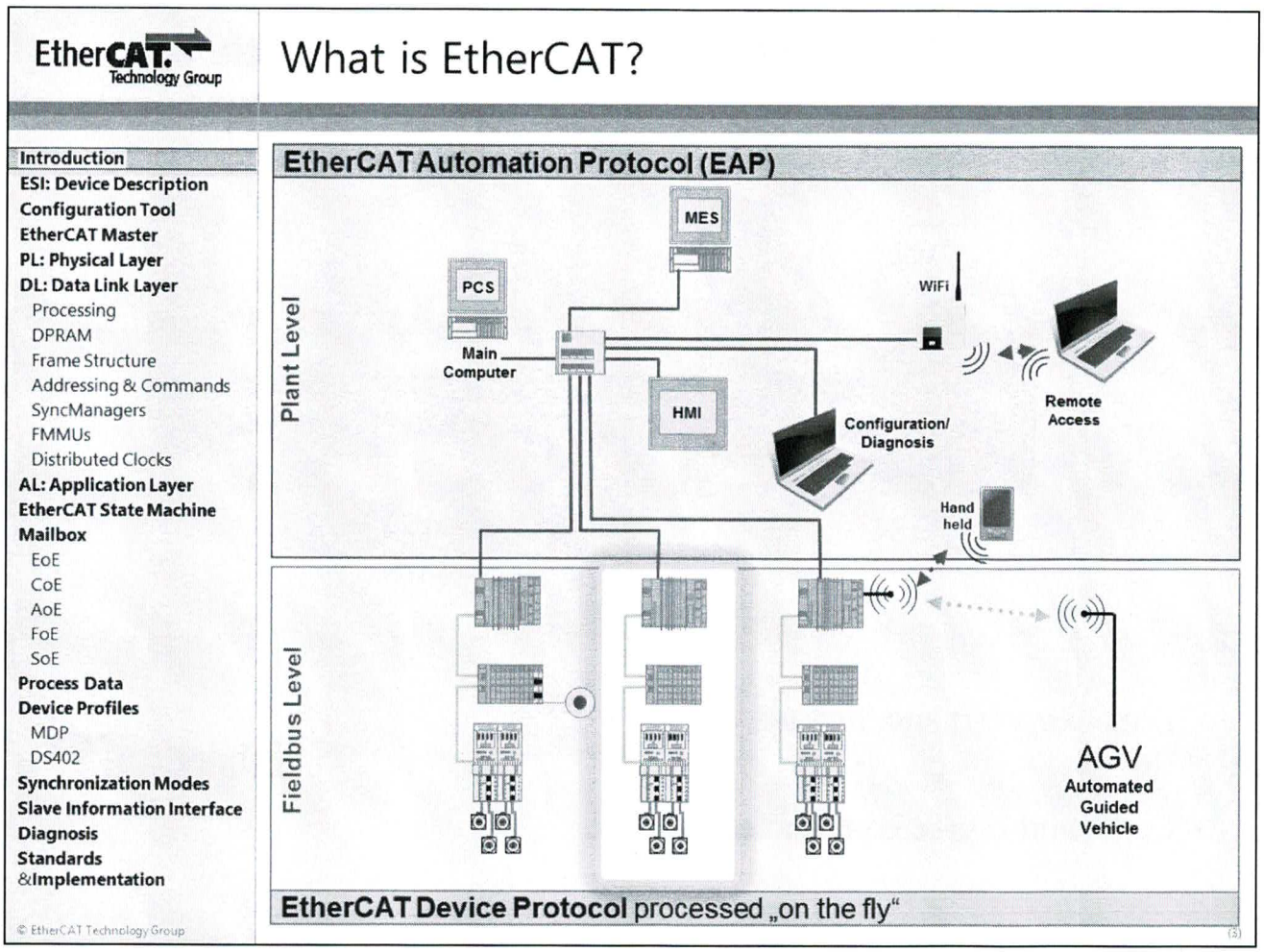

- **EtherCAT Device Protocol** (EtherCAT fieldbus): master-slave communication between real-time controllers and field devices (I/Os, servodrives, sensors, actuators, ...).

- **EtherCAT Automation Protocol** (EAP): communication between controllers, or between controllers and MES/ERP systems, on standard factory networks.

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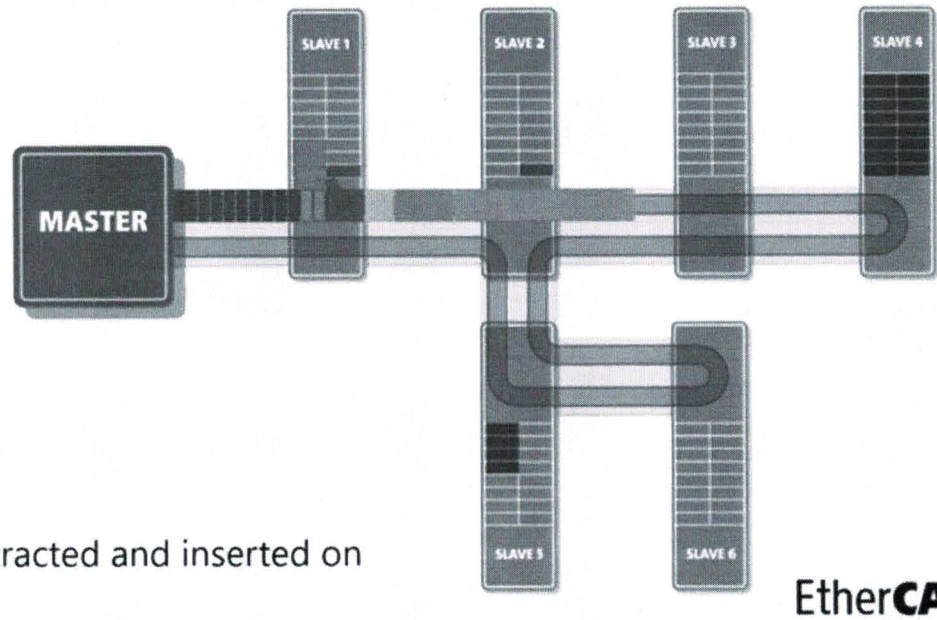
Functional Principle: Ethernet "on the fly"



- Data extracted and inserted on the fly
- Cyclic and acyclic communication

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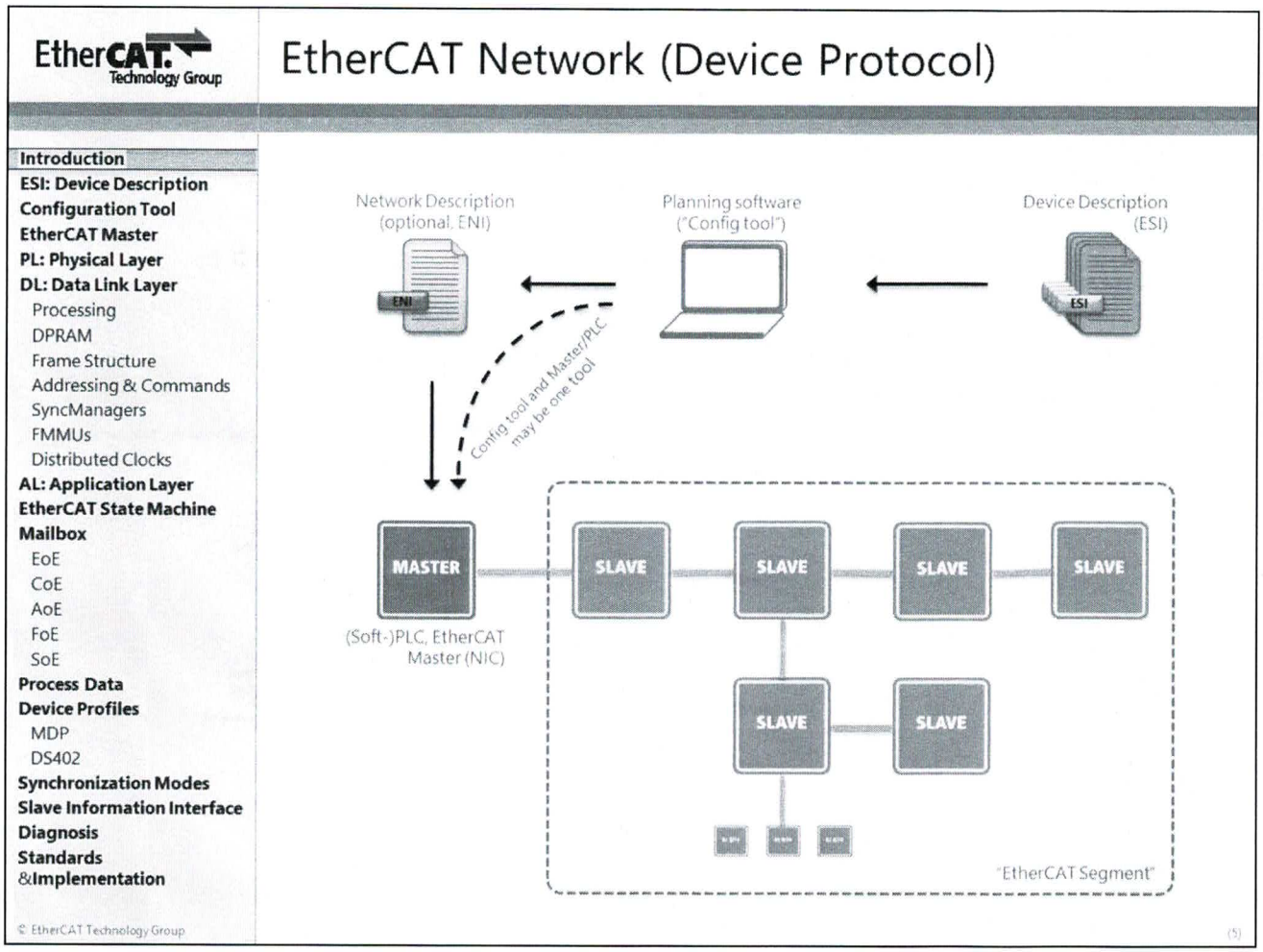
Cyclic data size can range from 1 Bit to 60 kByte (by using several frames if needed)



- **ESI**: EtherCAT Slave Information
- **ENI**: EtherCAT Network Information

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EtherCAT Slave Information (ESI)

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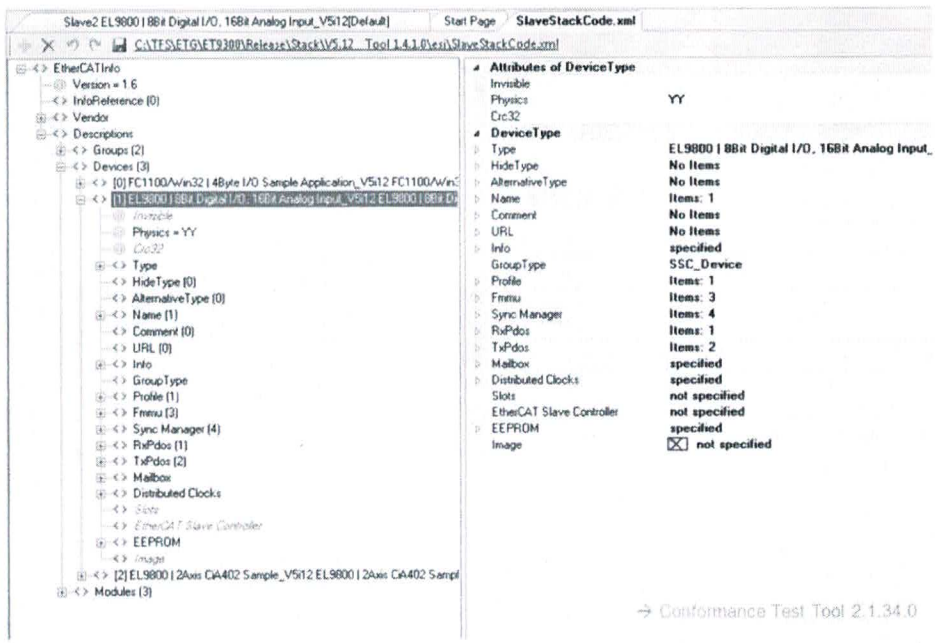
Standards &Implementation

ESI file contains information about:

- Vendor
- Device (several devices can be described in one file)



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Reference: ETG.2000 „EtherCAT Slave Information“

ESI file can be edited in Conformance Test Tool, as well as with any XML editor.

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EtherCAT Configuration Tool

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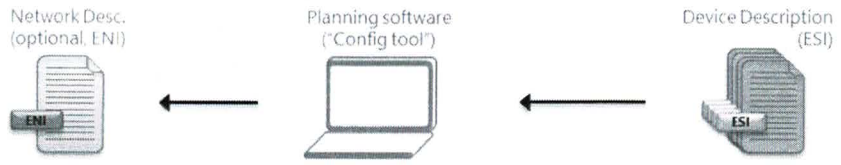

- Reads Device Descriptions (ESI)
- Enables the configuration of the network
  - Topology, parameters, process data, ...
- Can be a standalone tool or part of a software suite
- Export network description (ENI)

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Reference: ETG.2100 "EtherCAT Network Information"

Configuration Tool: EtherCAT Knowledge Base

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EtherCAT Master

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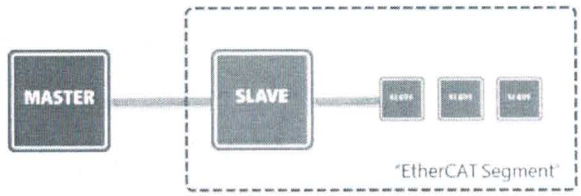

- Reads ENI file or uses own Config Tool
- Handles network interface (NIC)
- Operates the network
  - Send cyclic and acyclic telegrams
  - State Machine
- Provides interface to PLC

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NIC: Network Interface Controller

PL | EtherCAT

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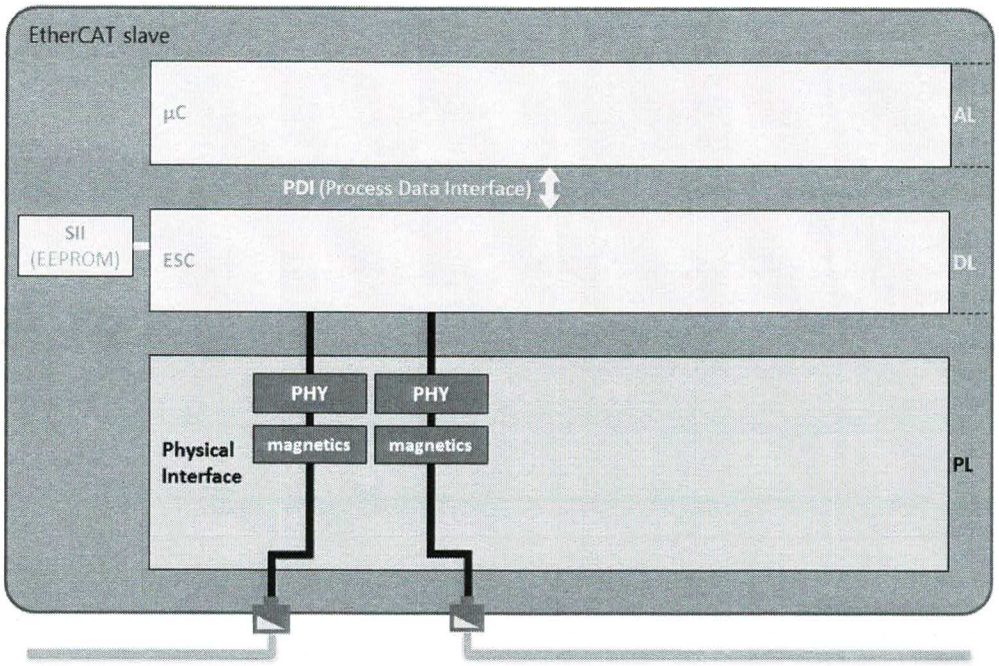

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PL | EtherCAT P

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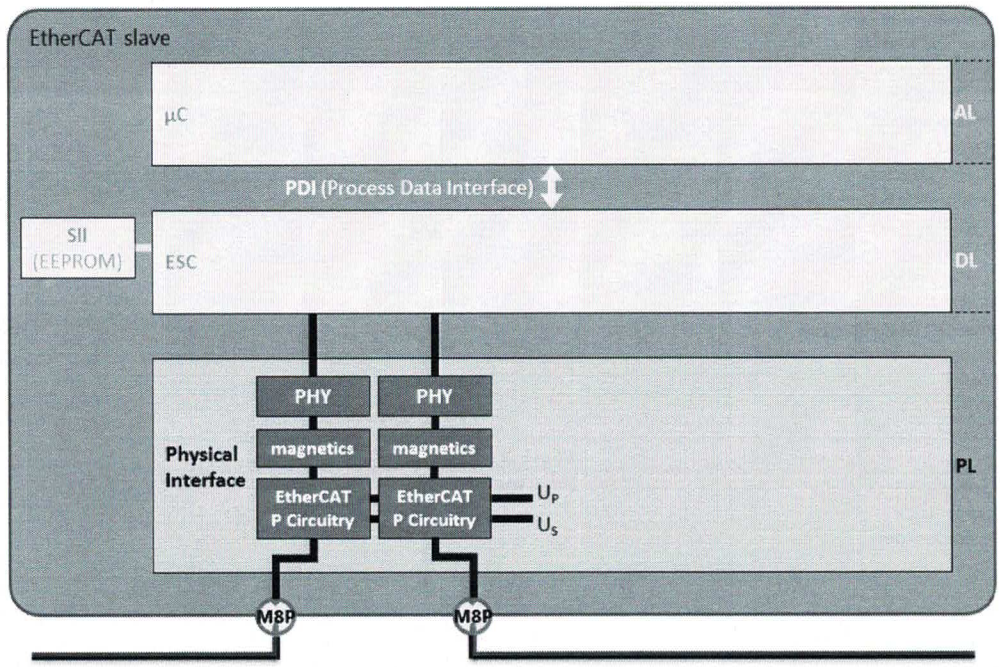

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Further information: https://www.ethercat.org/p

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Physical Layer

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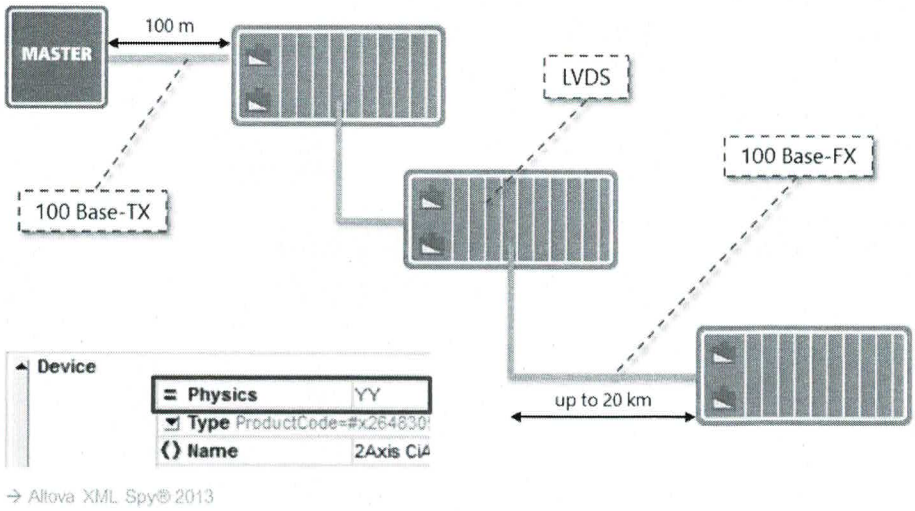
Physical signal variants of EtherCAT:



Any number of physical layer changes possible.

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- **100 BASE-TX** (copper cable up to 100 m between 2 nodes)
  - Most popular physical layer for Fast Ethernet
  - Shielded twisted pair (STP) with 2 pairs of wires
  - Cable categories CAT5, 6, 7 can be used
  - RJ45 connector standard, M12 connector for IP67

- **100 BASE-FX** (fiber optic up to 20 km between 2 nodes)
  - All media options possible
  - Requirements for TX-to-FX converter, e.g.
    - Link Lost Forwarding
    - No store-and-forward

- **LVDS** (backplane connection for modular devices)
  - Interface for low cost backplane applications
  - Not intended for connections over cable
  - according to ANSI/TIA/EIA-644

Ethernet G
4x Faster (not 10x)
for Line Topology
↳ not standardized yet → August
handed over from
BECKHOFF to ETG

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PL | Topology

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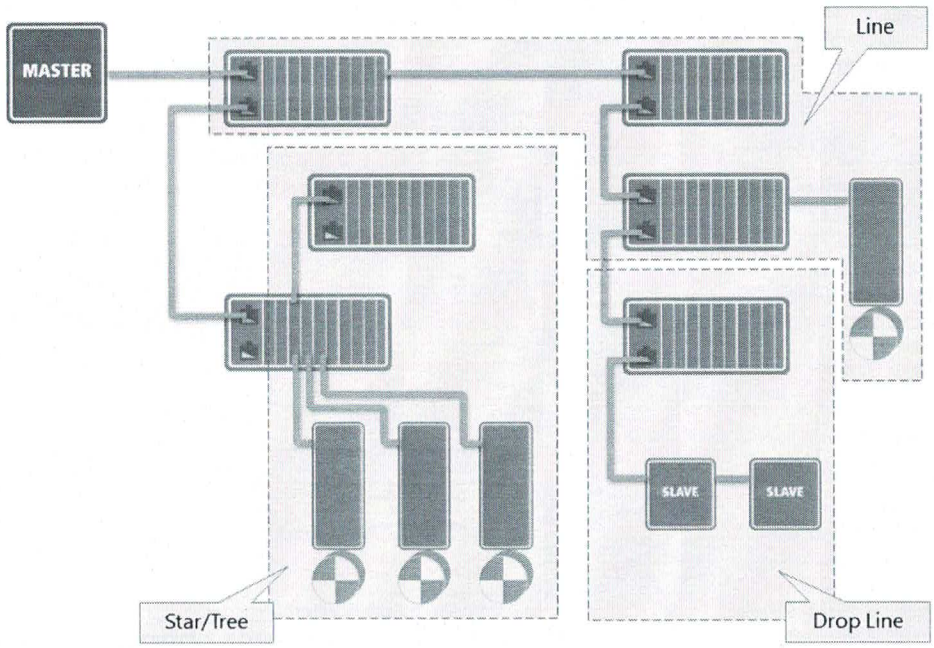

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Flexible Topology

Up to 65.535 devices within one EtherCAT network

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DL | ESC

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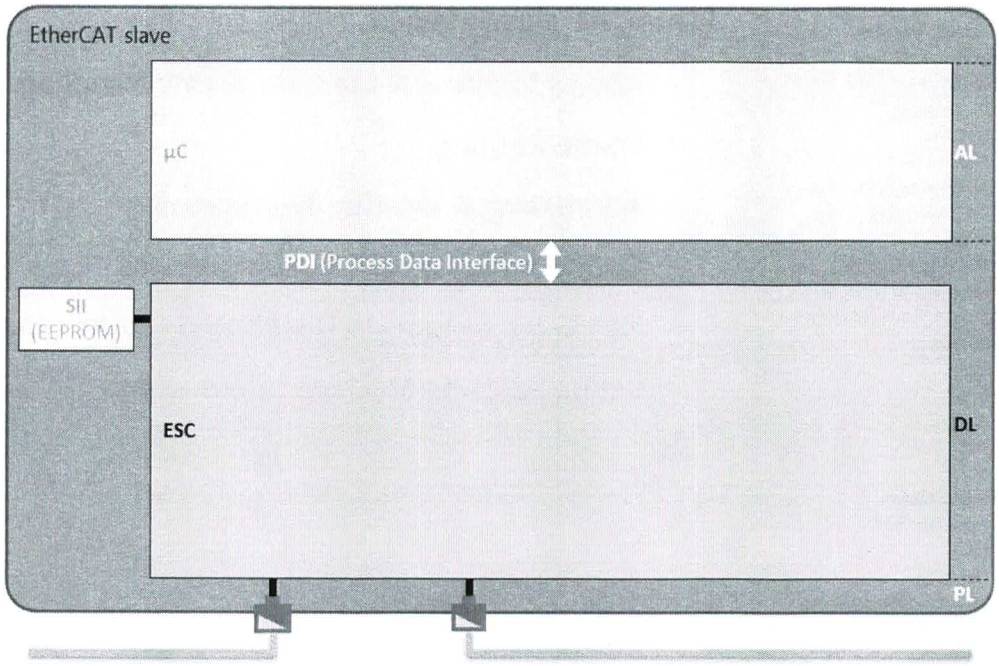

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Purpose of EtherCAT Slave Controller (ESC)

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ESC overtakes the low-level, hard real-time tasks in an EtherCAT slave device

- Access to Physical Medium & Link Handling
- Frame Routing
- Addressing & On-the-fly processing
- Configuration of ESC building blocks
- Hardware support to Distributed Clocks synchronization
- Set up AL State Machine interactions

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DL | Frame Processing

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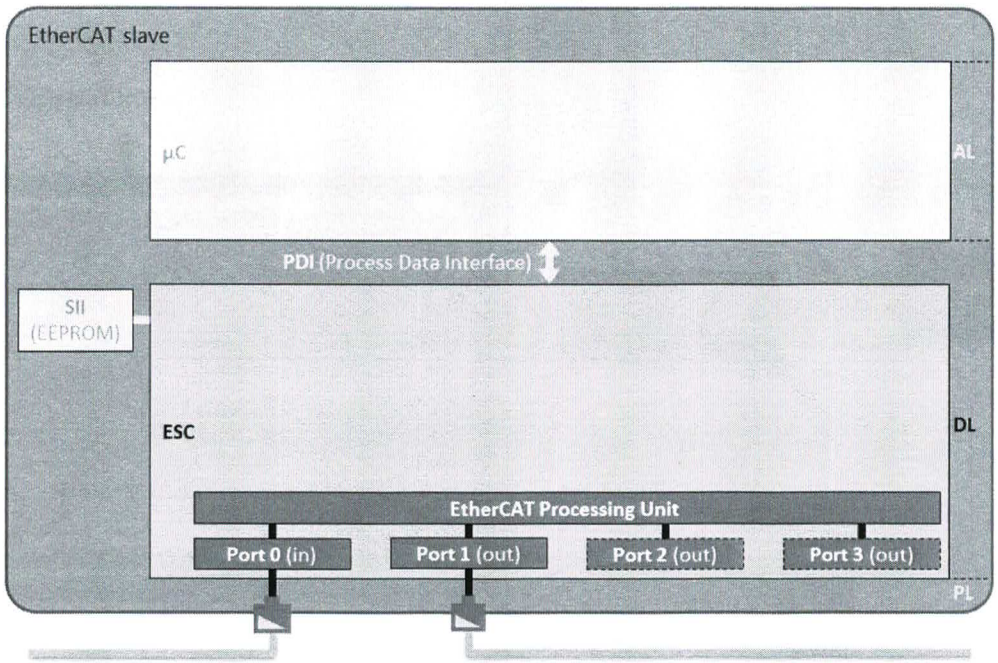

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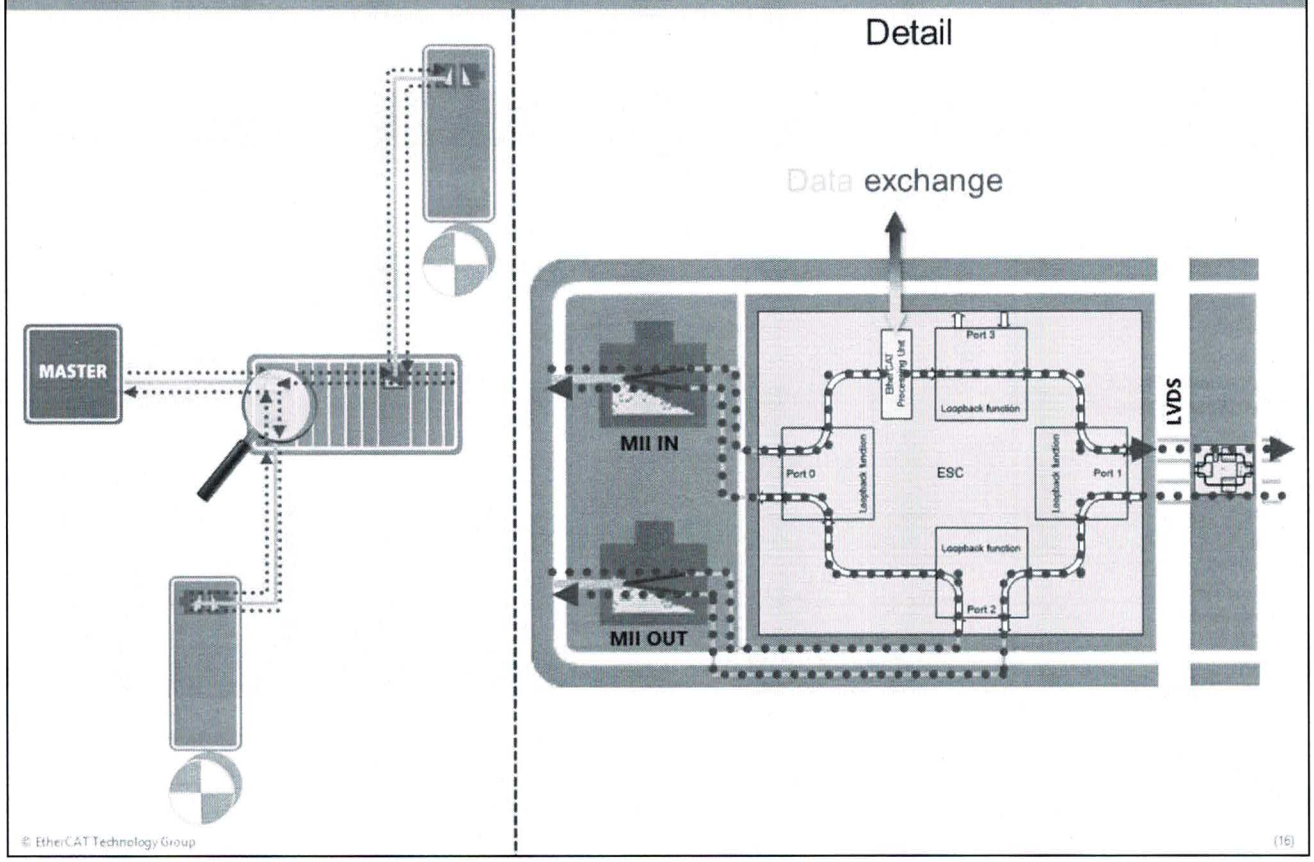
- Port 0 is the upstream port and always leads to the master (IN port). This port supports special functions:
  - Port 0 automatically opens when all ports are closed, acting as recovery port for the slave
  - Port 0 enables to detect and drop frames circulating on the network

DL | Frame Processing



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PL | Cable Redundancy

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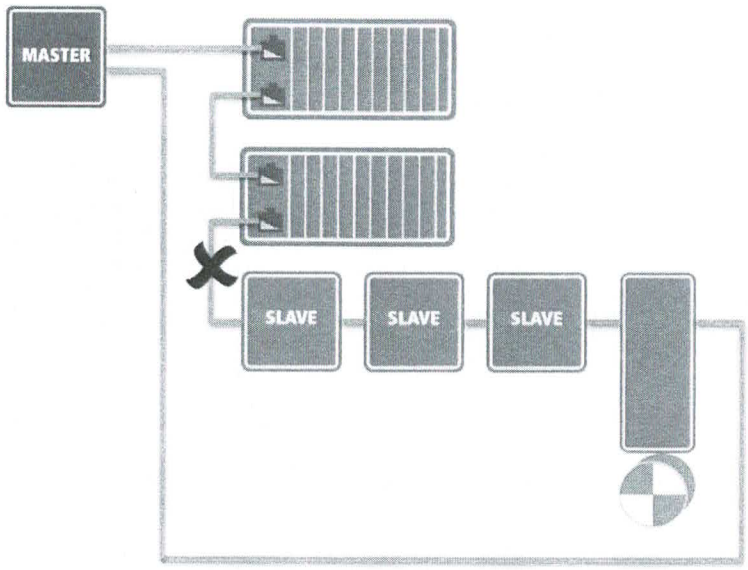
Only a second Ethernet port is needed on the master – possible with all EtherCAT Slave devices



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On slave side, cable redundancy is automatically supported by ESCs: no additional features needed.

DL | DPRAM

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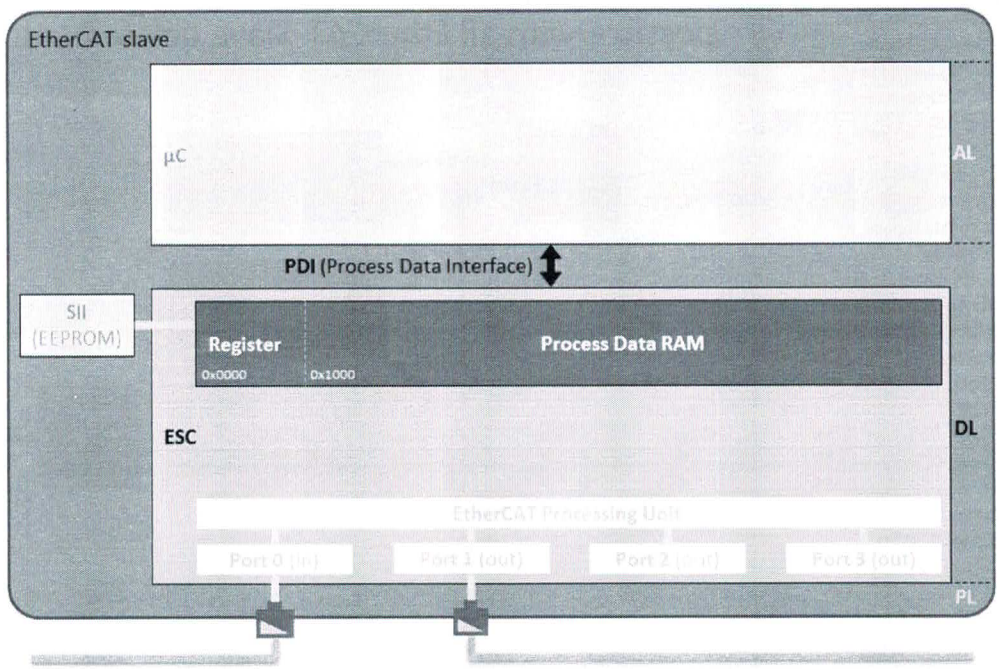

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DL | DPRAM

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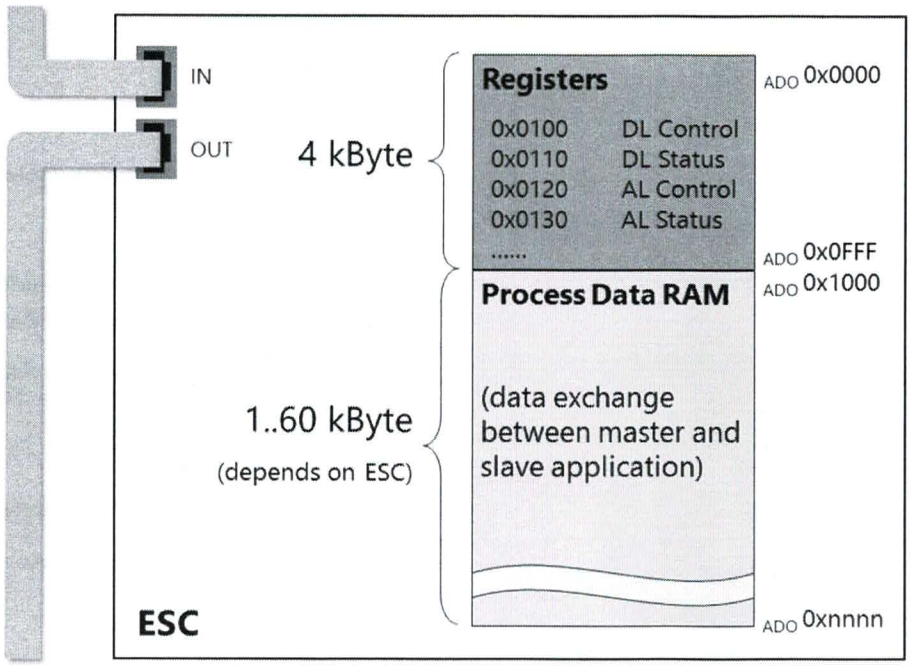
The DPRAM consists of two ranges: Registers and Process Data RAM.



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- **Registers** contain low-level ESC settings and diagnostic information.
- **Process Data RAM** is a free memory available for master and slave application to exchange data.
- Write Access:
  - Shadow registers for all registers integrated
  - DPRAM write shall be controlled by SyncManagers

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Registers

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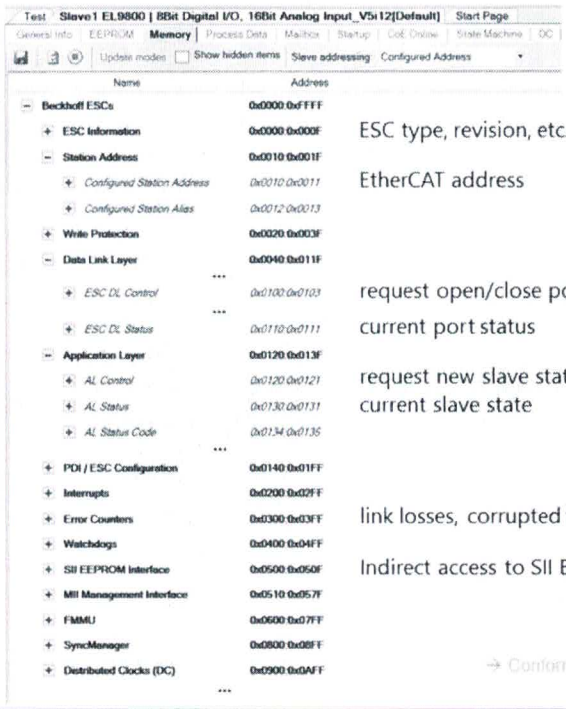
- Contain basic ESC settings/information
- Structure is identical for all ESCs



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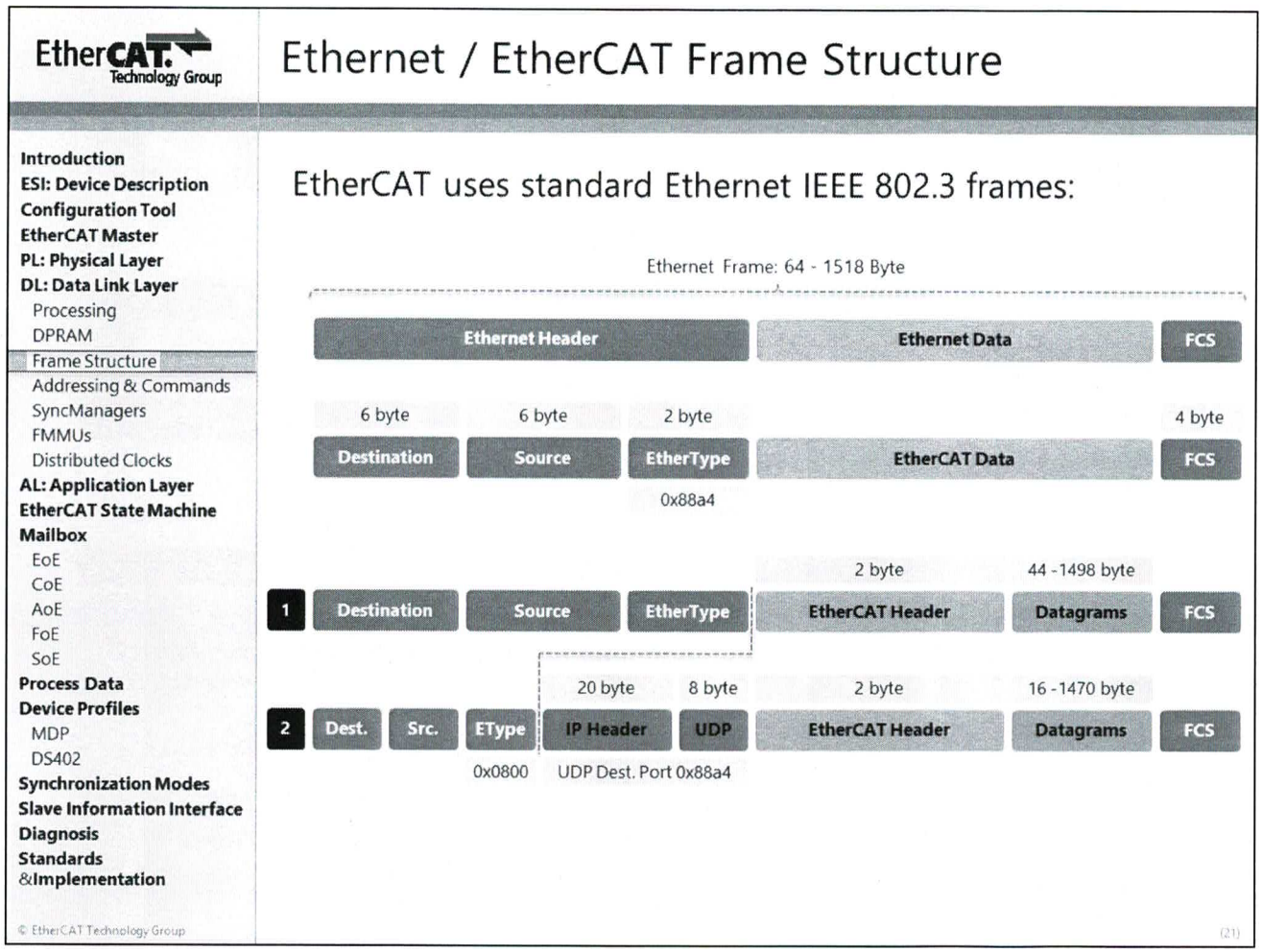
Reference: ESC Hardware Data Sheet



1. EtherCAT Datagrams are carried by raw Ethernet frames
   - Default case, always possible when the EtherCAT segment is connected to the master directly (EtherCAT Direct Mode)

2. EtherCAT Datagrams are encapsulated into UDP/IP protocol
   - Mandatory when the EtherCAT segment is connected to the master through a standard switch (EtherCAT Open Mode)
   - Also possible in Direct Mode, e.g. if the master uses the standard OS driver to send frames

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EtherCAT Frame Header

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The EtherCAT header contain the information about the EtherCAT type carried by the frame:

EtherCAT Header		
11 bit	1 bit	4 bit
Length	**R**	**Type**

Type	Meaning
0	Reserved
1	EtherCAT Device Communication The only type that is evaluated by the ESC!
2,3	Reserved
4	EAP Process Data Communication
5	EAP Mailbox Communication
6-15	Reserved

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EAP: EtherCAT Automation Protocol

Types 4 and 5: Master-Master Communication

EtherCAT Datagrams

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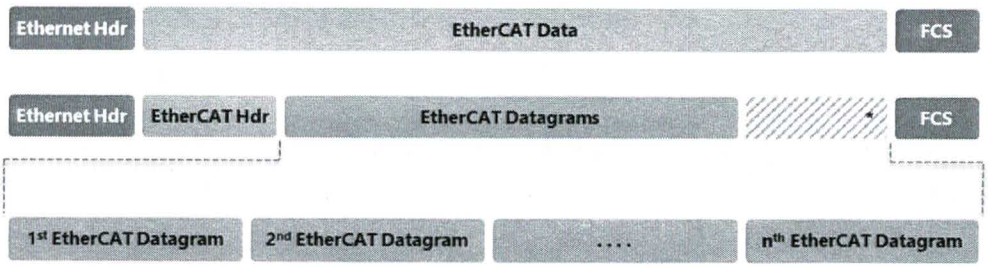
The payload of an EtherCAT frame (with Type = 1) consists of a variable number of EtherCAT Datagrams.



*add 1-32 padding bytes if Ethernet frame is less than 64 bytes

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EtherCAT Datagram Header

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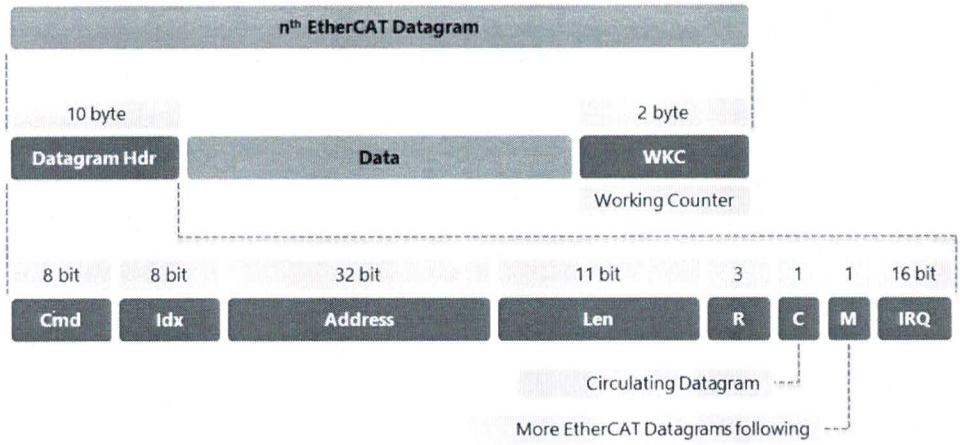
Each EtherCAT Datagram consists of a Header, a Data field and a Working Counter (WKC).



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Cmd: datagram type

Idx : set by master to identify lost or duplicated datagrams

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EtherCAT Commands Overview

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The master can access the DPRAM of EtherCAT slave(s) by using different addressing mechanisms:

Auto Increment Addressing
A specific position in the network is addressed (e.g. topology discovery).
Command abbreviation: APxx

Fixed Physical Addressing
A slave with a specific configured address is addressed (e.g. mailbox communication).
Command abbreviation : FPxx

Broadcast Addressing
All network slaves are addressed (e.g. state machine monitoring).
Command abbreviation : Bxx

Logical Addressing
A subset of slaves is addressed through a logical address space (e.g. process data exchange).
Command abbreviation : Lxx

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Each addressing mode is combined with the command (Cmd):

- **xxRD** (Read) → addressed slave(s) write content into the datagram
- **xxWR** (Write) → addressed slave(s) read content out of the datagram
- **xxRW** (ReadWrite) → addressed slave(s) read, and thereafter write content into the same datagram
- **xxRMW** = (ReadMultipleWrite)→ the addressed slave writes content into the datagram, all other slaves read it out of the same datagram

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Address Field

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8 bit	8 bit	32 bit		11 bit	3	1	1	16 Bit	
Cmd	Idx	Address		Len	R	C	M	IRQ	
		16 Bit (ADP)	16 Bit (ADO)						
APxx		Position	Offset						Auto Increment Addressing
FPxx		Address	Offset						Fixed Physical Addressing
Bxx		(not relevant)	Offset						Broadcast Addressing
Lxx		Logical Address							Logical Addressing

Address field in each datagram is 32-bit

- Higher 16 bits address the device (65.535 devices possible) and lower 16 bits specify an offset in DPRAM (max. 64 kByte) of addressed device

or

- 32 bits used for logical addressing

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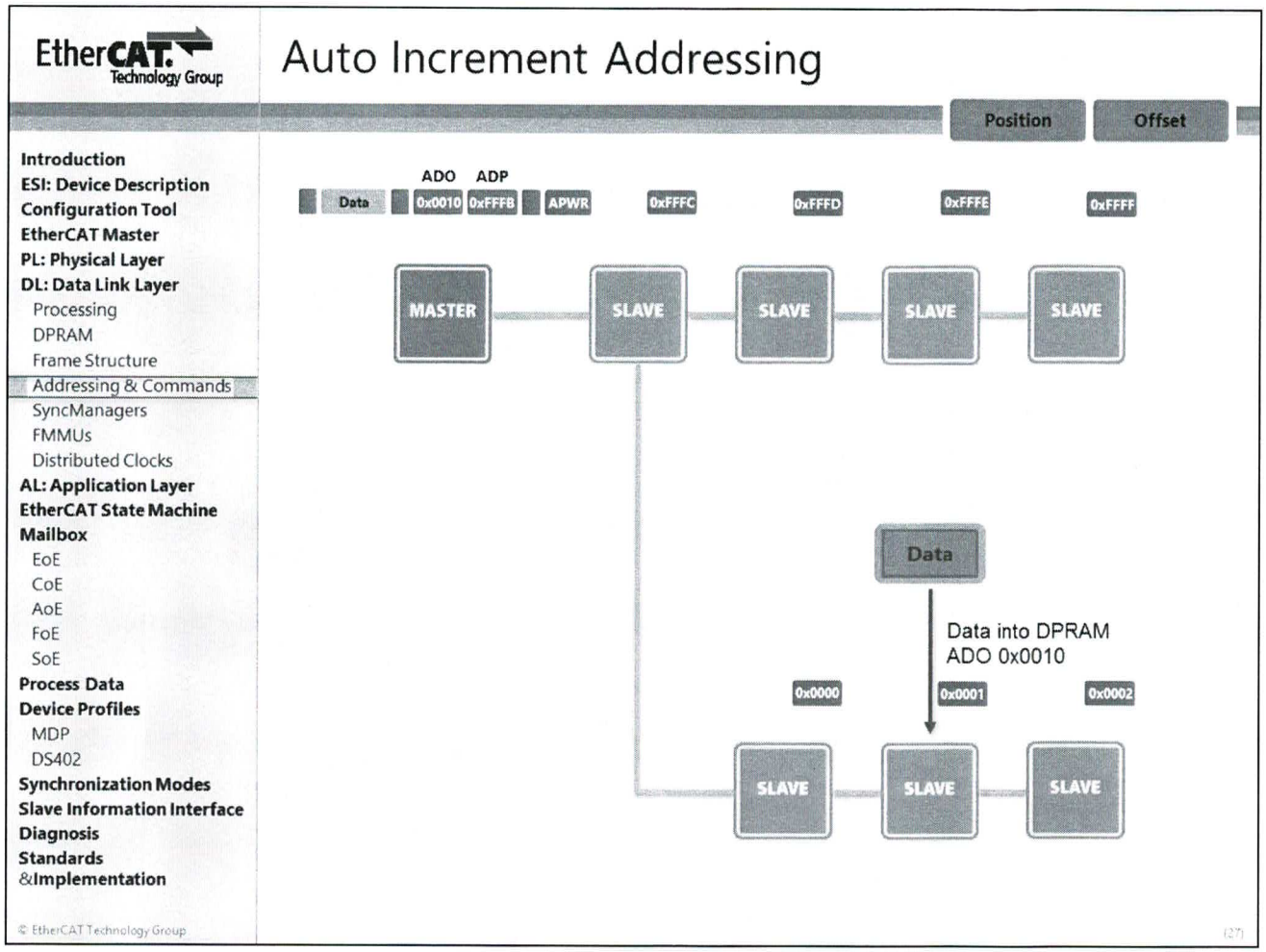
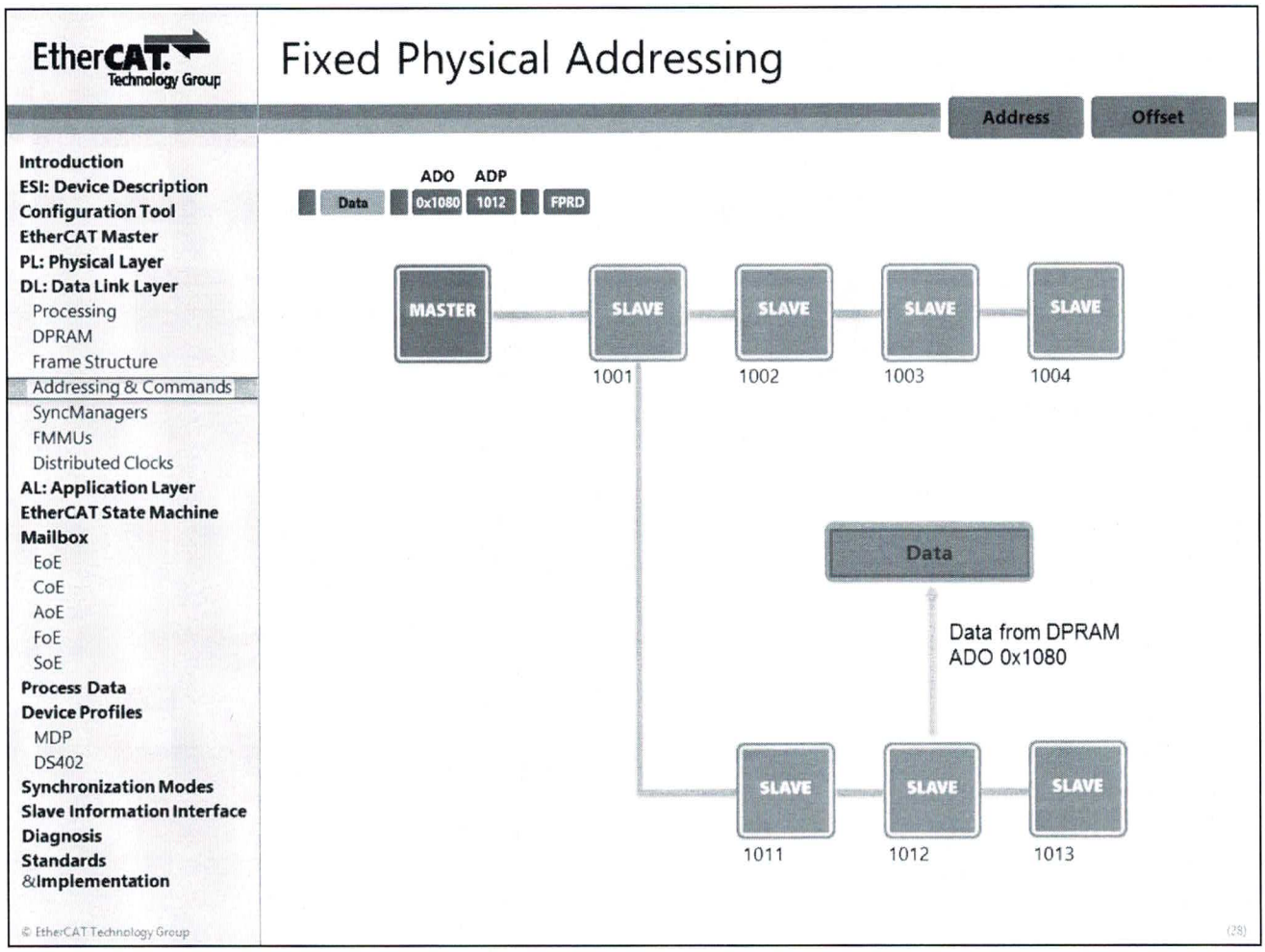
- **ADP** = Address Position → which slave is addressed
- **ADO** = Address Offset → which DPRAM location is accessed



- Master writes a negative Auto Increment address (16 bit) into ADP depending on position
  - Slave which receives ADP == 0x0000 is addressed
  - Each slave increments ADP by 1

- *Offset* addresses local Address Space of device



- A fixed 16-bit address is assigned to each slave (written by master into $_{ADO}$0x0010)
  - Independent from slave position
  - Written by master during start-up
  - Fixed address lost after power loss

- *Offset* addresses local Address Space of device

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Broadcast Addressing

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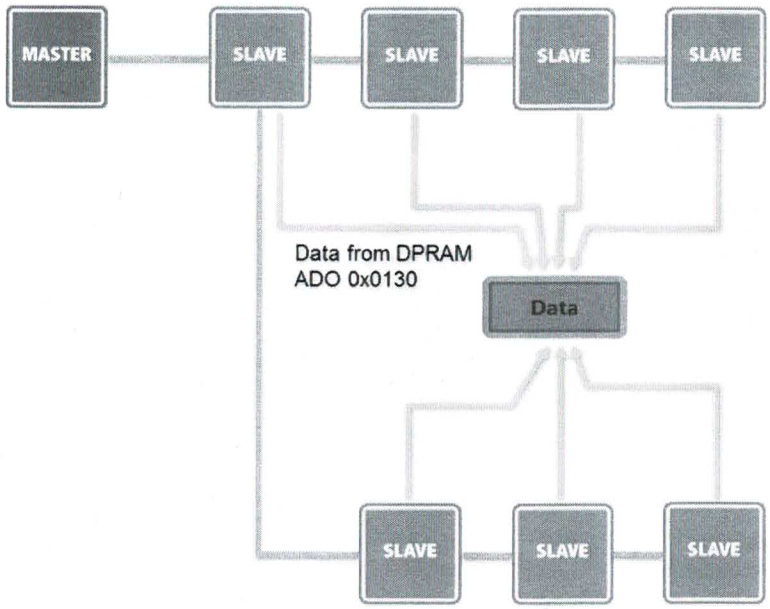

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Read data are logic OR of single register values

Logical Addressing

Logical Address

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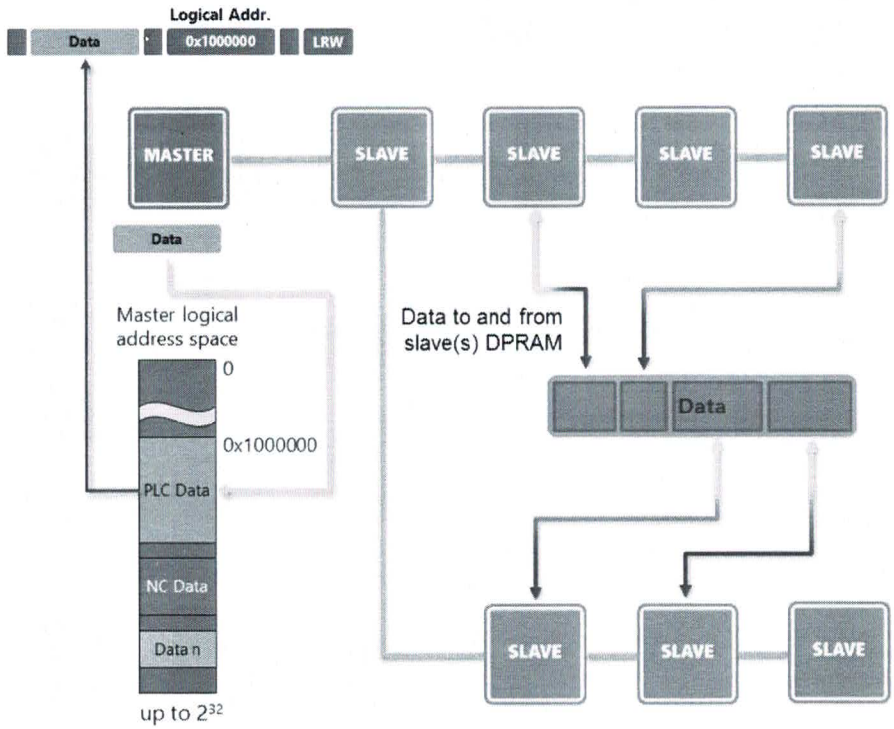

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- Slave reads/writes the logical process image of master
- More slaves can share the same memory interval

EtherCAT Datagram Working Counter

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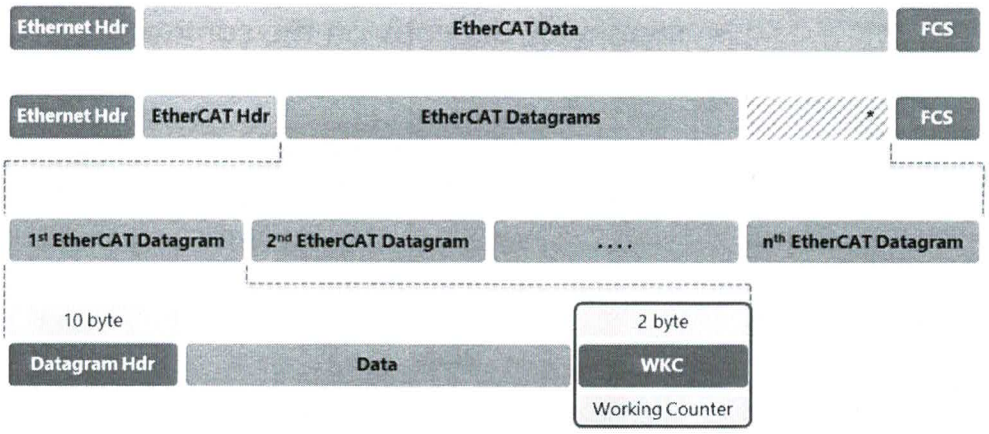

*add 1-32 padding bytes if Ethernet frame is less than 64 bytes

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Working Counter (WKC)

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- WKC is incremented after each successful access
- Increment depends on the command:

Command		Increment
Read	xxRD	+1
Write	xxWR	+1
Read Write → Read → Write	xxRW	 +1 +2

- The returning WKC value is compared by master with the expected value
- In case of invalid WKC, input data carried by the corresponding datagram are discarded

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Working Counter Example (LRD)

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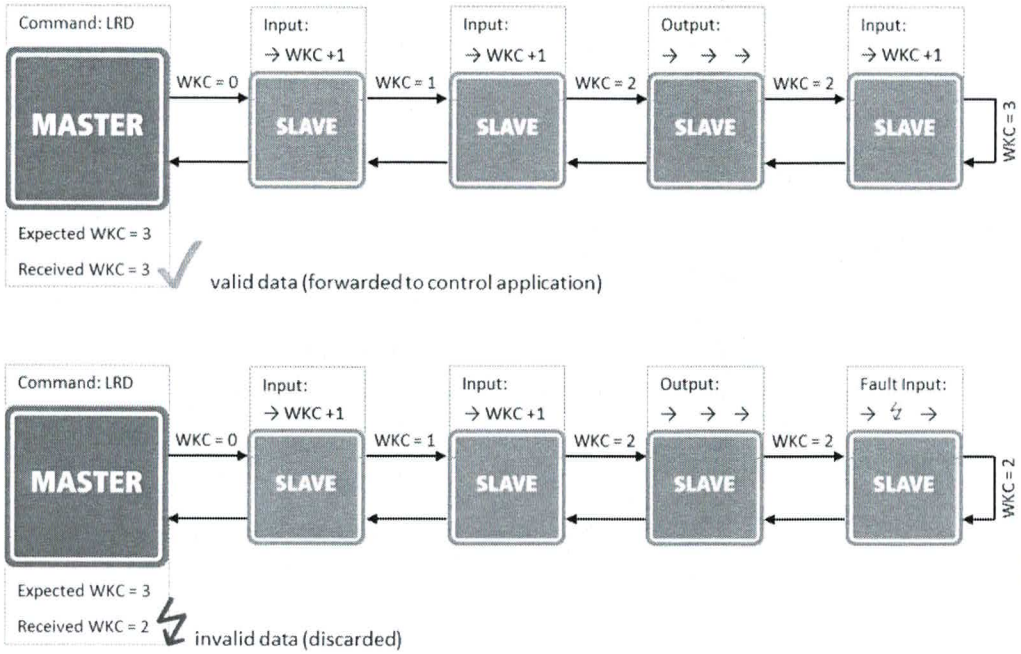

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DL | SyncManager

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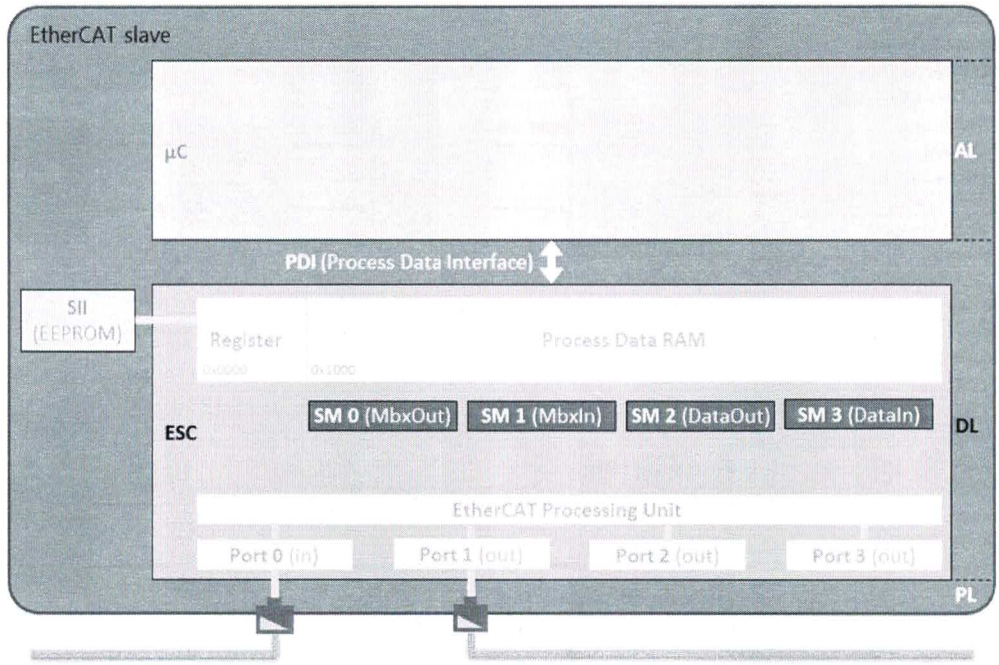

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- SyncManagers protect a Process Data RAM interval from simultaneous access → data consistency
- Up to 16 independent SyncManager channels

Sm (4)

	MinSize	MaxSize	DefaultSize	StartAddress	ControlByte	Enable	Text
1	#x24	#x80	#x80	#x1000	#x26	1	MBoxOut
2	#x24	#x80	#x80	#x1080	#x22	1	MBoxIn
3			2	#x1100	#x64	1	Outputs
4			6	#x1400	#x20	1	Inputs

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The SyncManager configuration registers start at $_{ADO}$0x0800

SM0:

0x800:0x801 : Physical Start Address

0x802:0x803 : Length (in Byte)

0x804 : Control Register (including type and direction)

0x805 : Status

0x806 : Activate

0x807 : PDI Control

SM1:

0x808:0x809 : Physical Start Address

...

SyncManagers | Types

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- **Mailbox (1-buffer) Type**
  - 1 buffer SyncManager supports handshake
  - Data overflow protection
  - Writing side must write before reading side can read
  - Reading side must read before writing side can write again
  - Used for non-process data communication
- **Buffered (3-buffer) Type**
  - 3 buffer SyncManager guarantees consistent data delivery and access to the newest data any time
  - Always a free buffer to write
  - Always a consistent buffer to read (except before the first writing)
  - Used for process data communication

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Mailbox Type (1-buffer) Read Example

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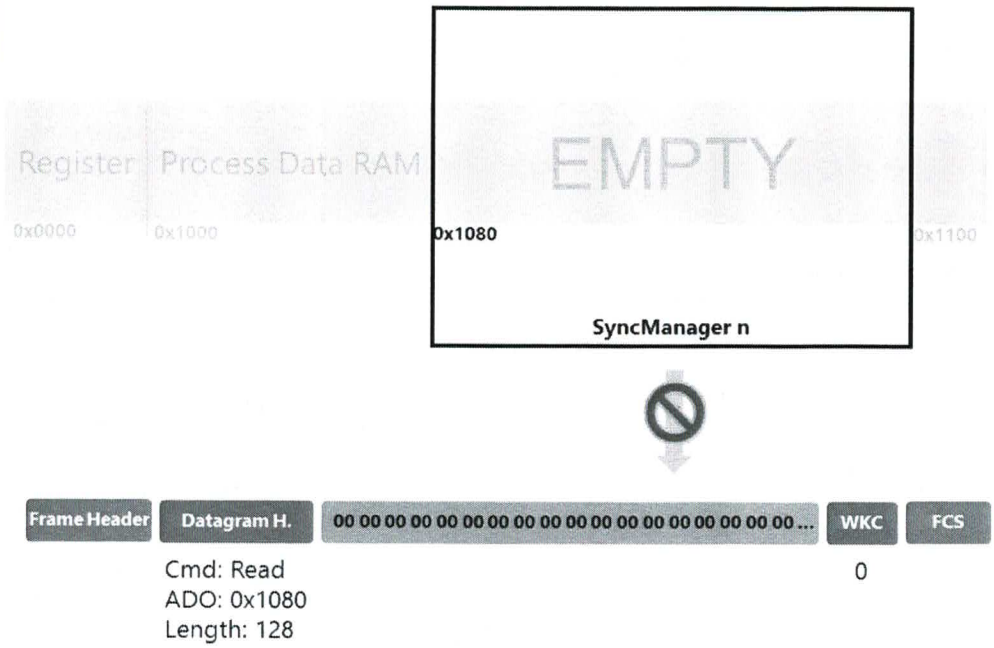

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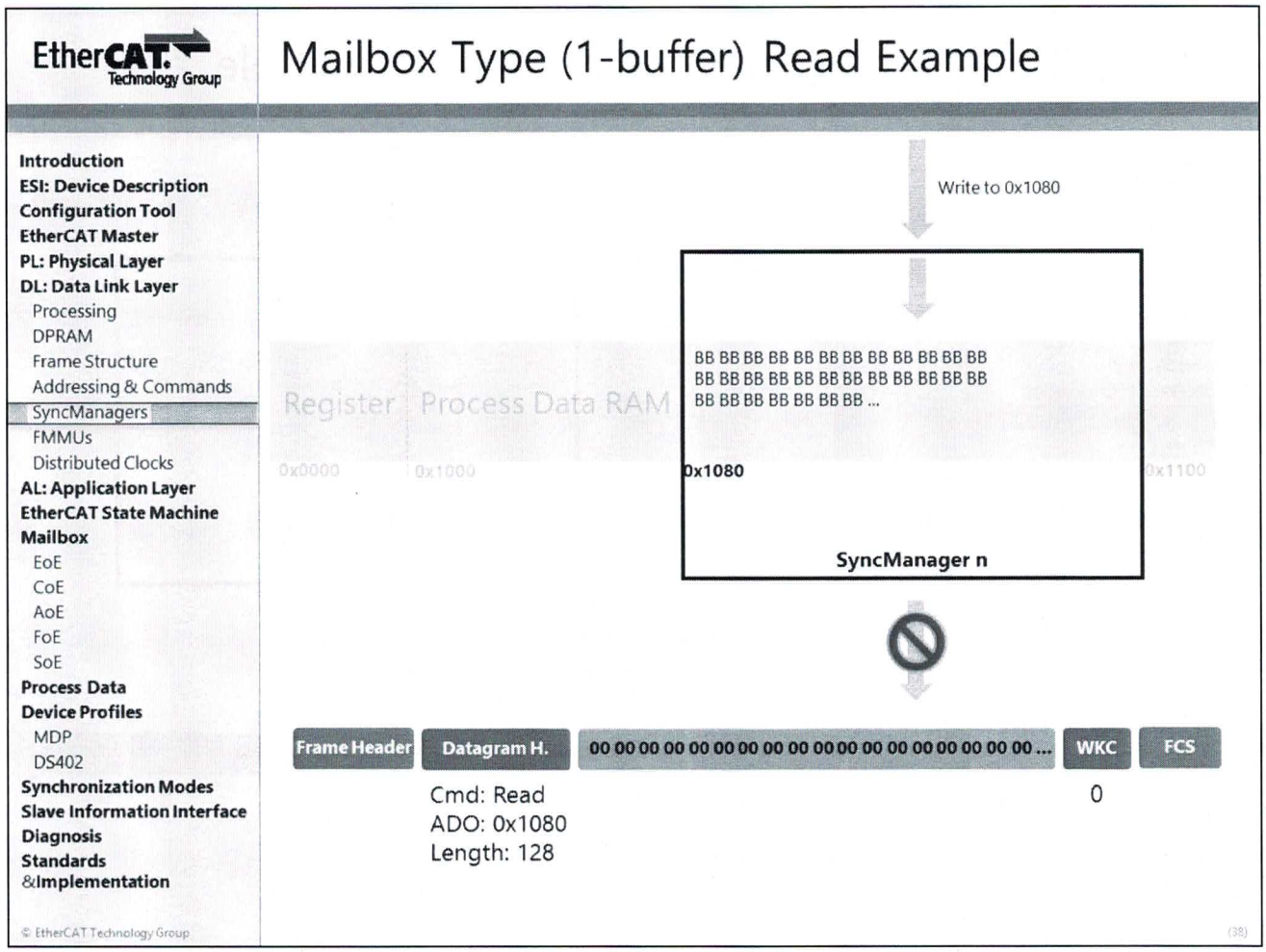
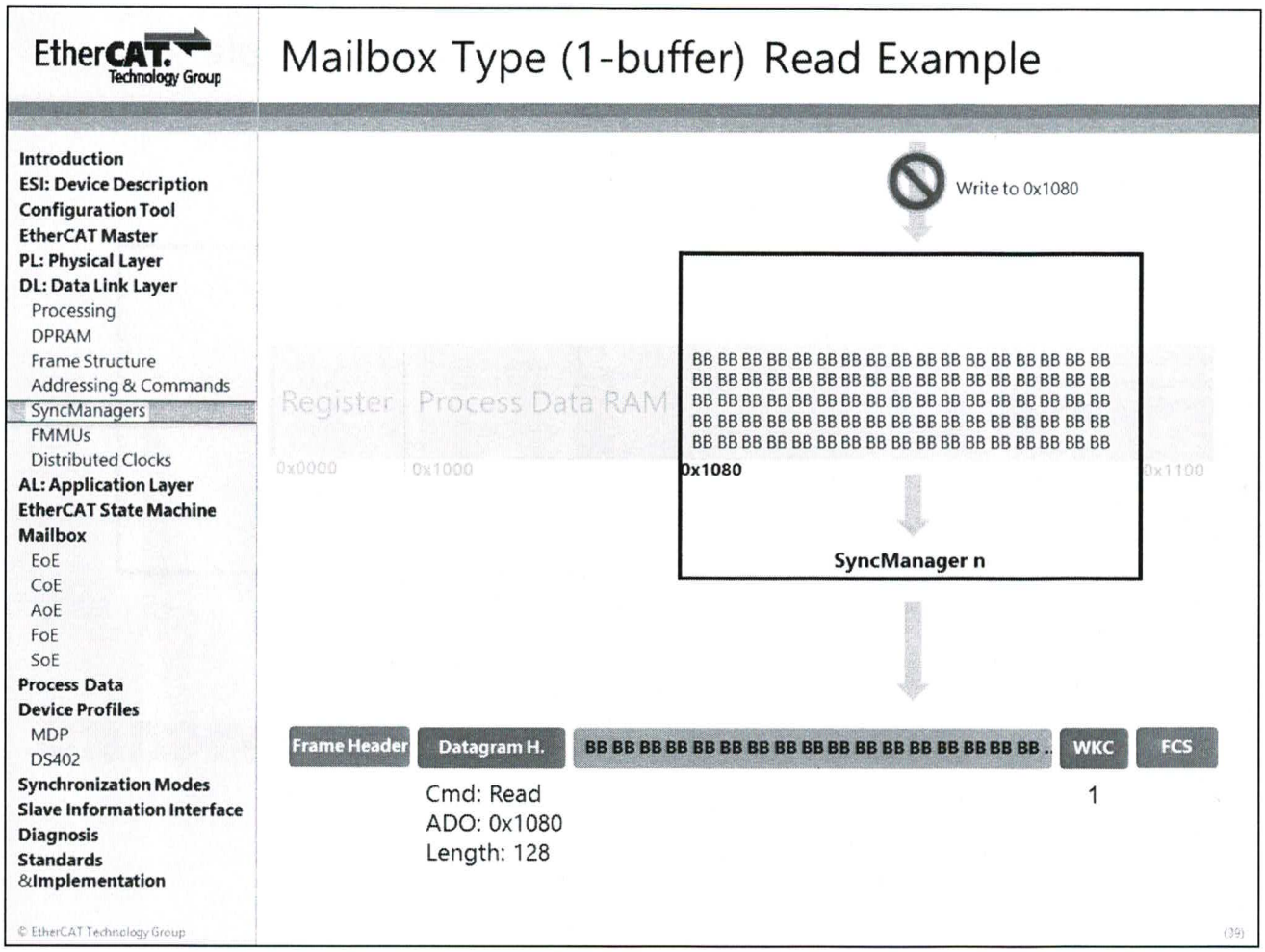
Read access to an empty SyncManager failes

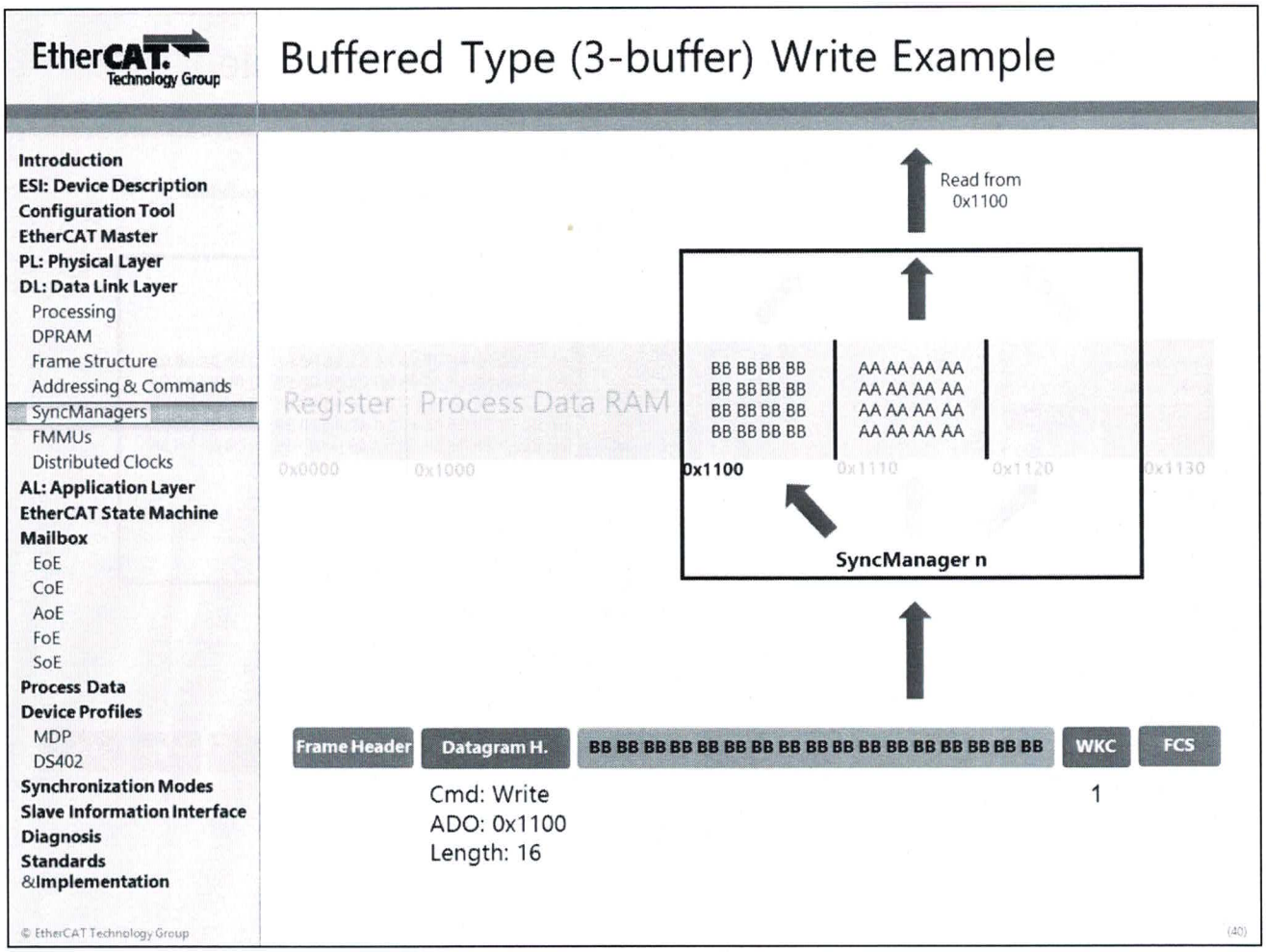


Read access to a not complete written SyncManager failes



Read access to a full SyncManager is valid

Write acceess to a full or not complete read SyncManager fails



To exchange n data bytes, 3*n memory bytes required

Mechanism handled by SyncManager (ECAT and PDI always use start address), shall be taken into account when determining Start Address of next SyncManager.

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Buffered Type (3-buffer) Write Example

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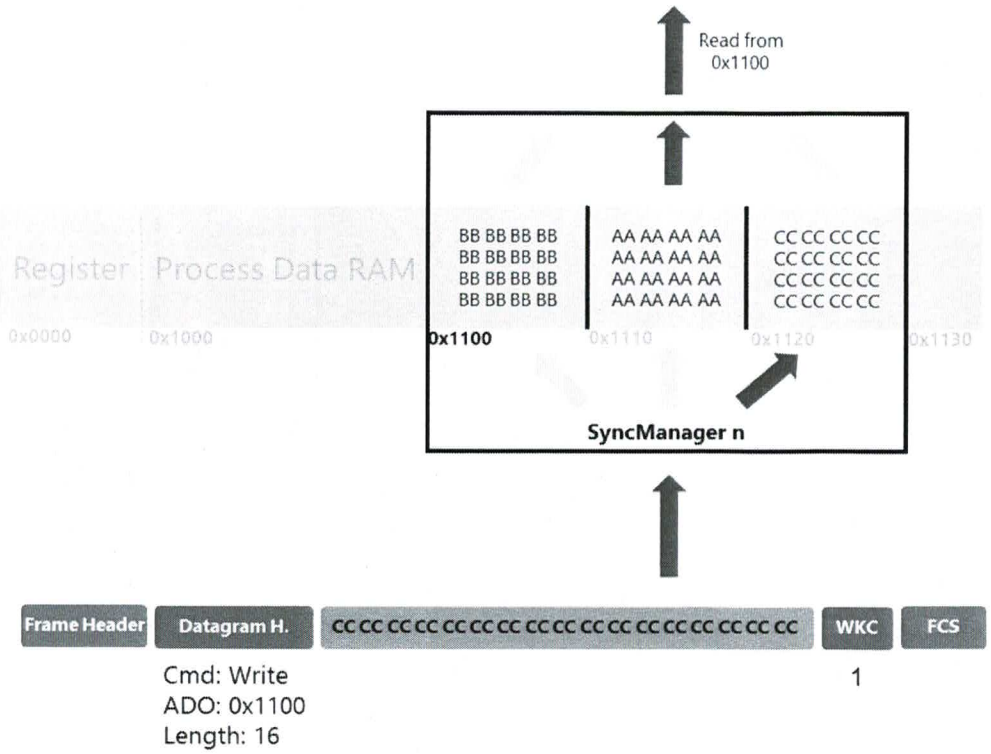

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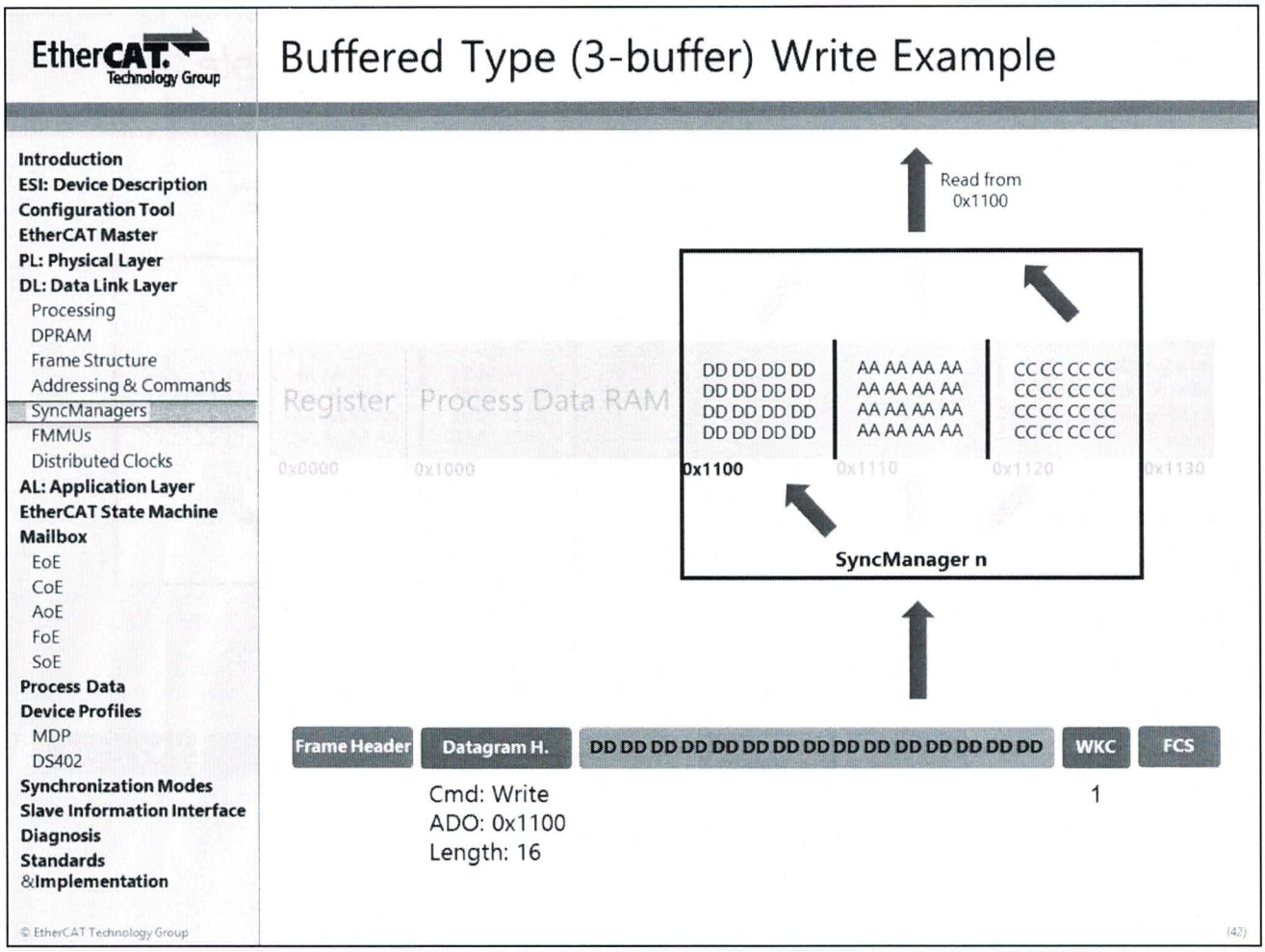

Data „C" is provided for read access because it is the latest complete available data

Data „B" is overwritten by data „D"

DL | FMMU

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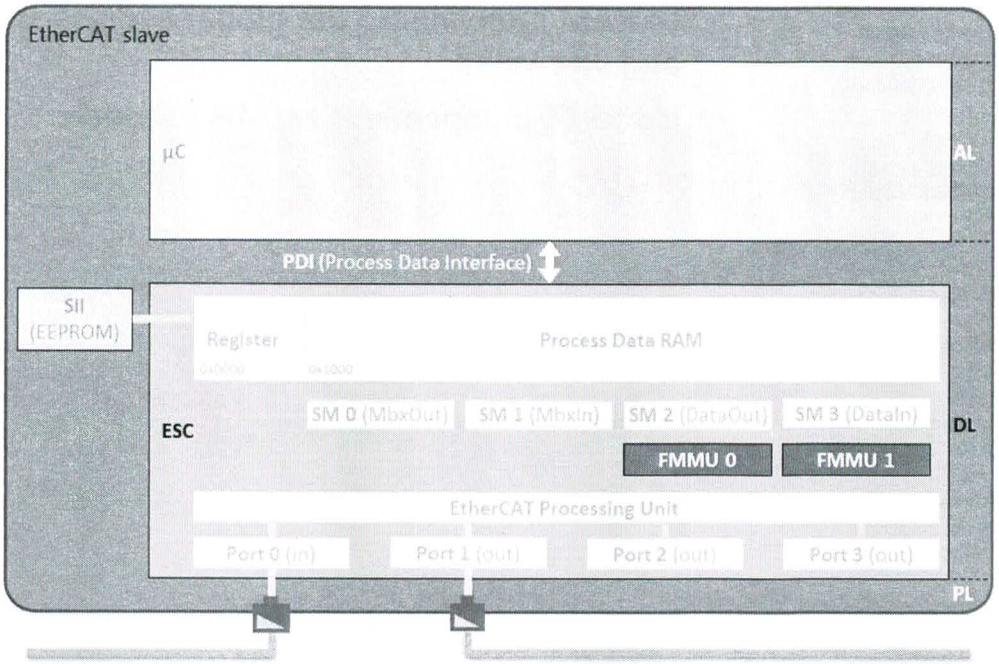

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FMMU | Overview

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- FMMUs (Fieldbus Memory Management Units) map a DPRAM interval into the global address space of master and vice versa
- Up to 16 independent FMMU channels

Fmmu (3)

	Abc Text
1	Outputs
2	Inputs
3	MBoxState

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Bit-wise configuration of the memory section possible

FMMU configuration registers start at $_{ADO}$0x0600

FMMU0:

0x600:0x603 : Logical Start Address

0x604 : 0x605 : Length (number of all concerned Bytes)

0x606 : Logical Start bit (within the first byte)

0x607 : Logical Stop bit (within the last byte)

0x608:0x609 : Physical Start Address

0x60A : Physical Start bit

0x60B : Type (including direction)

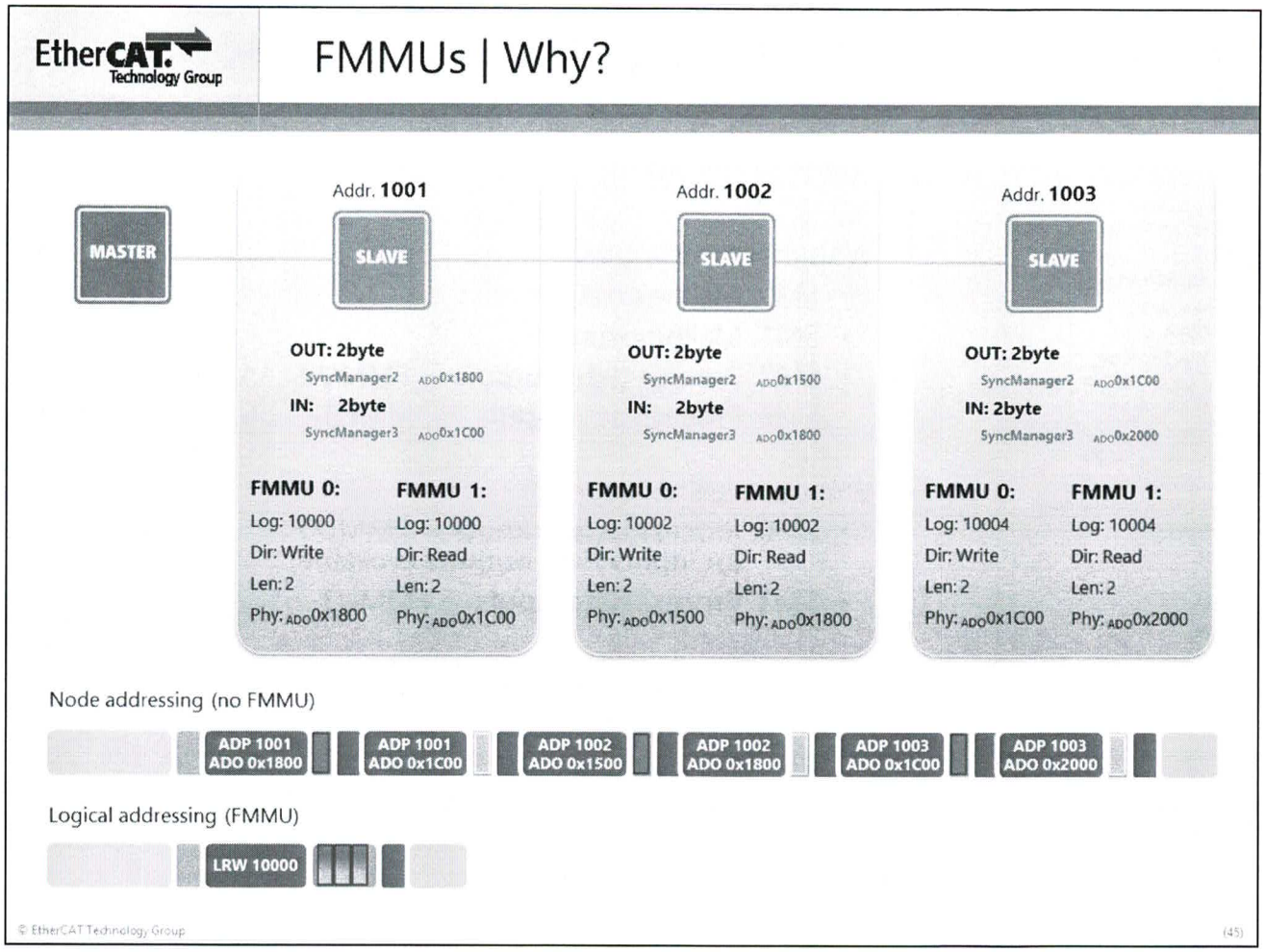
0x60C : Activate

0x60D:0x60F : Reserved

FMMU1:

0x610:0x613 : Logical Start Address

....



- Without FMMUs (APxx, FPxx): each slave needs to be addressed with a single Datagram (10 bytes header, 2 bytes WKC). Each communication direction needs a seperate Datagram (x2).

- With FMMUs (Lxx): each slave reads and writes its data in the same position. Multiple slaves can share the same Datagram.

SyncManager & FMMU | Assignment

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- Standard assignment
  - With mailbox support
    - SM0: Mailbox output
    - SM1: Mailbox input
    - SM2: Process data outputs → FMMU0
    - SM3: Process data inputs → FMMU1
  - Without mailbox support
    - SM0: Process data outputs → FMMU0
      (or inputs if no outputs available)
    - SM1: Process data inputs → FMMU1
- Process data always fits exactly into a SyncManager

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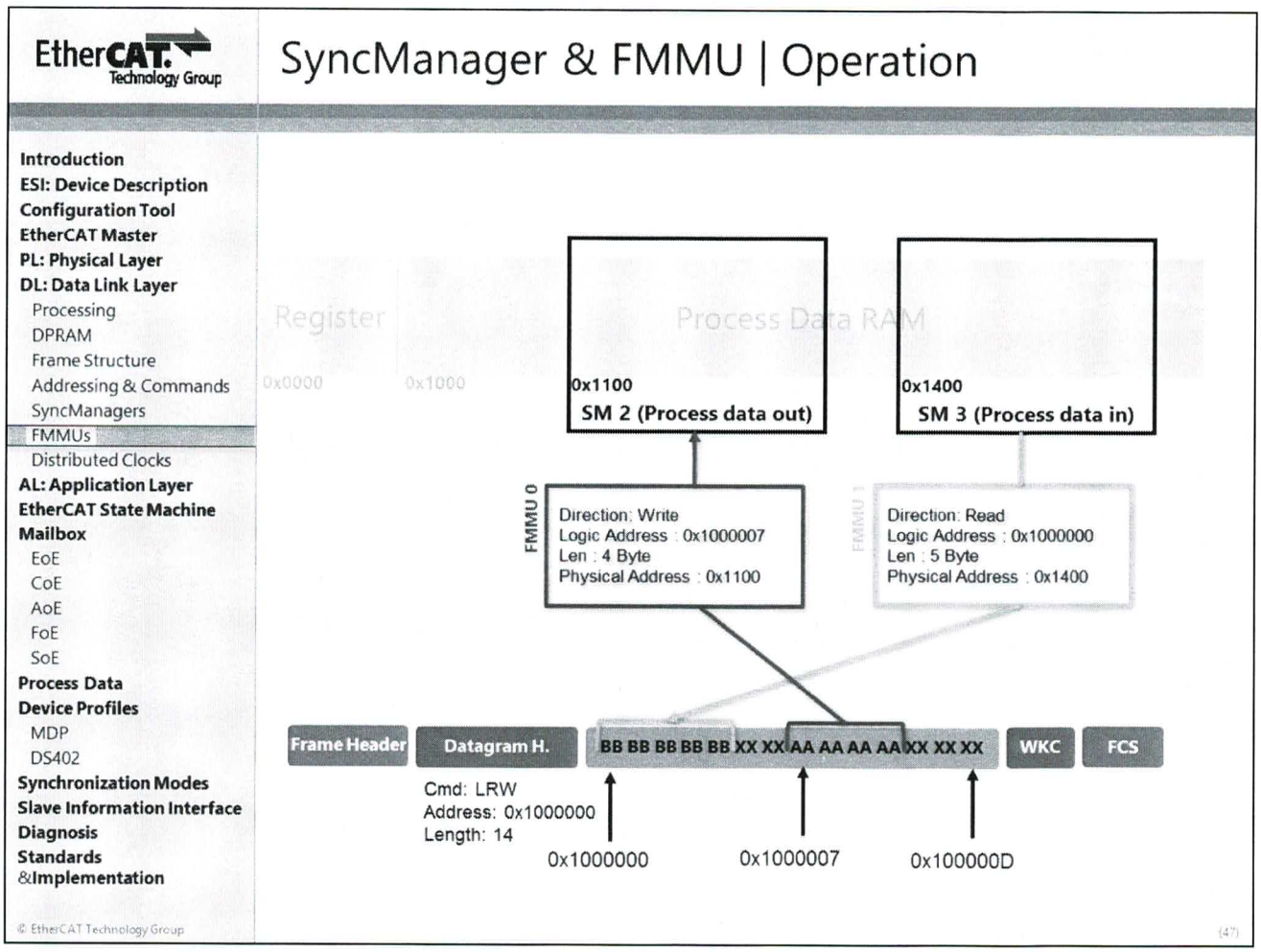

Addresses and Range for the SyncManager are defined by the ESI file

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Distributed Clocks

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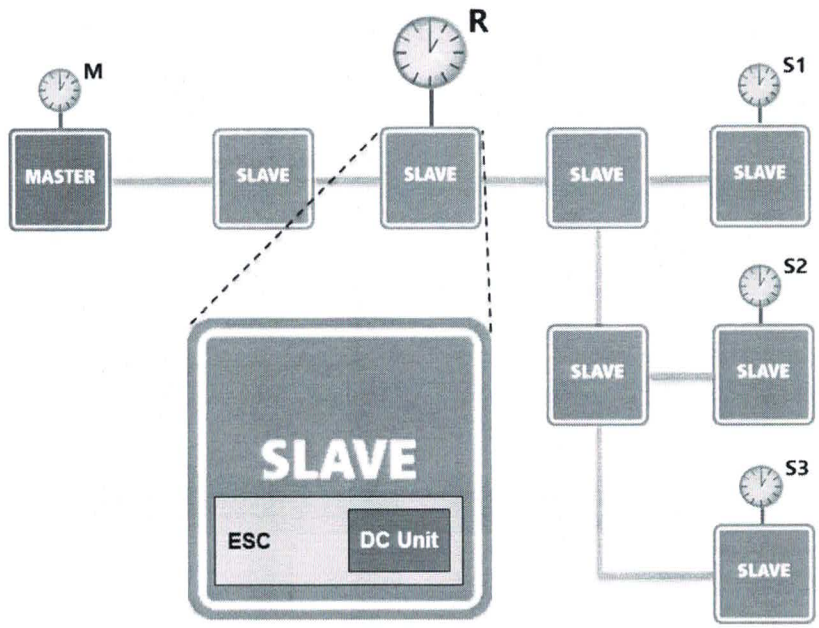
Enable precise synchronization (<< 1 µs) of EtherCAT devices.



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- **System Time**: time shared by all DC-synchronous devices.
  - Beginning: January, 1st 2000 at 0:00h
  - Base unit: 1 ns
  - Format: 64-bit value

- **Reference Clock**: EtherCAT device holding System Time.
  First DC-synchronized slave encountered by frames

- DC synchronization relies on ESC hardware features:
  Latch of local time value on each port when triggered by master
  Adjustment of local clock speed based on an external set-point

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DC | Operation

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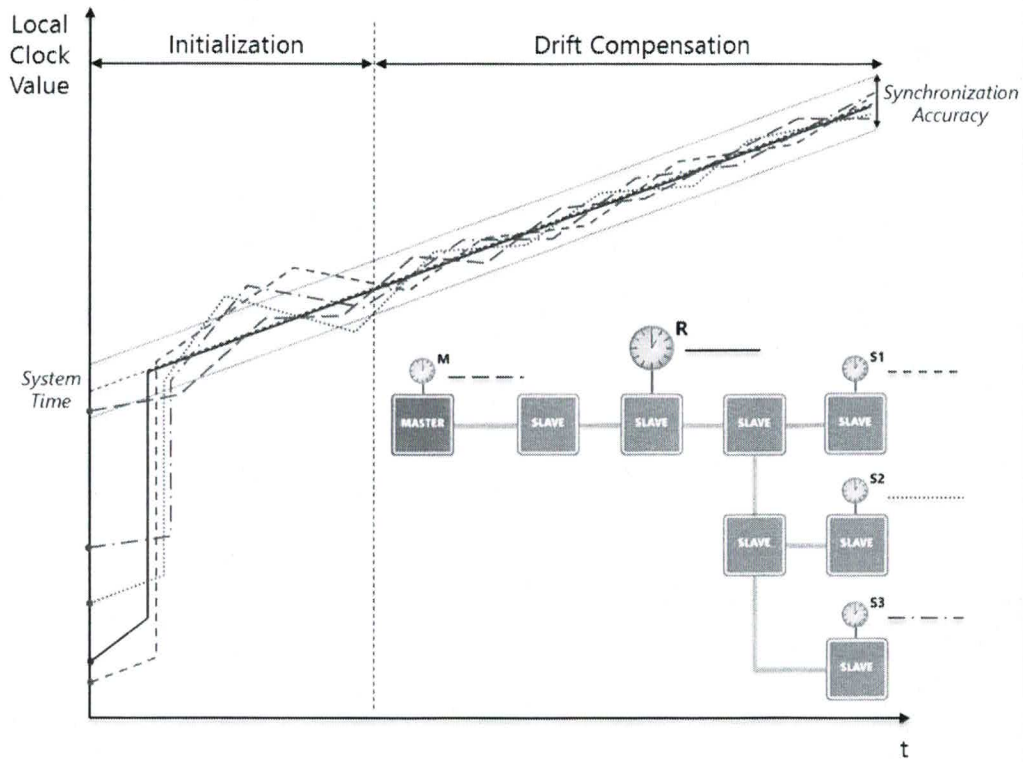

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DC operation consists of 2 phases:

- **Initialization**: initially independent clocks are adjusted to the System Time definition
- **Drift Compensation**: following deviations are corrected in order to keep synchronization

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DC | Initialization & Drift Compensation

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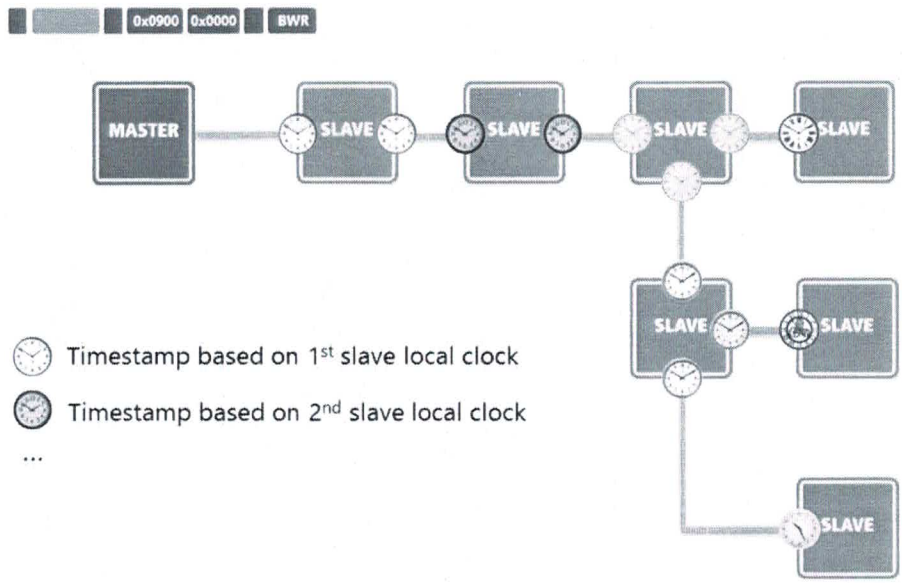
- The master triggers slaves to latch their local time values when a standard command is received on each port.



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- Latch is activated by write access to $_{ADO}$0x0900
  - Local time at port X is latched at SOF (Start of Frame)
  - At EOF (End of Frame) latched time at port X is copied into $_{ADO}$(0x0900+4*X)
- $_{ADO}$(0x0900+4*X) is in local clock units (at this stage, the local clock in each slave is still uncorrelated from others)

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DC | Initialization & Drift Compensation

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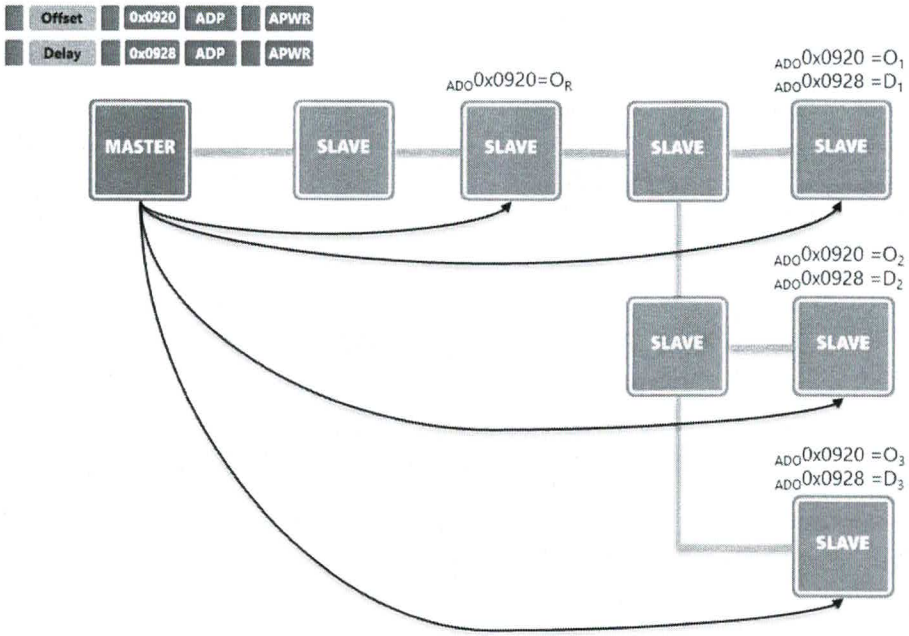
- The master reads time values latched from each slave, and calculates an offset and a delay for each DC device.



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- **Offset**: absolute difference between the local clock of slave N and the standard definition of System Time
- **Delay**: propagation time of frames between the reference clock and slave N

~ 100ns Accuracy
with 300 Devices

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DC | Initialization & Drift Compensation

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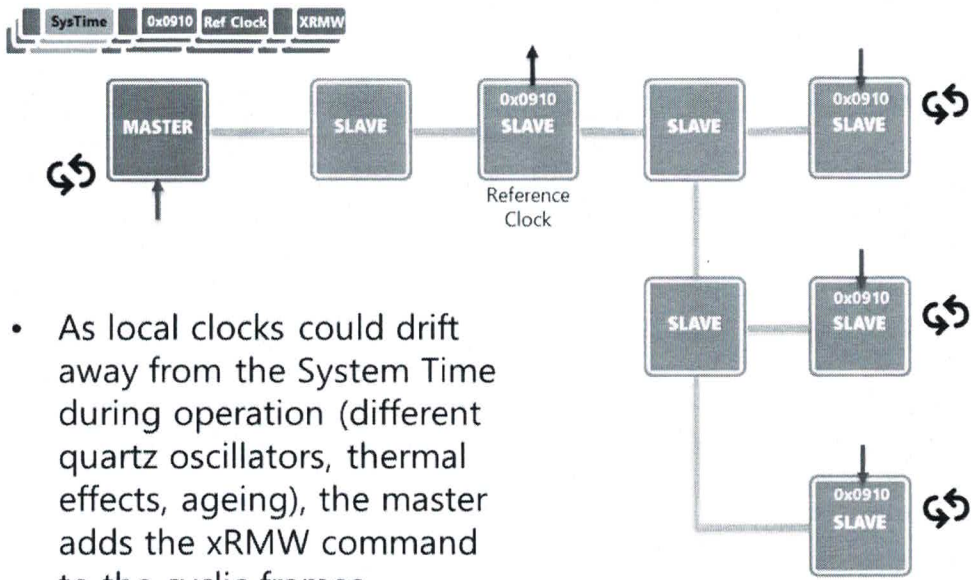
- Residual misalignments between local clocks are by triggering slaves to adjust clock speed multiple times.



- As local clocks could drift away from the System Time during operation (different quartz oscillators, thermal effects, ageing), the master adds the xRMW command to the cyclic frames.

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Whenever $_{ADO}$0x0910 is written, slave compares received System Time with its local time (corrected with Delay and Offset:

- (Local Clock + Offset) – (Received System Time + Delay) > 0 → Local Clock decelerates
- (Local Clock + Offset) – (Received System Time + Delay) < 0 → Local Clock accelerates

Sync Events

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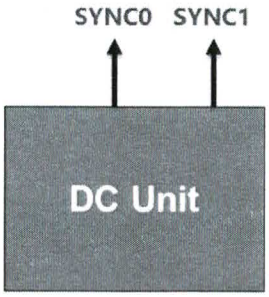
- Digital outputs for the ESC: are set when the System Time reaches predefined values.



- Can be used as:
  - Direct digital outputs (simple devices)
  - Interrupt sources for µC (complex devices)

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Sync Signal Generation Modes

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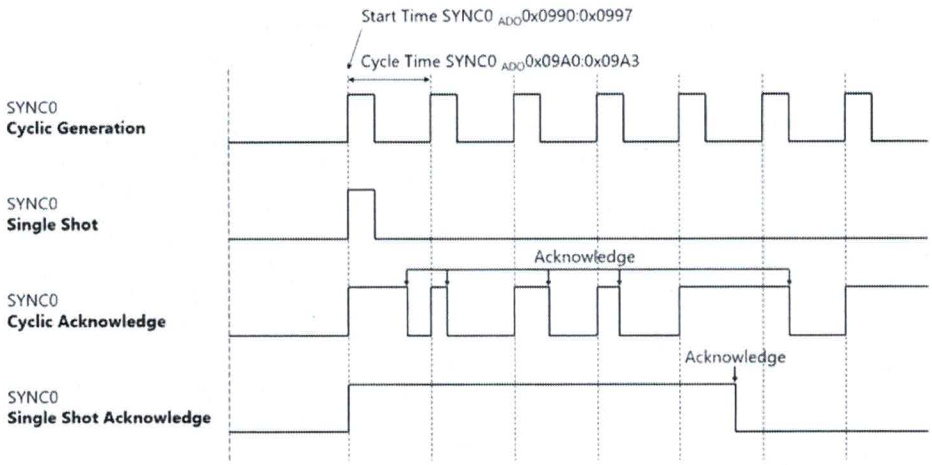
- Four operation modes are supported for SYNC signals (configured via dedicated registers).



- Second sync event (SYNC1) has a multiple integer period and optionally an offset with respect to SYNC0 event.

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Latch Events

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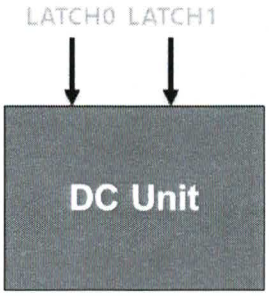
- Digital inputs for the ESC: when a positive and/or negative edge is detected, the corresponding System Time value is stored.



- The *Latch Time* registers ($_{ADO}$0x09B0:0x09CF) contain the stored time stamps
  - Can be cyclically read by the master as process data
- Single or continuous latch configurable

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AL | µC

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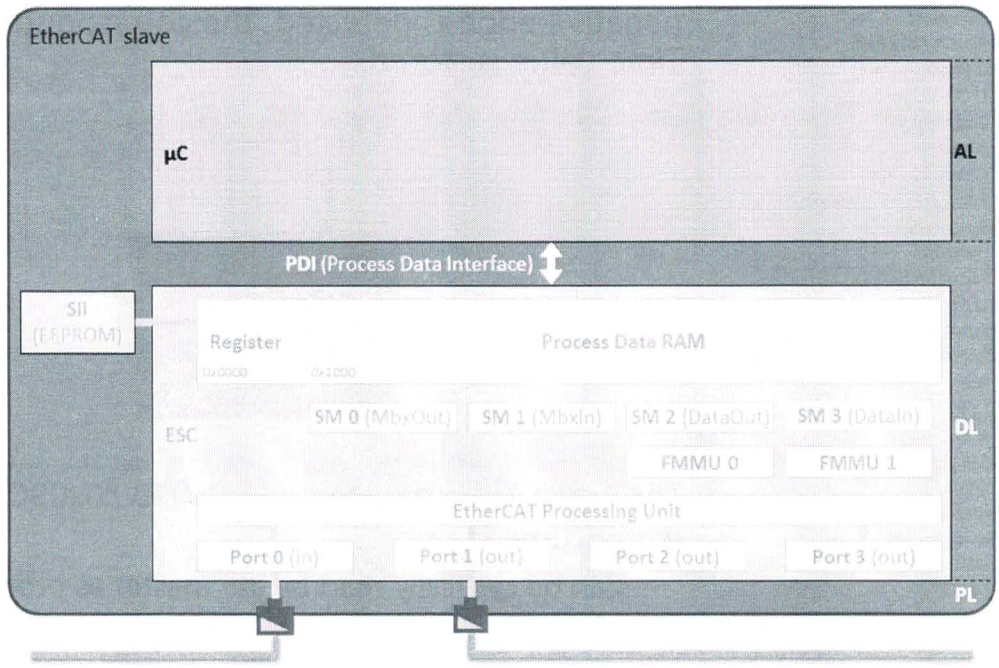

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Purpose of Application Layer (AL)

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- EtherCAT State Machine
  - Boot-up of device
  - Error handling
- Mailbox communication
  - Access parameters of an EtherCAT slave
  - Asynchronous transfer
  - Mailbox protocols
    - Ethernet over EtherCAT (EoE)
    - CAN application protocol over EtherCAT (CoE)
    - File transfer over EtherCAT (FoE)
    - Servo Drive over EtherCAT (SoE)
    - ADS over EtherCAT (AoE)
- Process data handling

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AL | EtherCAT State Machine (ESM)

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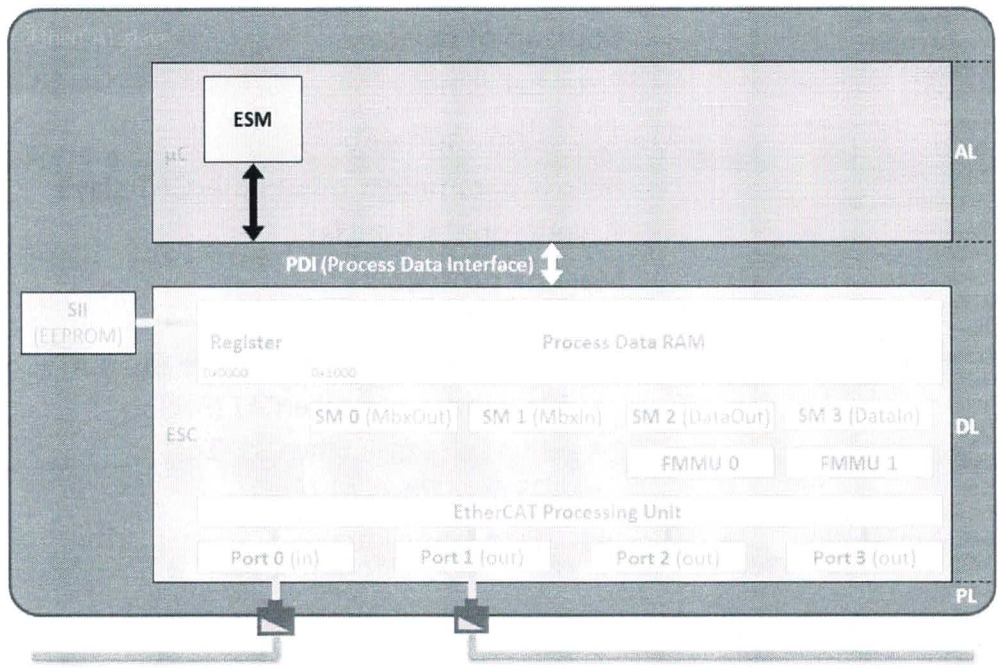

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Purpose of EtherCAT State Machine

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- Defines general communication states of EtherCAT slave devices
- Specifies the initialization and error handling of EtherCAT slave devices → Boot-up of the network
- States correspond to the communication relationship between master and slave
- Requested and current state of a slave device are reflected in the AL Control and AL Status registers

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EtherCAT State Machine

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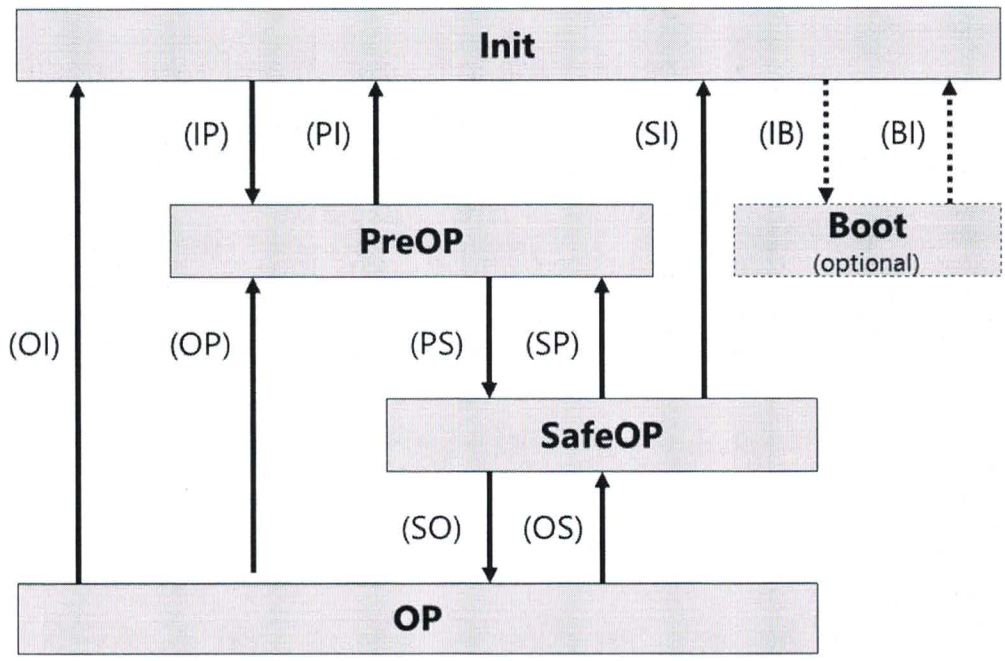

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- **Init** = Initialization
- **PreOP** = Pre-Operational
- **SafeOP** = Safe-Operational
- **OP** = Operational
- **Boot** = Bootstrap

State: INIT

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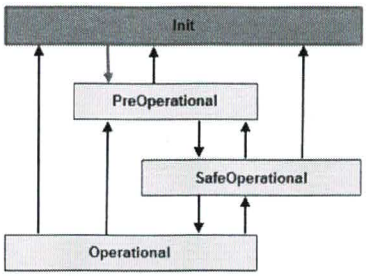
- **Init State**
  - No communication on the Application Layer
  - Master has access to the DL-Information registers



- **Transition to PreOP**
  - Master configures register, at least:
    - EtherCAT Fixed Address ($_{ADO}$0x0010)
    - Mailbox SyncManagers
  - Master requested PreOperational state
    - sets AL Control register
    - wait for AL Status register confirmation

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State: PREOP

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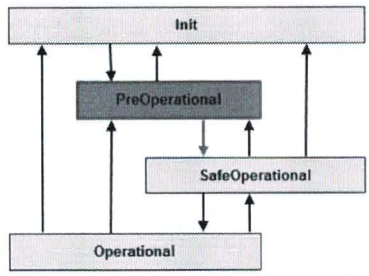
- **PreOP State**
  - Mailbox communication on the Application Layer
  - No Process Data communication



- **Transition to SafeOP**
  - Master configures application parameters using the Mailbox
    - e.g.: process data mapping, application-specific settings
  - Master configures DL Register
    - Process Data SyncManagers
    - FMMUs
  - Master requested SafeOperational state
    - sets AL Control register
    - wait for AL Status register confirmation

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State: SAFE-OP

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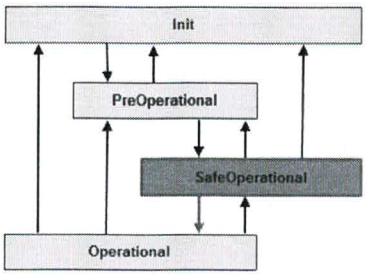
- **SafeOP State**
  - Mailbox communication on the Application Layer
  - Process Data communication, but only Inputs are evaluated – Outputs in 'Safe' state



- **Transition to OP**
  - Master sends valid Outputs
  - Master requests Operational state
    - sets AL Control register
    - wait for AL Status register confirmation

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State: OP

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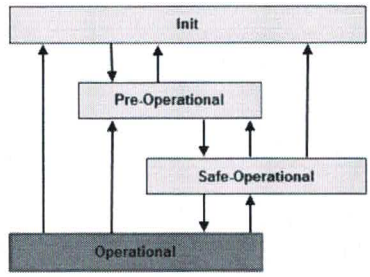
- **OP State**
  - Inputs and Outputs are valid



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State: BOOT

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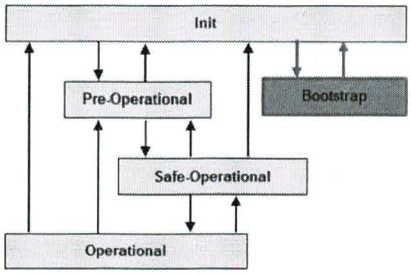
- **Boot State**
  - Boot State is optional – but recommended if firmware updates necessary
  - State changes only from and to 'Init'
  - No Process Data communication
  - Communication via Mailbox on Application Layer
  - Special mailbox configuration possible, e.g. larger mailbox size
  - Only FoE protocol (file transfer) available



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EtherCAT State Machine: Control and Status

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- Registers for EtherCAT State Machine (ESM)
  - **AL Control** ($_{ADO}$0x0120)
    - Master requests a new state to the slave
    - Master acknowledges state machine errors
  - **AL Status** ($_{ADO}$0x0130)
    - Slave reports its current state
    - Slave indicates state machine errors
  - **AL Status Code** ($_{ADO}$0x0134)
    - In case of error (e.g. rejecting) an error code is set

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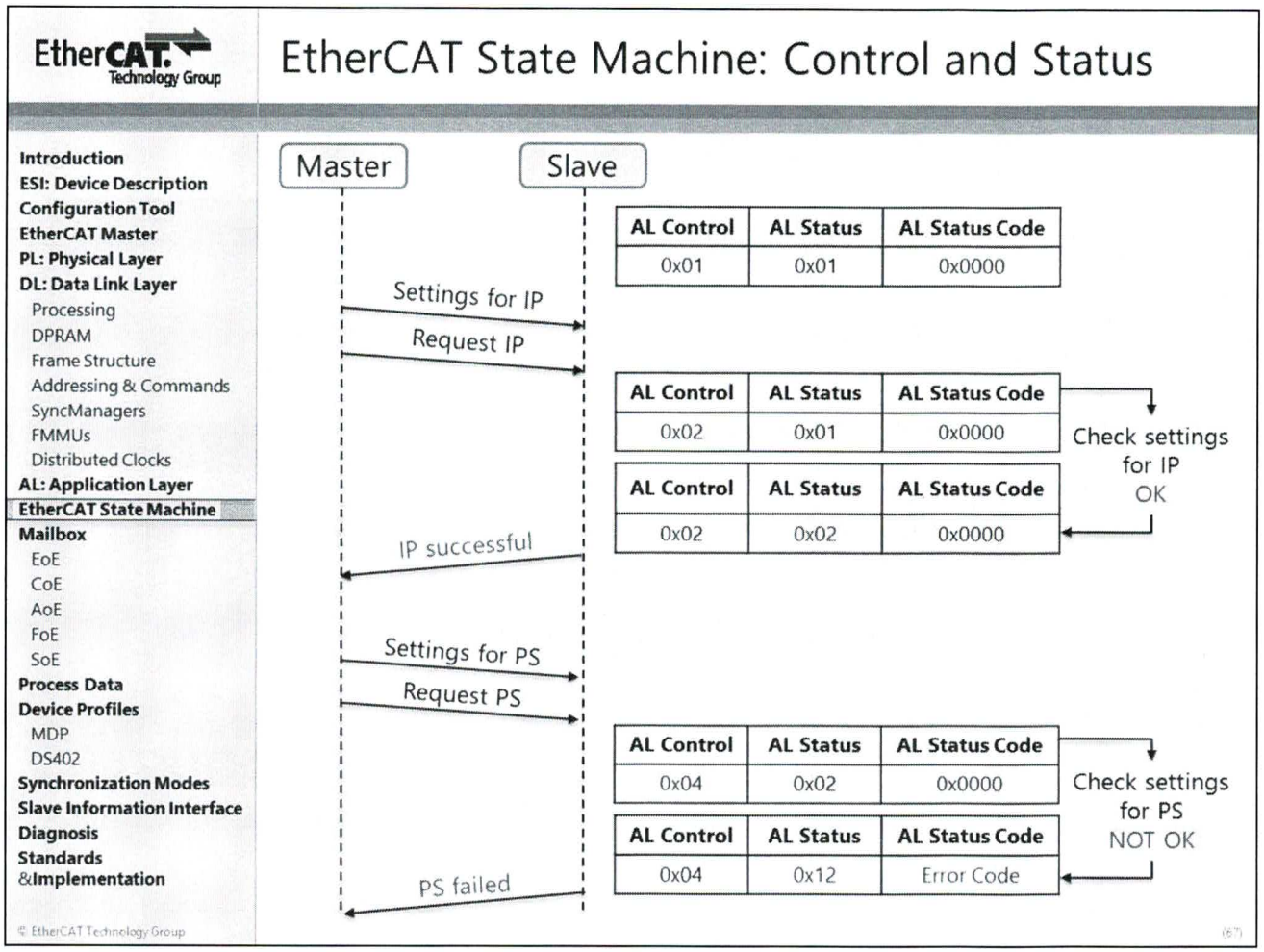

AL Status Codes are specified in ETG.1020.

AL | Mailbox

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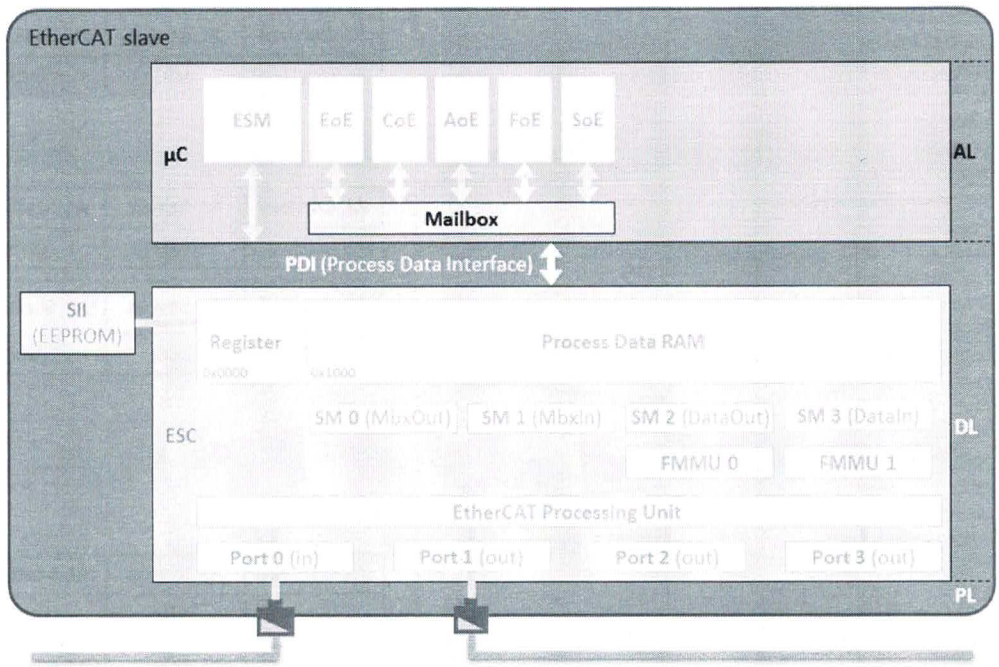

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Mailbox Transfer (acyclic communication)

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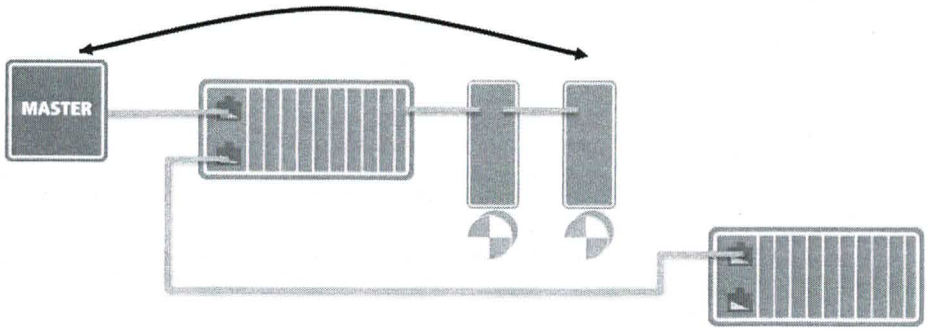
Mailbox transfer (e.g. parameter data)

Communication in both directions



- Available from state PreOperational
- 2 dedicated SyncManagers
  - SM0 ("MBoxOut"): Master to Slave
  - SM1 ("MBoxIn"): Slave to Master
- Multiple protocols defined
- Simple IO-Device (no parameter) → no Mailbox necessary

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Mailbox Transfer

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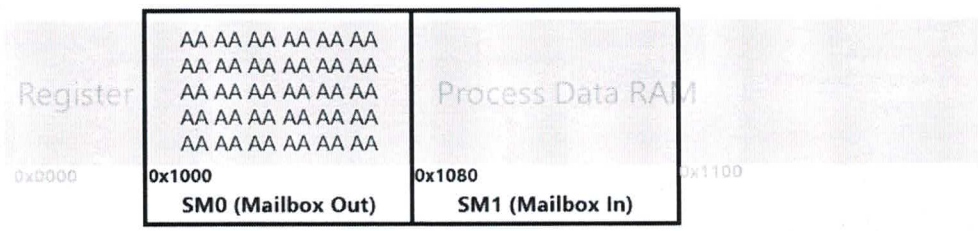

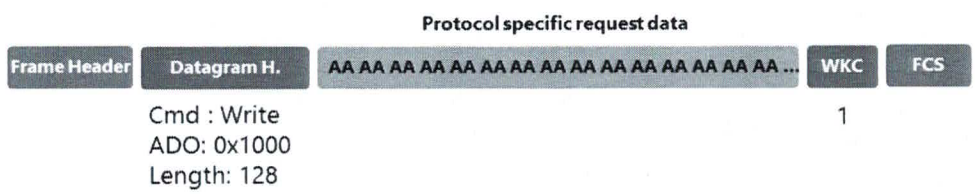

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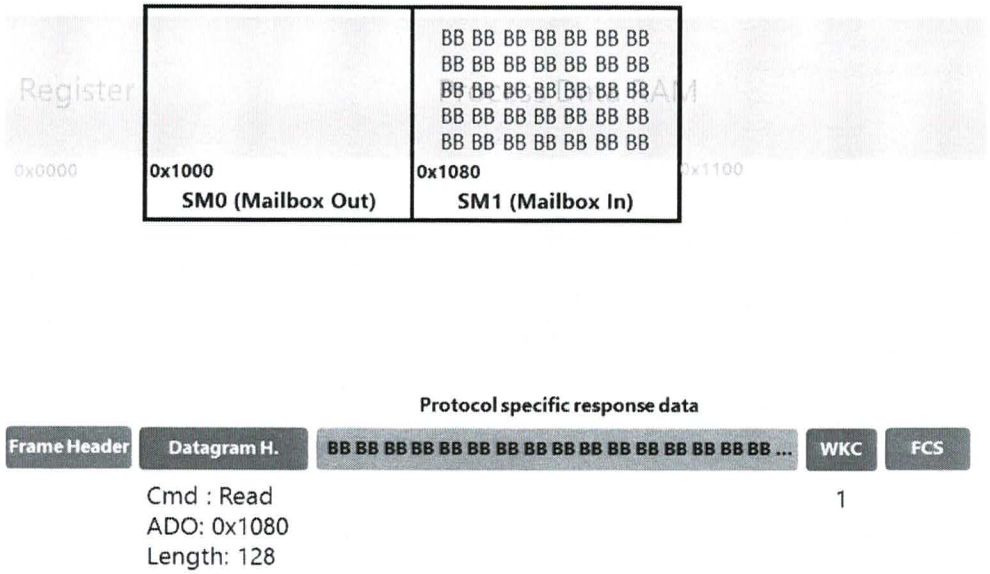

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Mailbox Interface Datagram

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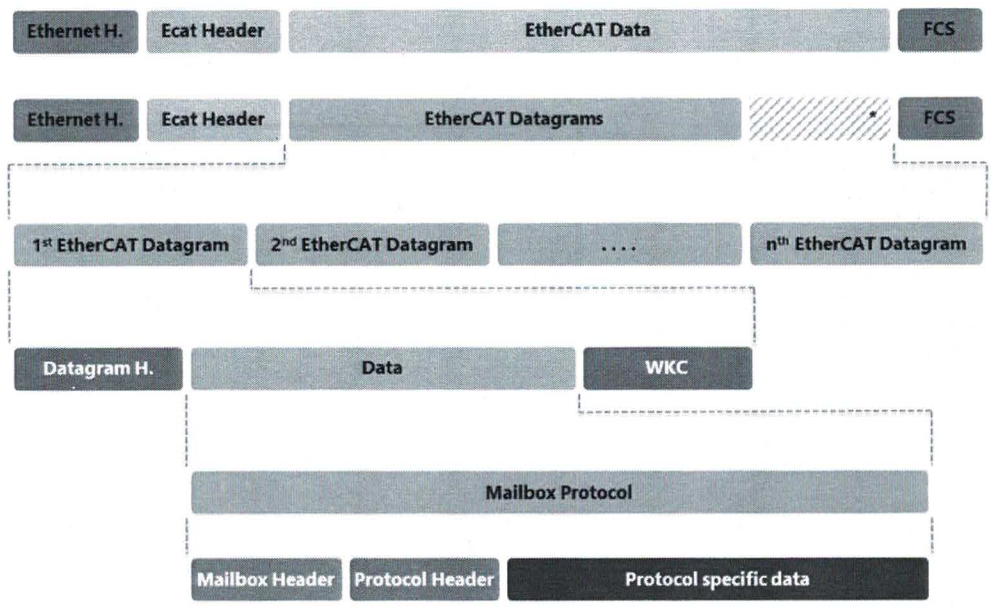

*add 1-32 padding bytes if Ethernet frame is less than 64 bytes

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Mailbox Header

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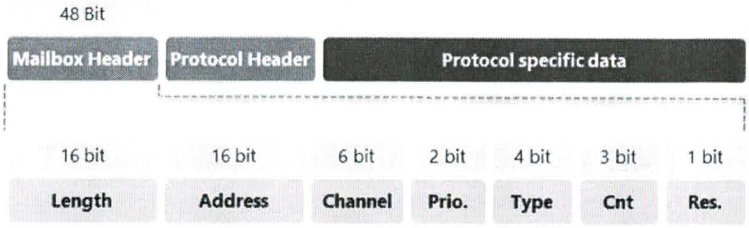

Length	Length of following data in byte
Address	Fixed address of source slave (S -> M) Fixed address of the destination slave (M->S)
Channel	reserved for future use
Priority	reserved for future use
Type	Mailbox Type, Protocol identifier for following data 0 Mailbox Error 1 AoE (ADS over EtherCAT) 2 EoE (Ethernet over EtherCAT) 3 CoE (CAN application protocol over EtherCAT) 4 FoE (File Access over EtherCAT) 5 SoE (Servo Drive over EtherCAT) 15 VoE (Vendor specific profile over EtherCAT)
Cnt	Sequence number Iterates from 1-7 with every new mailbox service

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Mailbox Protocol Types

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- Ethernet over EtherCAT (**EoE**)
  - Tunnels standard Ethernet communication (e.g. TCP/IP) over EtherCAT
- CAN application protocol over EtherCAT (**CoE**)
  - Access of a CANopen® object dictionary
- ADS over EtherCAT (**AoE**)
  - Routes data to subordinated or cascaded systems
- File Access over EtherCAT (**FoE**)
  - Download and upload files (e.g. firmware download)
- Servo Drive over EtherCAT (**SoE**)
  - Access the Servo Profile Identifier (IDN)
- Vendor specific Profile over EtherCAT (**VoE**)
  - Vendor specific protocol tunneled over EtherCAT

FSoE in Coe

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* CANopen is a trademark of the CAN in Automation e.V.

AL | EoE

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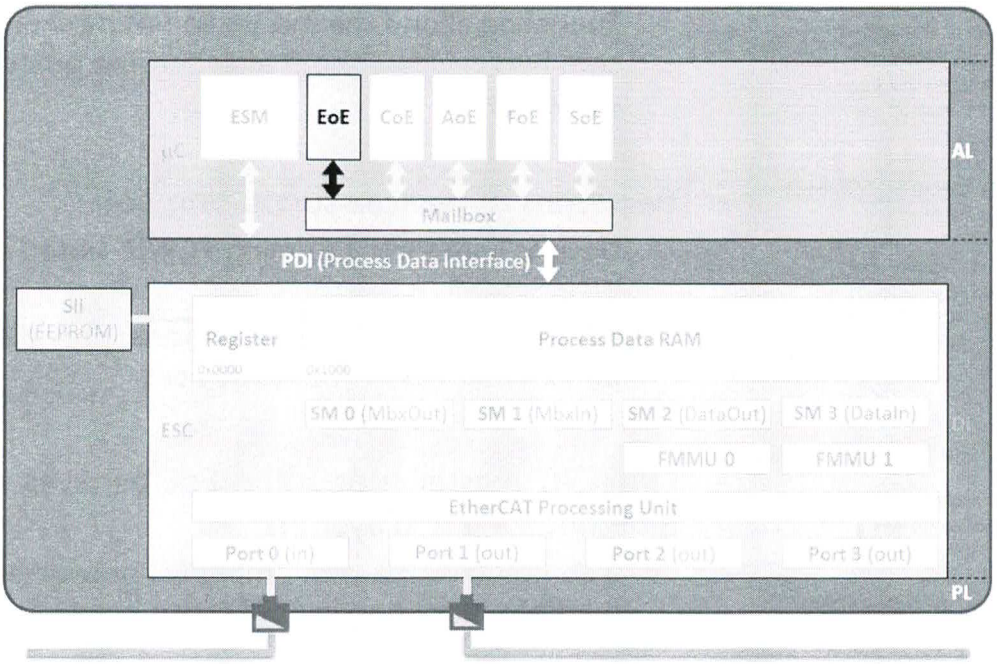

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Ethernet over EtherCAT (EoE)

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- Tunnels Ethernet communication over EtherCAT
  - Tunneling allows the master to optimize Ethernet communication without affecting the process data exchange.
- Two types of devices supporting EoE
  - Devices with locally running TCP/IP-based applications (e.g. Web Server)
  - Infrastructure devices (Switchports) providing connection for external TCP/IP-based devices.
- EtherCAT master supporting EoE behaves as 'Virtual Ethernet Switch' (Layer 2)
  - If communication with other LAN networks shall be possible, IP routing in OS/Master needed.

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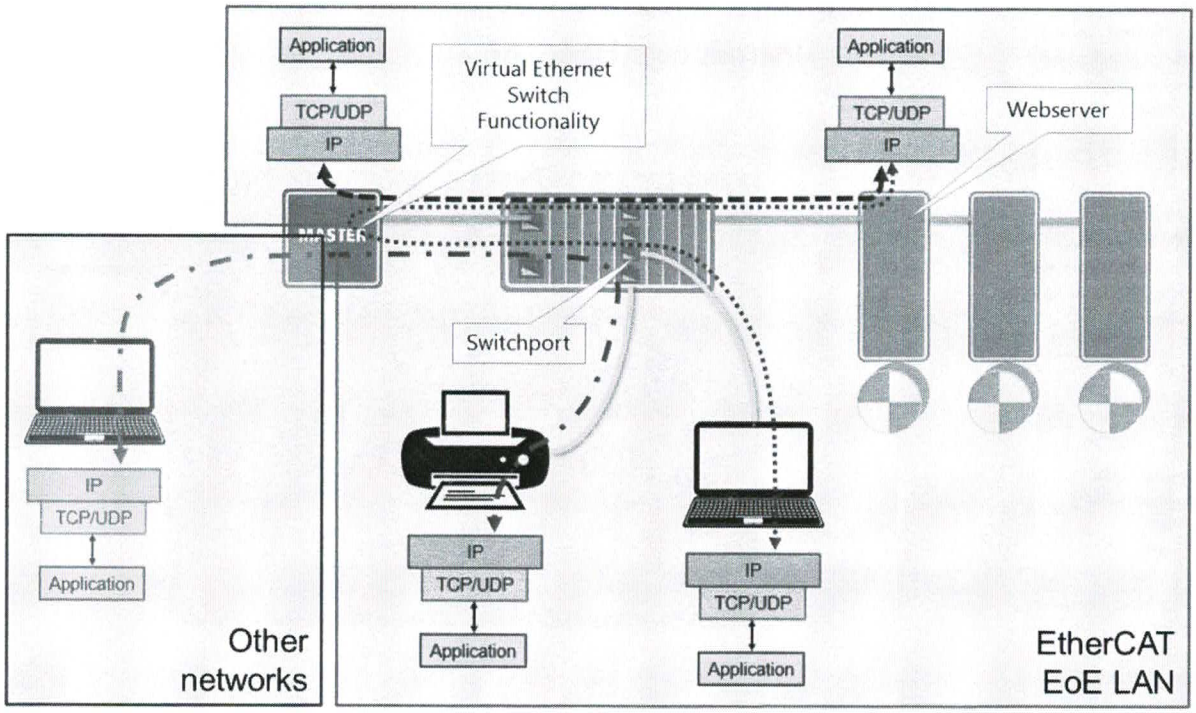
EoE Architecture

- TCP/IP end points are connected transparently



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TCP/IP traffic can be routed both within the EtherCAT EoE LAN and to/from other networks (in this case, IP Routing in master device is needed).

EoE Switchport: Any Ethernet Protocol

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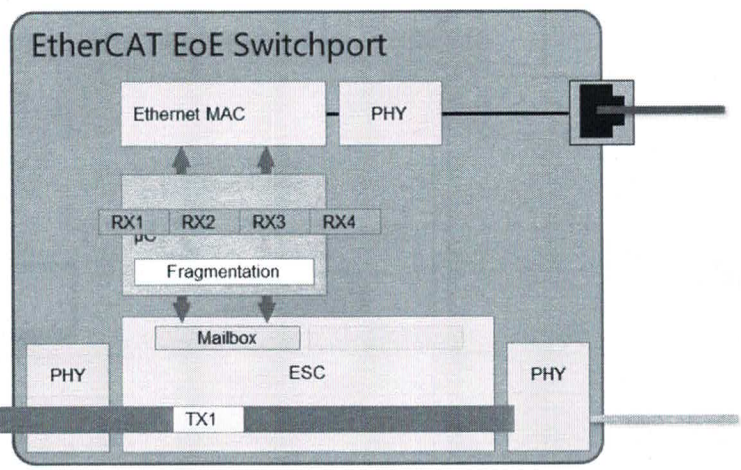
- Interface to any Ethernet Device or Network
- Ethernet Frames are inserted into EtherCAT Protocol:
  - 'Ethernet over EtherCAT'



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AL | CoE

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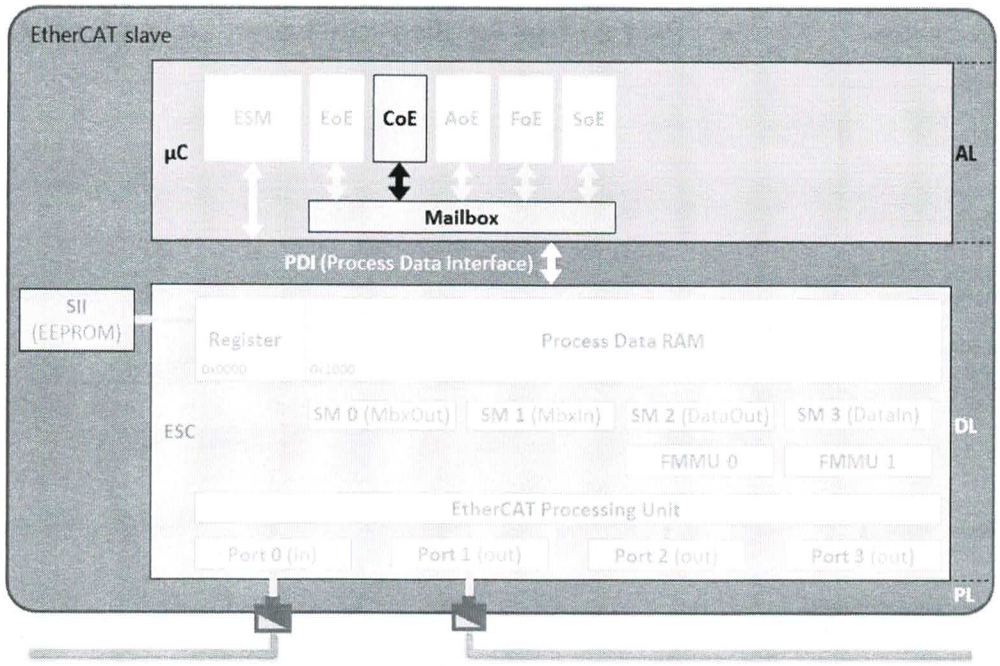

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- Recommended protocol for service data access
  - Configuration of communication parameter
  - Configuration of device specific parameter

- Easy migration path from CANopen® Devices to EtherCAT device supporting CoE protocol Stacks can be re-used

Object Dictionary (OD)

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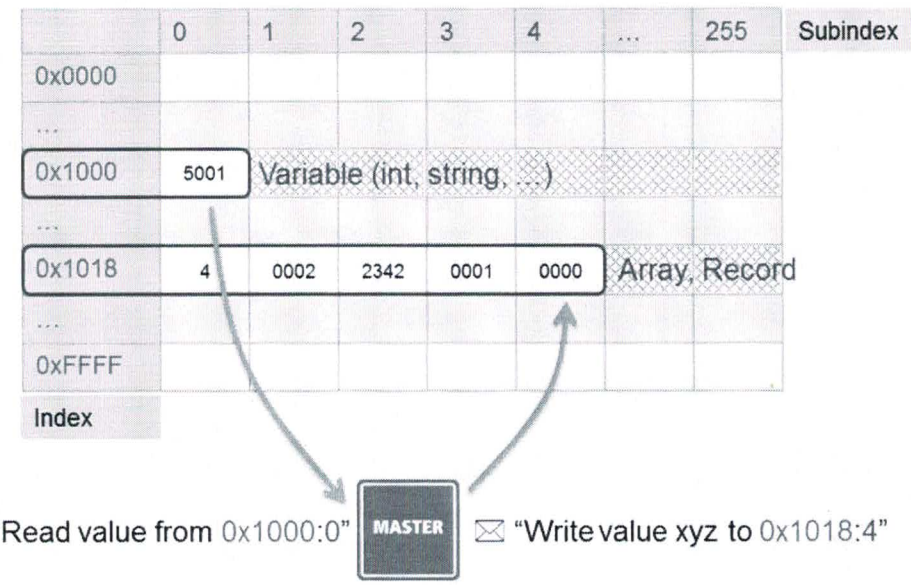
- Table of variables, addressed by *Index* and *Subindex*
- Part of the Application Layer, i.e. part of stack



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	0	1	2	3	4	…	255	Subindex
0x0000								
…								
0x1008	'Slave'							
…								
0x1018	4	0002	2342	0001	0000			
…								
0xFFFF								
Index								

5 value

Does not exist

"Object"

"Object entry"

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Object Dictionary Structure

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Specified areas within the object dictionary

Index	Use
0x0000 – 0x0FFF	Data type area Examples: 0x0001 – Boolean 0x0008 – Real32 ...
0x1000 – 0x1FFF	Communication area Examples: 0x1008 – Device Name 0x1018 – Identity Object (Vendor ID, S/N, ...) ...
0x2000 – 0x5FFF	Manufacturer specific area Examples: Parameters and process data of the device ...
0x6000 – 0xFFFF	Profile specific area Examples: Parameters and process data of the device, specified in a profile (e.g. servo drive). ...

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Object Dictionary in ESI

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OD is described in element Profile of ESI file.

Profile
- ChannelInfo (3)
- Dictionary
  - DataTypes
  - Objects
    - Object (23)

	Index	Name	Type	BitSize	Info	Flags
1	#x1000	Device type	UDINT	32	Info	Flags
2	#x1001	Error register	USINT	8	Info	Flags
3	#x1008	Device name	STRING(51)	408	Info	Flags
4	#x1009	Hardware version	STRING(4)	32	Info	Flags
5	#x100A	Software version	STRING(4)	32	Info	Flags
6	#x1018	Identity	DT1018	144	Info	
7	#x10F1	Error Settings	DT10F1	64	Info	
8	#x10F8	Timestamp Object	ULINT	64		Flags
9	#x1601	DO RxPDO-Map	DT1601	304	Info	
10	#x1802	TxPDO Parameter	DT1802	24	Info	
11	#x1A00	DI TxPDO-Map	DT1A00	304	Info	
12	#x1A02	AI TxPDO-Map	DT1A02	272	Info	
13	#x1C00	Sync manager type	DT1C00	48	Info	
14	#x1C12	RxPDO assign	DT1C12	32	Info	
15	#x1C13	TxPDO assign	DT1C13	48	Info	
16	#x1C32	SM output parameter	DT1C32	488	Info	
17	#x1C33	SM input parameter	DT1C33	488	Info	
18	#x6000	DI Inputs	DT6000	24	Info	
19	#x6020	AI Inputs	DT6020	48	Info	
20	#x7010	DO Outputs	DT7010	24	Info	
21	#x8020	AI Settings	DT8020	112	Info	
22	#xF000	Modular Device Profile	DTF000	48	Info	
23	#xF010	Module Profile List	DTF010	112	Info	

→ Altova XML Spy® 2013

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SDO & PDO

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Service Data Object

- Access to an Object acyclically using Mailbox services
- Used for parameters, diagnostics, ...

Process Data Object

- CANopen®: Access to objects cyclically as process data, but EtherCAT does not use Mailbox communication for process data

  → PDO: "application data package, intended to be transmitted cyclically as process data"

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*) CANopen® is a registered trademark of the CAN in Automation e.V., Erlangen, Germany

CoE Services: SDO Down-/Upload

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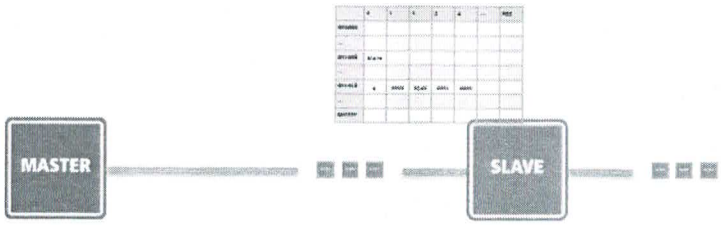

SDO Download — "Activate Filter" — Write value to OD of a specific device

SDO Upload — "Diag Message" — Read value from OD of a specific device

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CoE Services: SDO Information

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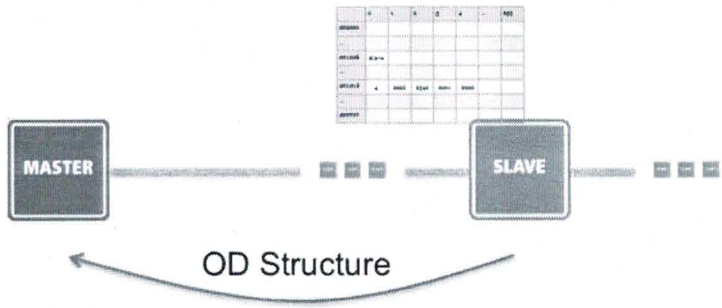

Information about OD
- Available objects (list of indexes)

Description of an Object
- Name
- Code (Variable, Array, Record)

Description of an Object Entry
- Name
- Access rights
- …

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Example: SDO Download (Request)

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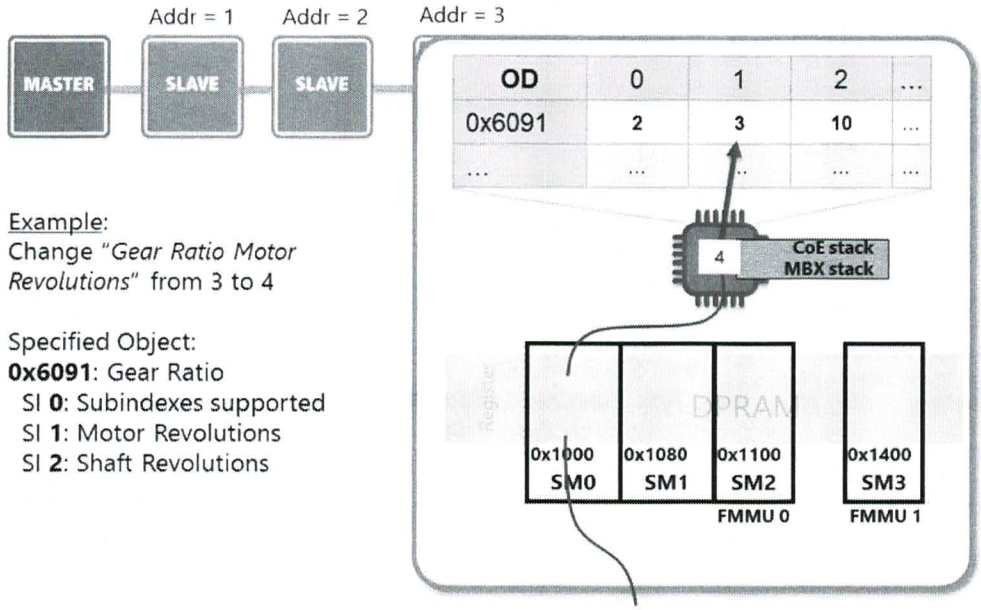
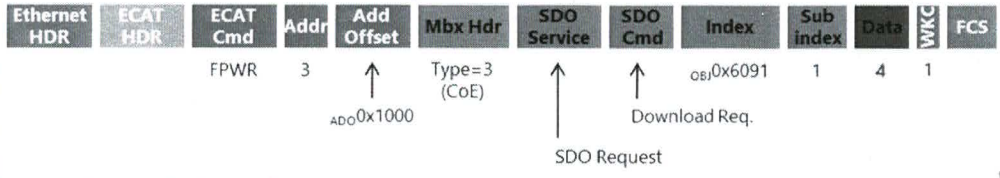


Example:
Change *"Gear Ratio Motor Revolutions"* from 3 to 4

Specified Object:
0x6091: Gear Ratio
SI **0**: Subindexes supported
SI **1**: Motor Revolutions
SI **2**: Shaft Revolutions



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Example: SDO Download (Response)

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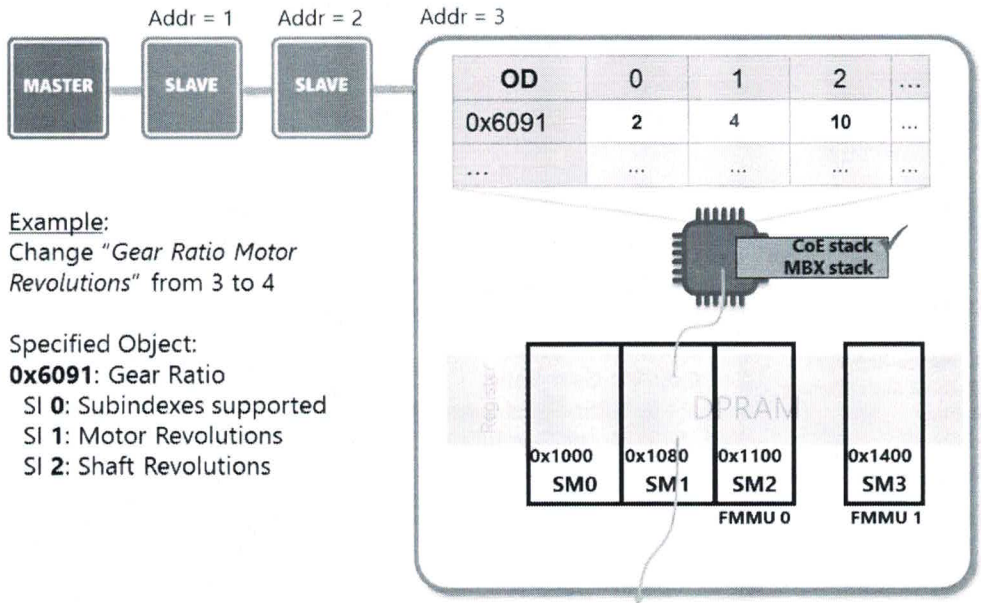

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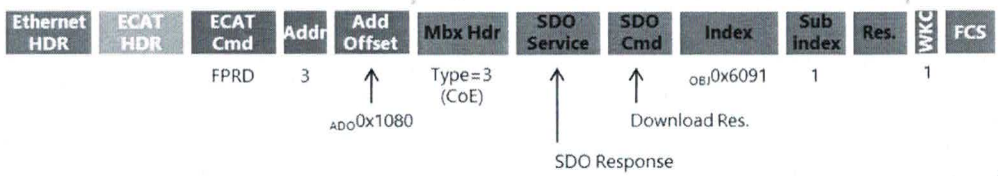

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CoE | Object Dictionary (example)

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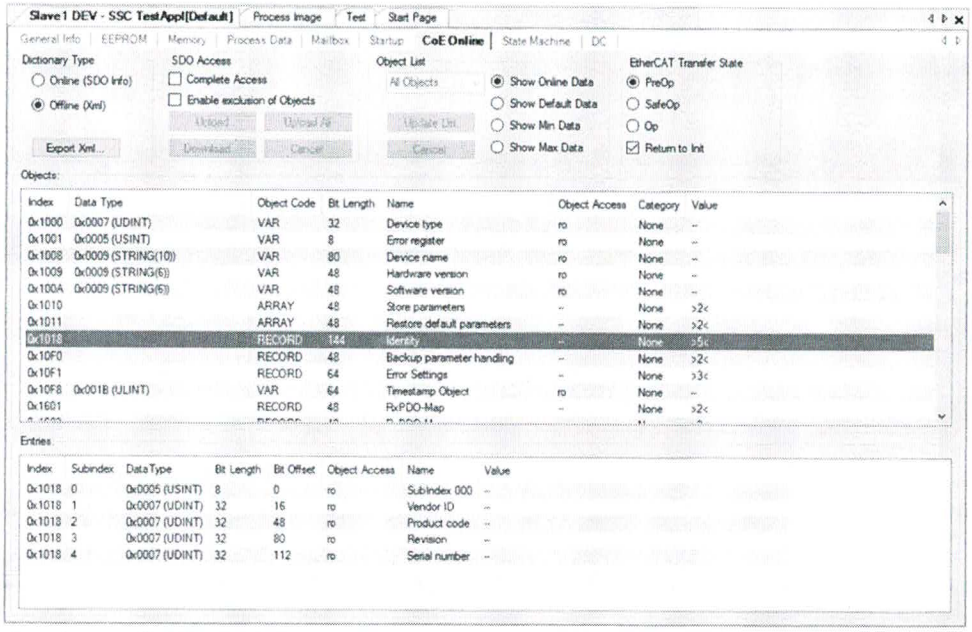

→ Conformance Test Tool 2.1.34.0

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AL | AoE

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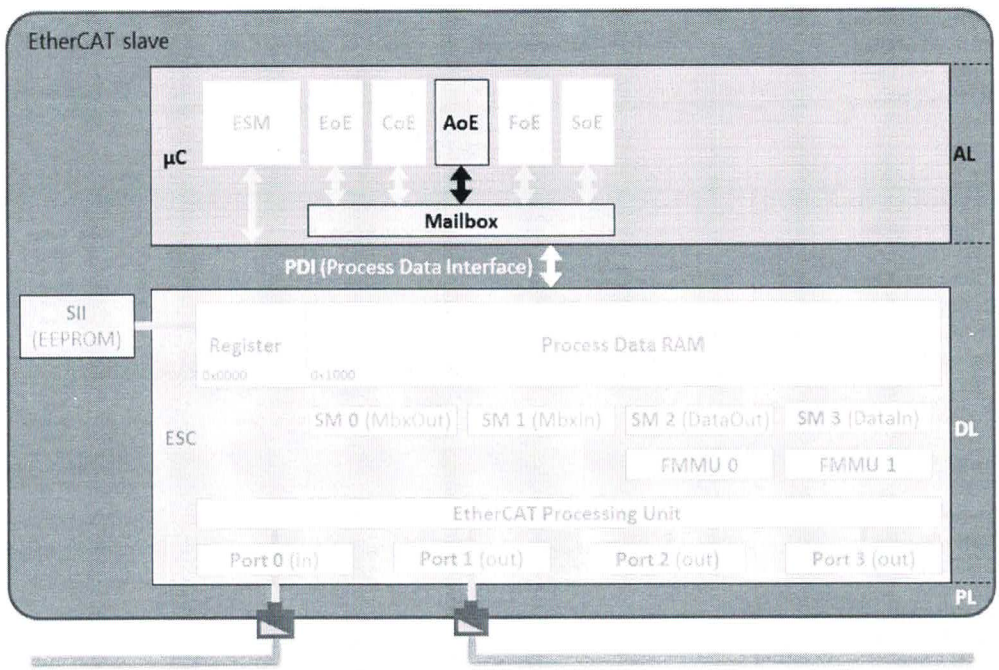

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AoE | Client-Server Relationship

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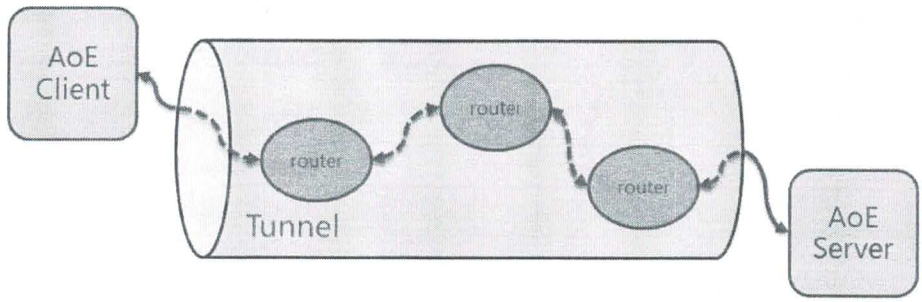
AoE (ADS over EtherCAT) is a client-server protocol:



- Provides tunneling and routing mechanisms through EtherCAT, yet requiring no TCP/IP stack (≠ EoE)
- Identifies messages uniquely, enabling transfer of parallel services (≠ CoE)
- Can map other Mailbox protocols as payload
- Standard for acyclic data transfer on EAP

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5 services defined:

- **Read**: Read data from AoE server
- **Write**: Write data to AoE server
- **ReadWrite**: Write data to, and read data from AoE server
- **WriteControl**: Change state of AoE server or its sub-device
- **Fragmentation**: Fragmentation of one of previous AoE services

AoE | User Case: Gateways

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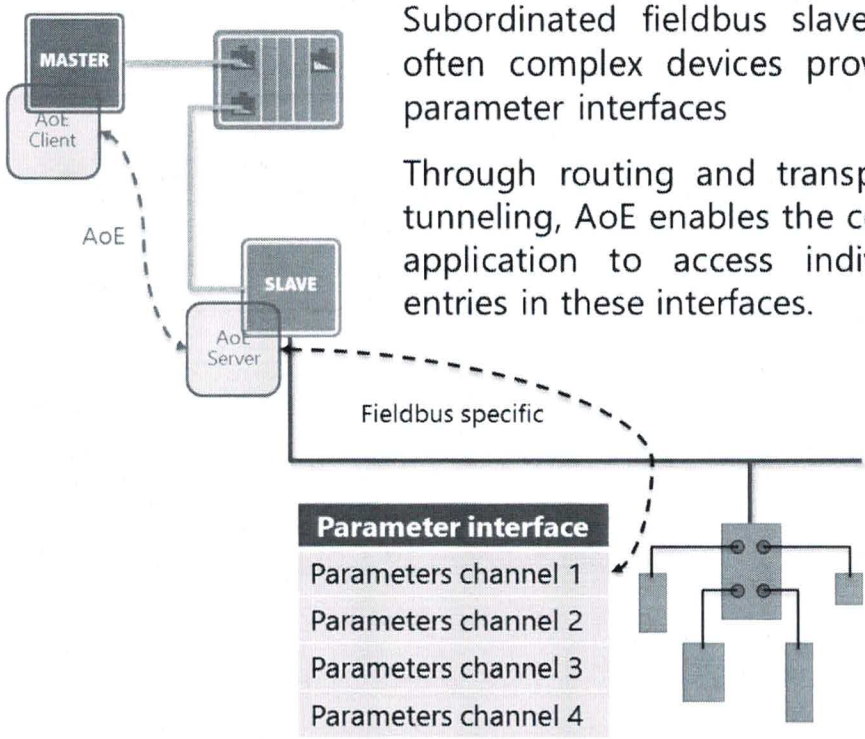

Subordinated fieldbus slaves are often complex devices providing parameter interfaces

Through routing and transparent tunneling, AoE enables the control application to access individual entries in these interfaces.

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AL | FoE

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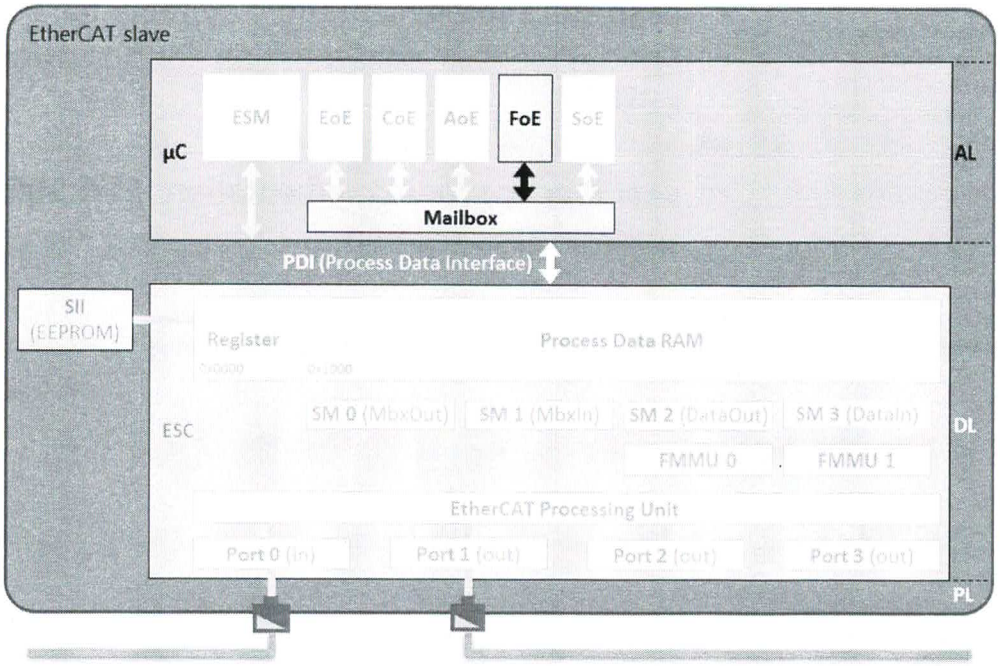

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File Access over EtherCAT (FoE)

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Standards &Implementation

- Similar to TFTP (Trivial File Transfer Protocol, RFC 1350)
- Lean stack implementation, suitable for bootstrap loaders
- Special mailbox configuration for bootstrap mode possible

- Best Practice for implementation: **ETG.5003** Part 2 "FW Update" specification

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6 services defined:

- **WRQ**: Write request with "file name"
- **RRQ**: Read request with "file name"
- **DATA**: Data block (full mailbox size used)
- **ACK**: Acknowledgment of DATA and WRQ requests
- **ERR**: Error notification with predefined error codes
- **BUSY**: Busy notification in case of longer procedures, extension to TFTP (e.g. erasing of flash modules)

AL | SoE

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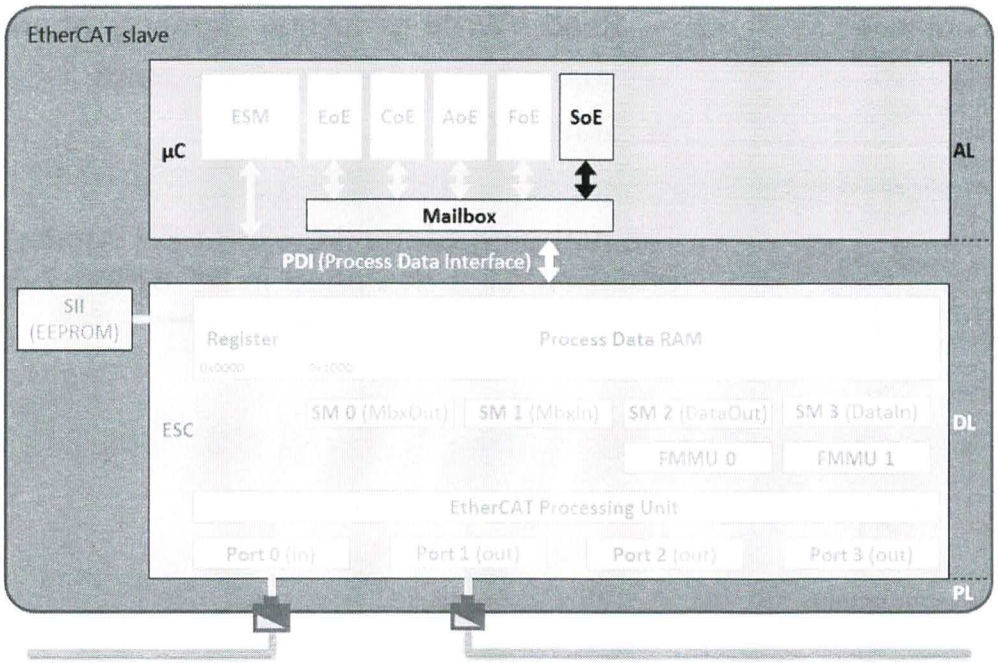

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Servo Drive over EtherCAT (SoE)

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- Implements Service Channel
  - Read / Write to several elements of an IDN
  - Support of Procedure Commands
  - Slave Info
- The mapping of the IEC 61800-7-1 Annex D (SERCOS™) on EtherCAT is described in IEC 61800-7-3 Annex D

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IDN = Ident Number

Process Data (cyclically, no Mailbox)

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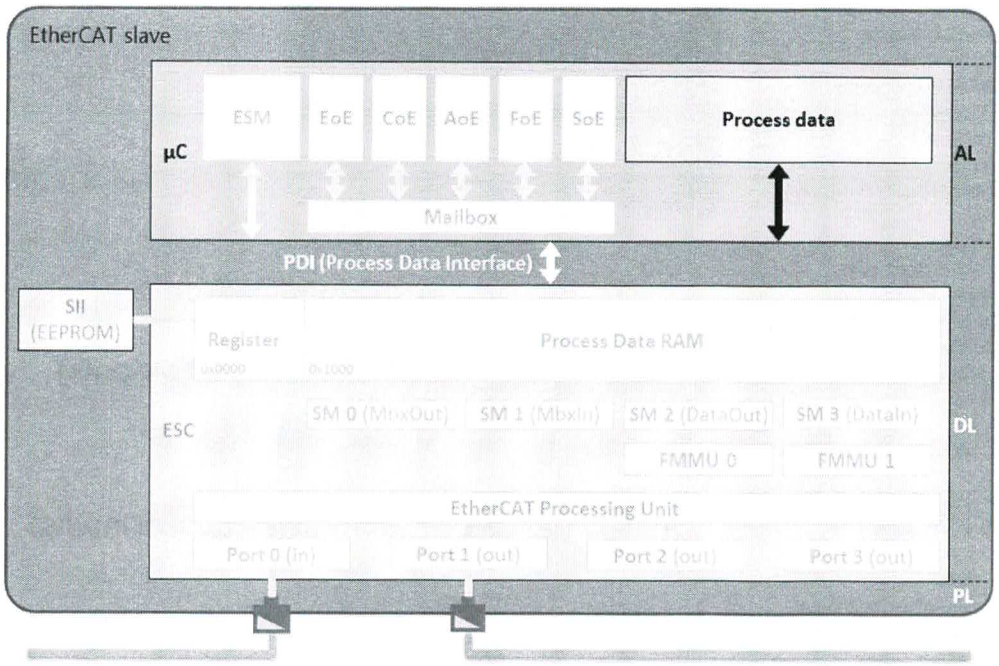

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Process Data Handling | Example (EVA Kit)

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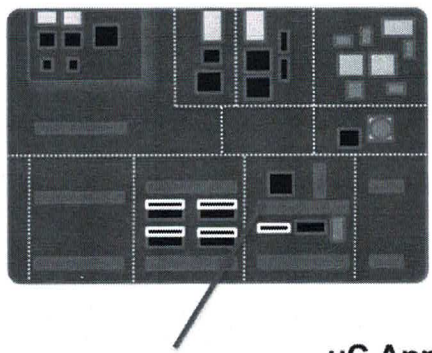

µC Application:

8 LEDs (digital outputs)

8 Switches (digital inputs)

1 potentiometer (analog input)

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Example based on Profile 5001 (Modular Device Profile MDP) → refer to Device Profiles

Process Data Handling | Data Exchange

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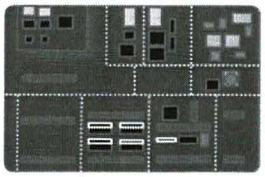
Mapping?



Register

0x0000 | 0x1000

Process Data RAM

0x1100
SM 2 (Process data out)

0x1400
SM 3 (Process data in)

FMMU 0
Direction: Write
Logic Address : 0x1000007
Len : 2 Byte
Physical Address : 0x1100

FMMU 1
Direction: Read
Logic Address : 0x1000007
Len : 4 Byte
Physical Address : 0x1400

Frame Header	Datagram H.	XX XX XX XX XX XX XX AA AA AA AA XX XX XX	WKC	FCS

Cmd: LRW
Address: 0x1000000
Len: 14 Byte

3

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PDO Mapping | Application Structure

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Channel 1		Channel 2		Channel 3	
BOOL	*Switch 1*	BOOL	*LED 1*	BOOL	*Underrange*
BOOL	*Switch 2*	BOOL	*LED 2*	BOOL	*Overrange*
BOOL	*Switch 3*	BOOL	*LED 3*	BIT2	*Limit 1*
BOOL	*Switch 4*	BOOL	*LED 4*	BIT2	*Limit 2*
BOOL	*Switch 5*	BOOL	*LED 5*	*8 bit Padding*	
BOOL	*Switch 6*	BOOL	*LED 6*	BOOL	*TxPdoState*
BOOL	*Switch 7*	BOOL	*LED 7*	BOOL	*TxPdoToggle*
BOOL	*Switch 8*	BOOL	*LED 8*	INT	*Analog Input*
8 bit Padding		*8 bit Padding*			
1st TxPDO		1st RxPDO		2nd TxPDO	
Digital Inputs		*Digital Outputs*		*Analog Inputs*	
2 Byte		2 Byte		4 Byte	

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PDO Mapping | Object Structure

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OD	0	1	2	3	4	...	255
0x0000							
...							
0x1600 - 0x17FF	RxPDO Mapping Objects: Area in OD for Output "Packages" offset = 0x01 (one PDO for each channel)						
...							
0x1A00 - 0x1BFF	TxPDO Mapping Objects: Area in OD for Input "Packages" offset = 0x01 (one PDO for each channel)						
...							
0x6000 - 0x6FFF	Area for Input variables offset = 0x10 (16 objects for each channel)						
0x7000 - 0x7FFF	Area for Output variables offset = 0x10 (16 objects for each channel)						
...							
0xFFFF							

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PDO Mapping | Process Data Objects

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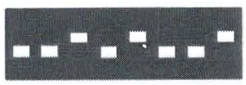

BOOL	*Switch 1*
BOOL	*Switch 2*
BOOL	*Switch 3*
BOOL	*Switch 4*
BOOL	*Switch 5*
BOOL	*Switch 6*
BOOL	*Switch 7*
BOOL	*Switch 8*

Channel 1:

→ Describe variables at 0x6000-0x600F

OD	0	1	2	3	4	...	8
0x0000							
...							
0x6000	8 "Highest Subindex"	0 "Switch 1"	0 "Switch 2"	1 "Switch 3"	0 "Switch 4"	...	1 "Switch 8"
...							
0xFFFF							

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BOOL	*LED 1*
BOOL	*LED 2*
BOOL	*LED 3*
BOOL	*LED 4*
BOOL	*LED 5*
BOOL	*LED 6*
BOOL	*LED 7*
BOOL	*LED 8*

Channel 2:

→ Describe variables at 0x70<u>10</u>-0x70<u>1F</u>

OD	0	1	2	3	4	...	8
0x0000							
...							
0x7010	8 "Highest Subindex"	0 "LED 1"	1 "LED 2"	0 "LED 3"	0 "LED 4"	...	0 "LED 8"
...							
0xFFFF							

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BOOL	*Underrange*
BOOL	*Overrange*
BIT2	*Limit 1*
BIT2	*Limit 2*
BOOL	*TxPdoState*
BOOL	*TxPdoToggle*
INT	*Analog Input*

Channel 3:

→ Describe variables at 0x6020-0x602F

OD	0	1	2	3	4	...	8
0x0000							
...							
0x6020	8 "Highest Subindex"	0 "Under range"	0 "Over range"	01 "Limit 1"	00 "Limit 2"	...	27135 "Analog Input"
...							
0xFFFF							

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PDO Mapping | Rx/TxPDOs in OD

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PDO Mapping Object defines the "Container" (PDO)

- SI0: Highest available Subindex
- SI1-255: reference to process data written as XXXXYYZZ
  - XXXX: Object of referenced variable
  - YY: Subindex of referenced variable
  - ZZ: Bitsize of referenced variable

OD	0	1	2	3	4	...	9
...							
0x1601	9 "Highest Subindex"	70100101 "1st Entry"	70100201 "2nd Entry"	70100301 "3rd Entry"	70100401 "4th Entry"	...	00000008 "8 bit padding"
...							
0x1A00	9 "Highest Subindex"	60000101 "1st Entry"	60000201 "2nd Entry"	60000301 "3rd Entry"	60000401 "4th Entry"	...	00000008 "8 bit padding"
0x1A01	Second channel has no Inputs → PDO mapping object does not exist						
0x1A02	9 "Highest Subindex"	60200101 "1st Entry"	60200201 "2nd Entry"	60200302 "3rd Entry"	60200402 "4th Entry"	... (incl. padding)	60201116 "8th Entry"
...							

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SM PDO Assign | Assign Objects

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Done:

- ✓ Define structure of variables of application
- ✓ Place the variables on the OD
- ✓ Define PDOs in the PDO Mapping Objects

Todo:

- Assign PDOs to SyncManagers (cyclic process data)

→ *SyncManager PDO Assign Object*

OD	0	1	2	...
...				
0x1C1x	"Highest Subindex"	xxxx "1st PDO"	xxxx "2nd PDO"	...
...				

Example: SM**2** (outputs) → SM PDO Assign Object = 0x1C1**2**
SM**3** (inputs) → SM PDO Assign Object = 0x1C1**3**

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SM PDO Assign | Example (EVA Kit)

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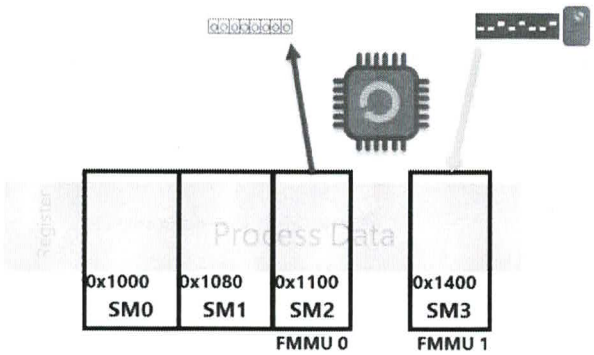
OD	0	1	2
...			
0x1C12	1 "Highest Subindex"	1601 1st RxPDO	
0x1C13	2 "Highest Subindex"	1A00 1st TxPDO	1A02 2nd TxPDO
...			

Assign Object for SM2 (outputs)

Assign Object for SM3 (inputs)



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Process data configuration

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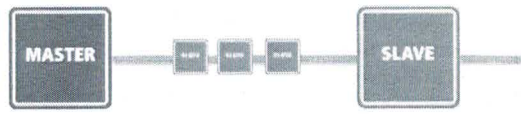
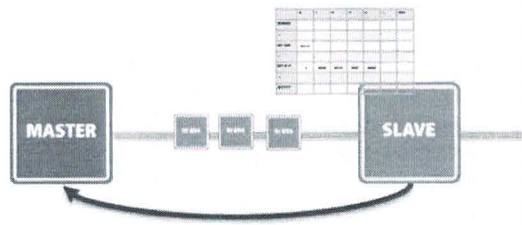
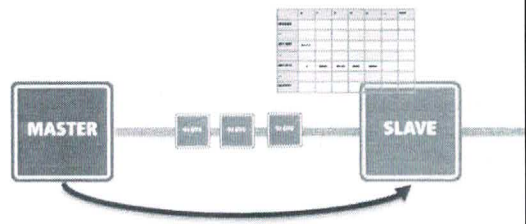
Fixed	CoE (OD) not needed Process Data Mapping in ESI	
PDO Upload	Master reads configuration from OD - SM Assignment - PDO Mapping - Process Data Objects	
PDO Download	Master writes configuration to OD - SM Assignment - PDO Mapping - Process Data Objects	

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- **Fixed process data**
  - No upload/download of process data configuration needed
  - Defined in device description (ESI/SII)

- **PDO upload** (PdoUpload)
  - Process data configuration defined in the slave
    (e.g. via serial cable and vendor specific software, gateway to another fieldbus, ...)
  - EtherCAT configuration tool reads the process data configuration from the slave via SDO upload service

- **PDO download** (PdoAssign/PdoConfig)
  - Process data configuration defined by user in the EtherCAT configuration tool
  - Configuration is written to the slave via SDO download

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Process data configuration (example)

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General Info | EEPROM | Memory | **Process Data** | Mailbox | Startup | CoE Online | State Machine | DC

Sync Manager

No.	Type	Ado	Size	StartAddress	ControlByte	Enabled
2	Outputs	0x0810	2	0x1100	0x64	True
3	Inputs	0x0818	6	0x1400	0x20	True

Settings

- [ ] Download PDO Assign
- [ ] Download PDO Config
- [ ] PDO Upload

PDO Assignment Sm 2

Index
[x] 0x1601

Pdos

Direction	Index	Size	Name	Fixed	SM	SU	Mandatory	Virtual	Source
Rx	0x1601	2.0	DO Outputs	True	2	0	True	False	ESI
Tx	0x1A00	2.0	DI Inputs	True	3	0	True	False	ESI
Tx	0x1A02	4.0	AI Inputs	True	3	0	True	False	ESI

Pdo Content:

Index	SubIndex	Size	Offset	Name	Type
0x7010	1	0.1	0.0	LED 1	BOOL
0x7010	2	0.1	0.1	LED 2	BOOL
0x7010	3	0.1	0.2	LED 3	BOOL
0x7010	4	0.1	0.3	LED 4	BOOL
0x7010	5	0.1	0.4	LED 5	BOOL
0x7010	6	0.1	0.5	LED 6	BOOL
0x7010	7	0.1	0.6	LED 7	BOOL
0x7010	8	0.1	0.7	LED 8	BOOL
0x0000	0	1.0	1.0		

Screenshot (partial) Conformance Test Tool 2.1.34.0

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Configuration Tools shall provide interface to change process data configuration

Process Data Structure in ESI

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ESI uses elements TxPDO and TxPDO similar to OD structure.

RxPdo

Fixed	true
Mandatory	true
Sm	2
Index	#x1601
Name	DO RxPDO-Map

Entry (9)

	Index	SubIndex	BitLen	Name	DataType
1	#x7010	1	1	LED 1	BOOL
2	#x7010	2	1	LED 2	BOOL
3	#x7010	3	1	LED 3	BOOL
4	#x7010	4	1	LED 4	BOOL
5	#x7010	5	1	LED 5	BOOL
6	#x7010	6	1	LED 6	BOOL
7	#x7010	7	1	LED 7	BOOL
8	#x7010	8	1	LED 8	BOOL
9	#x0	0	8		

TxPdo

Fixed	true
Mandatory	true
Sm	3
Index	#x1A00
Name	DI TxPDO-Map

Entry (9)

	Index	SubIndex	BitLen	Name	DataType
1	#x6000	1	1	Switch 1	BOOL
2	#x6000	2	1	Switch 2	BOOL
3	#x6000	3	1	Switch 3	BOOL
4	#x6000	4	1	Switch 4	BOOL
5	#x6000	5	1	Switch 5	BOOL
6	#x6000	6	1	Switch 6	BOOL
7	#x6000	7	1	Switch 7	BOOL
8	#x6000	8	1	Switch 8	BOOL
9	#x0	0	8		

TxPdo

Fixed	true
Mandatory	true
Sm	3
Index	#x1A02
Name	AI TxPDO-Map

Entry (8)

	Index	SubIndex	BitLen	Name	DataType
1	#x6020	1	1	Underrange	BOOL
2	#x6020	2	1	Overrange	BOOL
3	#x6020	3	2	Limit 1	BIT2
4	#x6020	5	2	Limit 2	BIT2
5	#x0	0	8		
6	#x1802	7	1	TxPDOState	BOOL
7	#x1802	9	1	TxPDO Toggle	BOOL
8	#x6020	17	16	Analog input	INT

→ Altova XML Spy® 2013

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Device Profiles | Motivation

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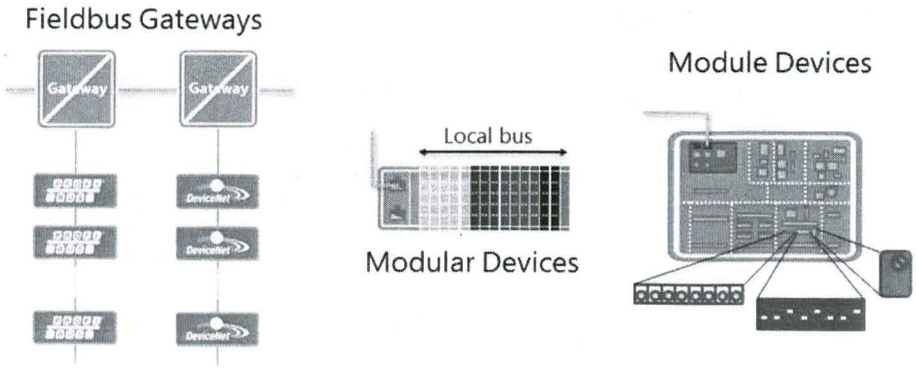
- Modeling of standardized data structures within a device
  - Object dictionary build up according the profile specification
- Usable for a large number of devices from very simple one to complex sub-structured
- Easy way for master and configuration tools to handle the device
- Specified in **ETG.5001**



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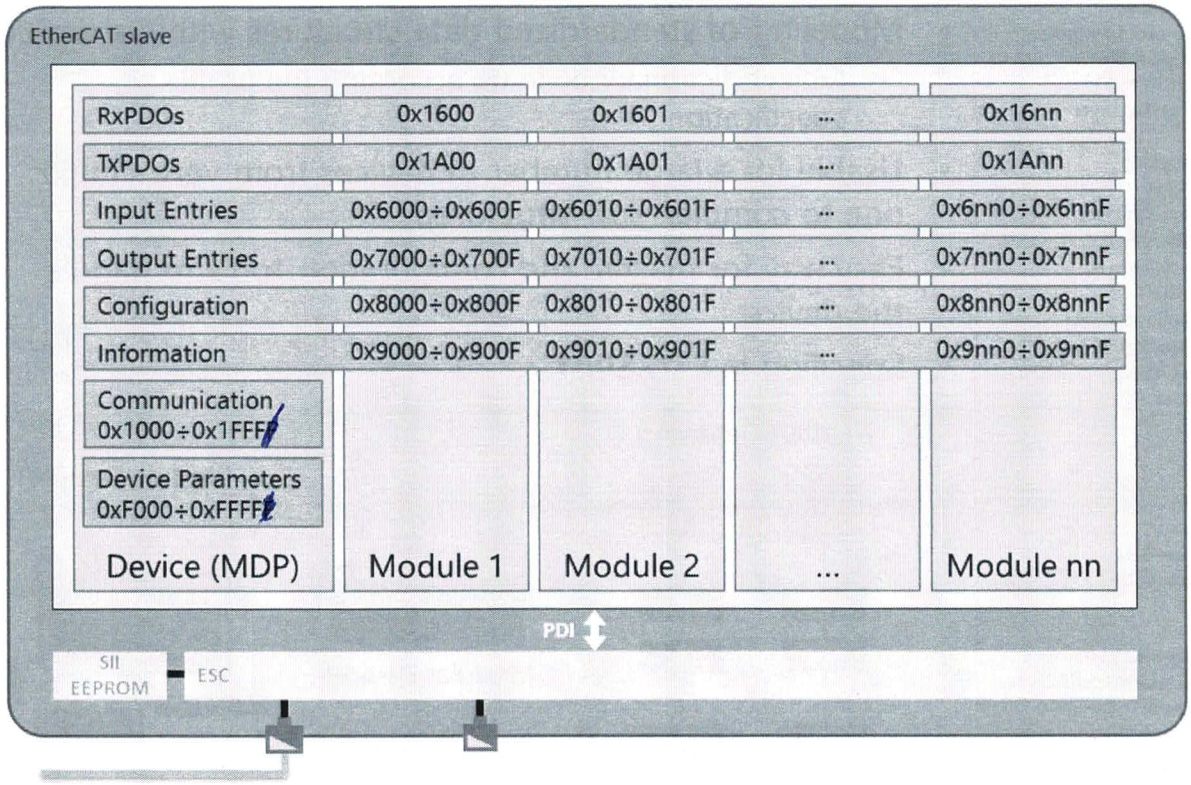
- **Fieldbus Gateways**
  - Gateways to other fieldbus networks
  - Each connected fieldbus device represents "module"

- **Modular Devices**
  - with physical connectable modules and/or functional modules
  - Each connected module represents a "module"

- **Module Devices**
  - EtherCAT device which consists of several channels (e.g. analog input, analog output, ...)
  - Each channel represents a "module"

MDP | OD Structure



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MDP | modular device (example)

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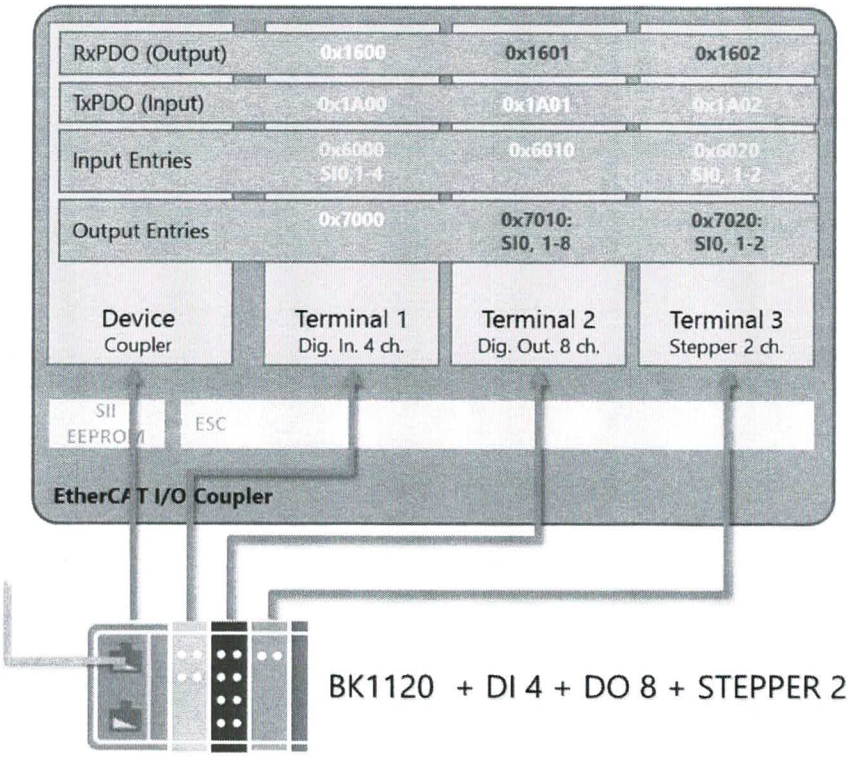

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MDP | fieldbus gateway (example)

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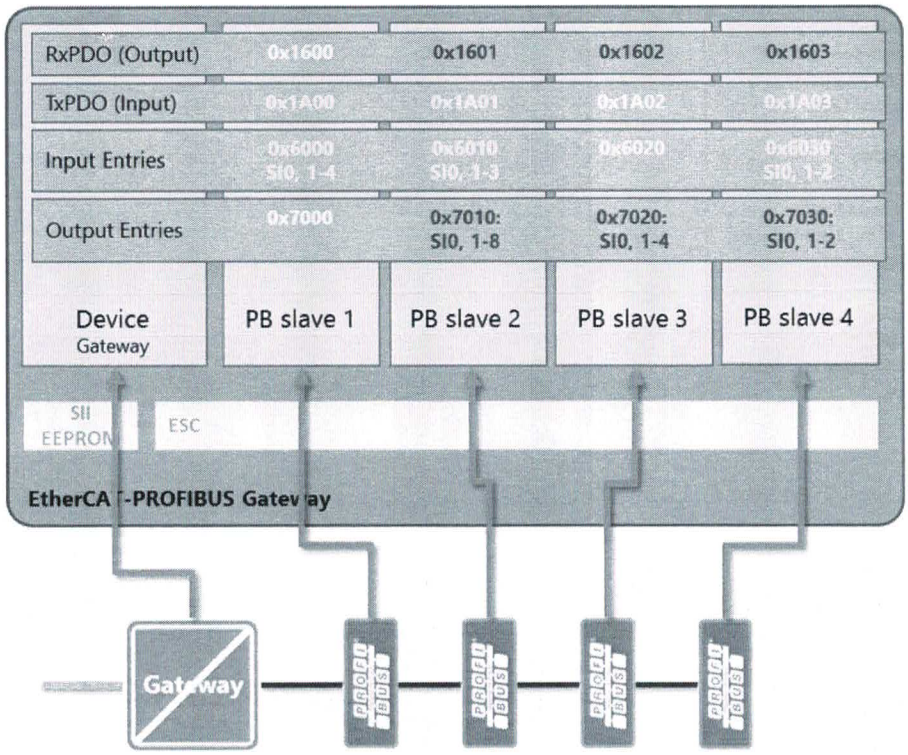

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CiA402 Drive Profile

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- Implementation Guideline **ETG.6010** for the CiA402 Drive Profile
  - Specify a common behavior of EtherCAT CiA402 servo drives according to IEC 61800-7
- Scope
  - EtherCAT CiA402 Servo Drives
  - No frequency converter
- Contents
  - Clarifications of the state machine
  - Modes of operation
  - Function Groups (FG)
    - FG Position, FG Velocity, FG Torque
    - FG Torque Limiting, FG Homing, FG Touch Probe
  - Endless Positioning

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CiA402 | servodrive (example)

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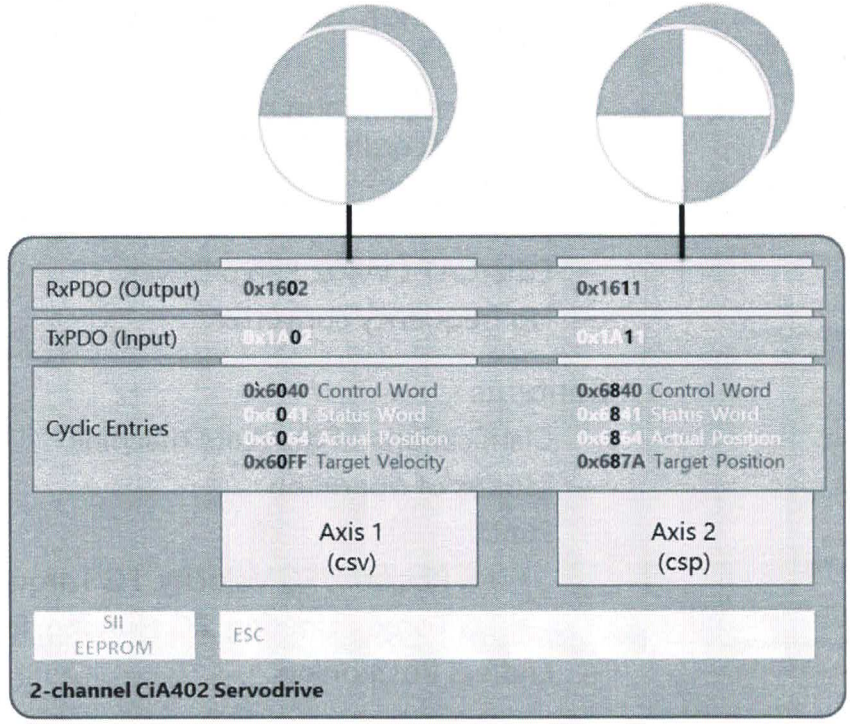

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csp = Cyclic Synchronous Position

csv = Cyclic Synchronous Velocity

Synchronization Modes

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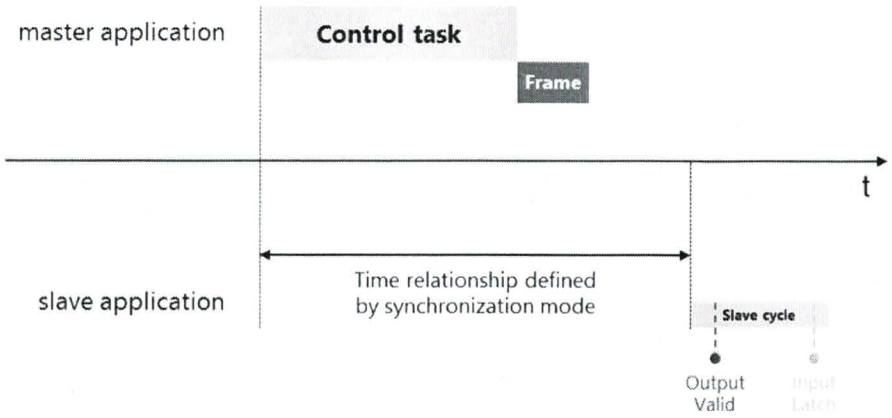
- Define a time relationship between the cyclic process data update on master and on slave side.



- Available synchronization modes for a slave:
  - Free Run
  - SM-Synchronous (synchronized to cyclic frames)
  - DC-Synchronous (synchronized to SYNC interrupts)

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Synchronization Modes

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- Synchronization modes supported by a slave and corresponding parameters are described in ESI file:

```
Dc
  OpMode
    Name            Synchron
    Desc            SM-Synchron
    AssignActivate  #x0
  OpMode
    Name            DC
    Desc            DC-Synchron
    AssignActivate  #x300
    CycleTimeSync0  Factor=1
    CycleTimeSync1  Factor=1
```

→ Altova XML Spy® 2013

- Synchronization relevant information is described in CoE objects 0x1C3**2** (outputs) and 0x1C3**3** (inputs).

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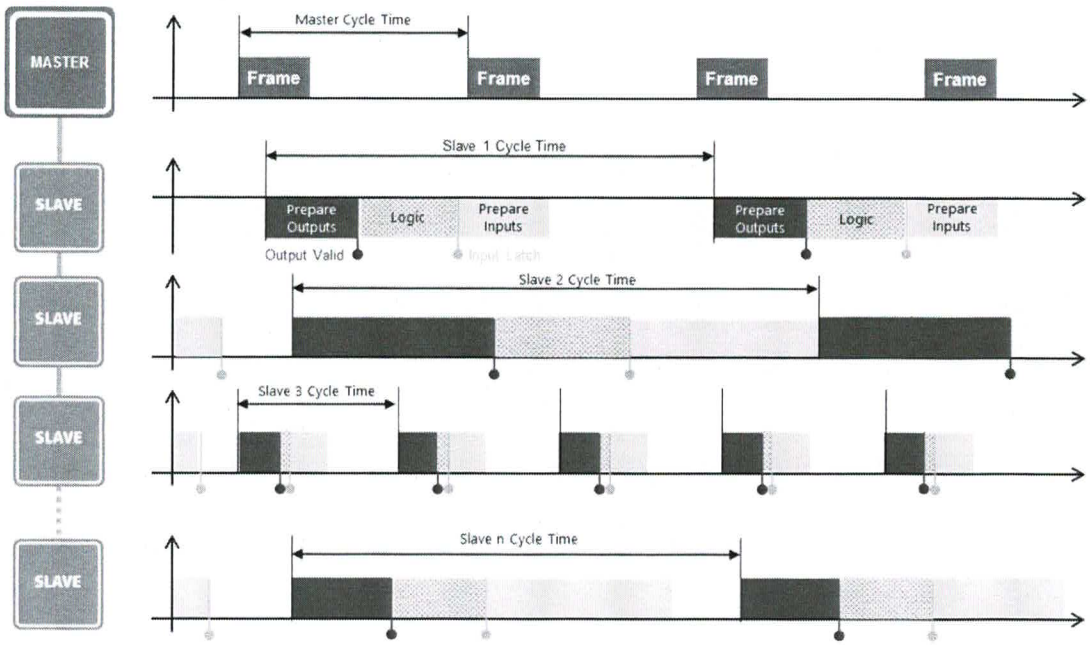
Synchronization modes, together with CoE objects 0x1C32/33 are specified in ETG.1020.

Free Run



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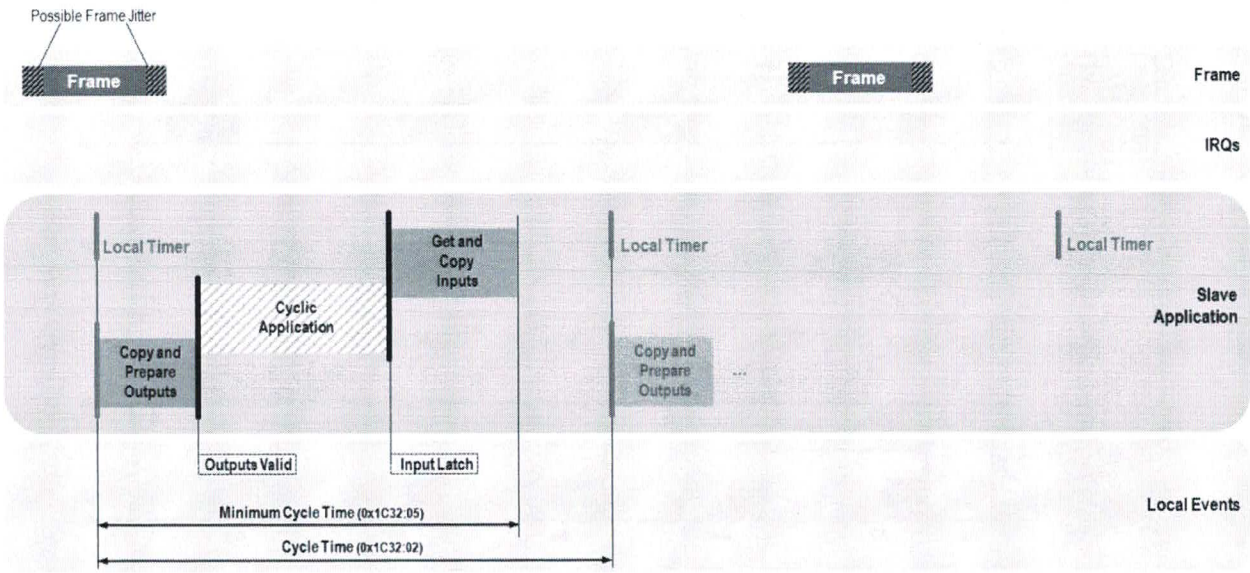
Free Run

Local Timer



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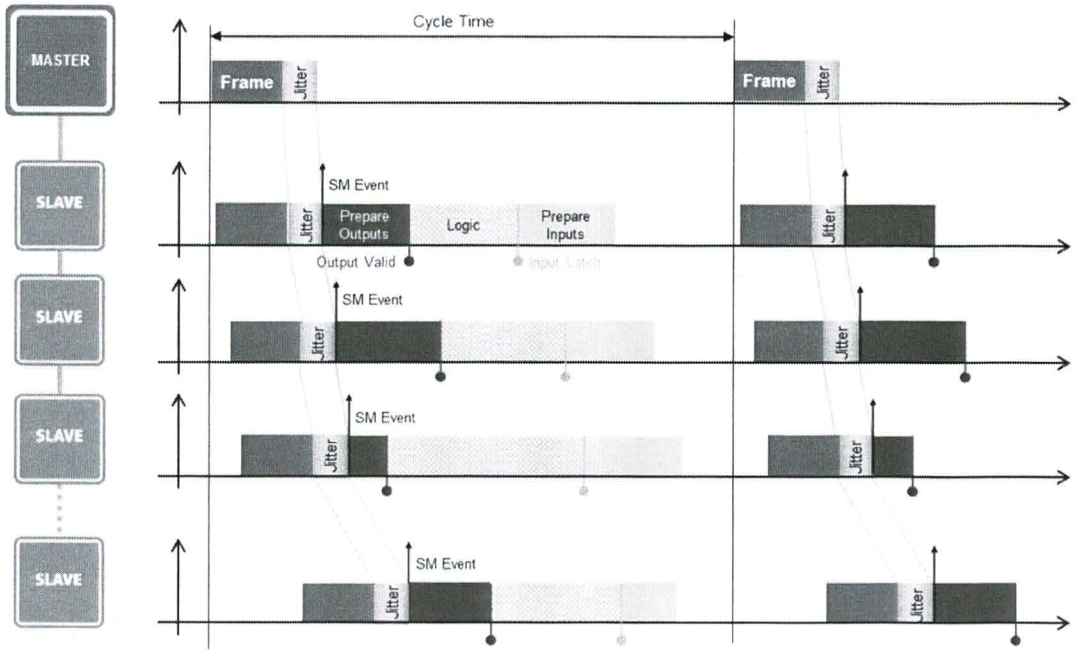
SM-Synchronous



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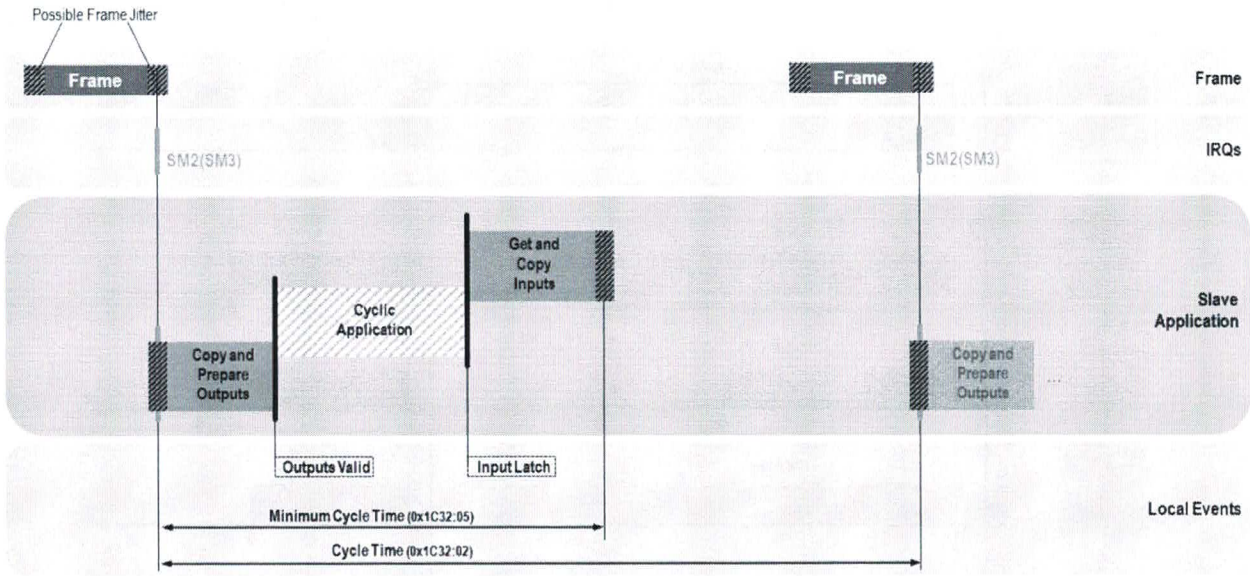
SM-Synchronous

SM Event



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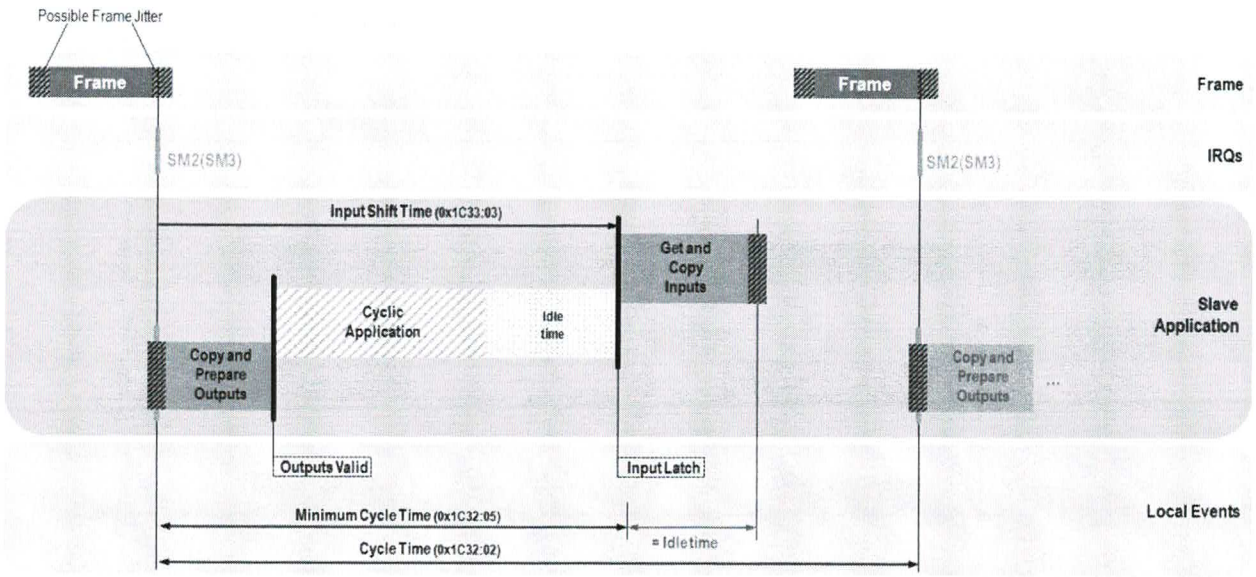
SM-Synchronous

SM Event (Shift of Input Latch via 0x1C33:03)



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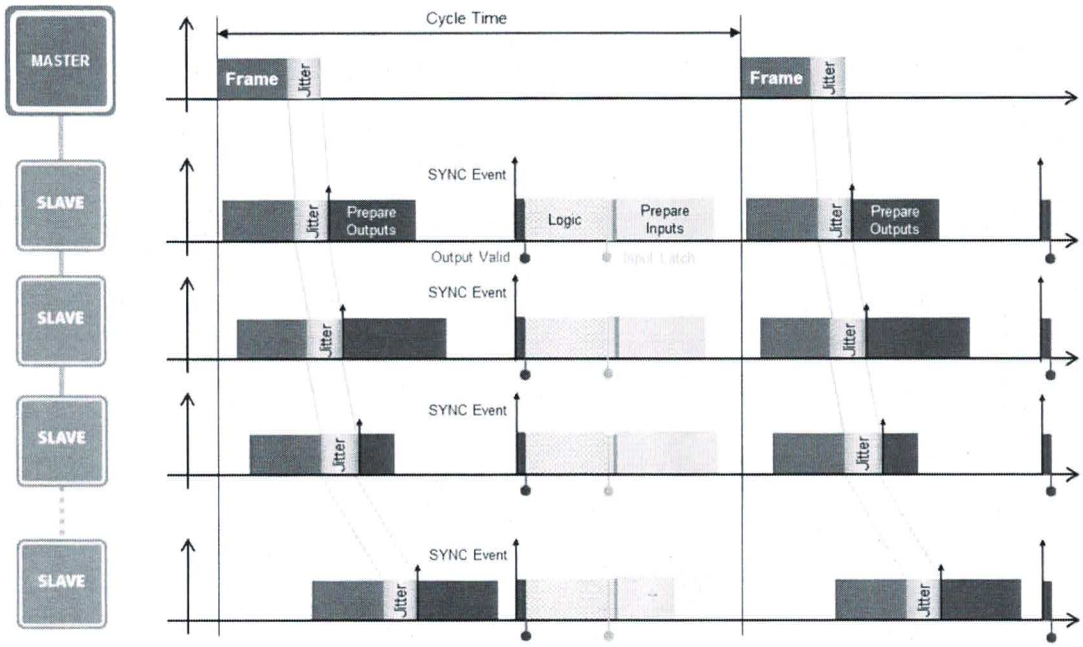
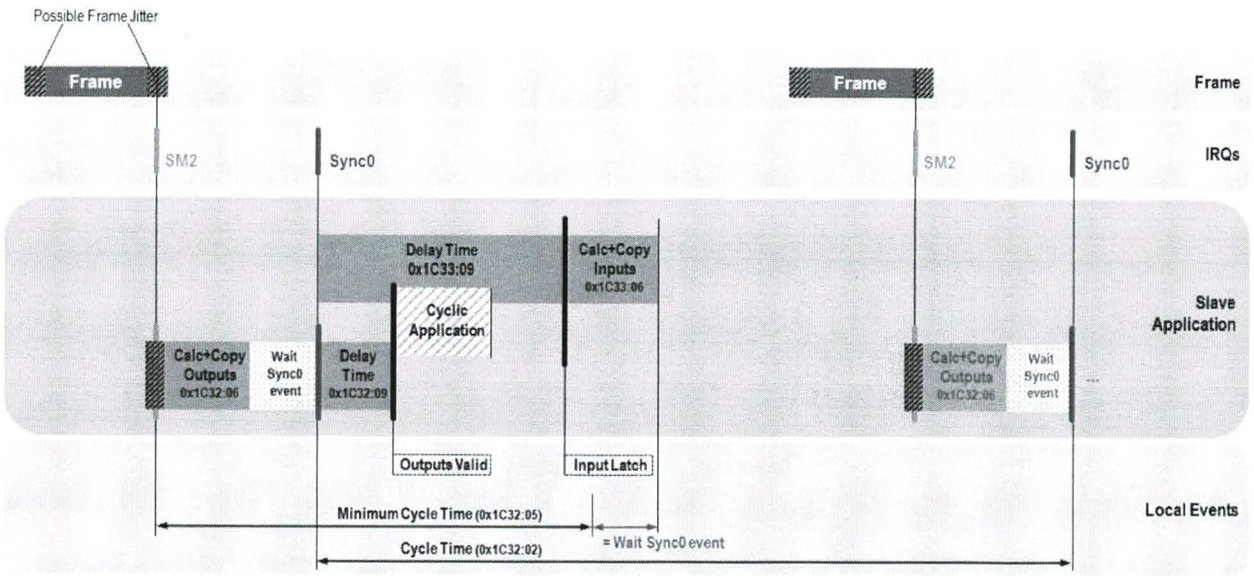
DC-Synchronous



DC-Synchronous

SM Event, Sync0 Event



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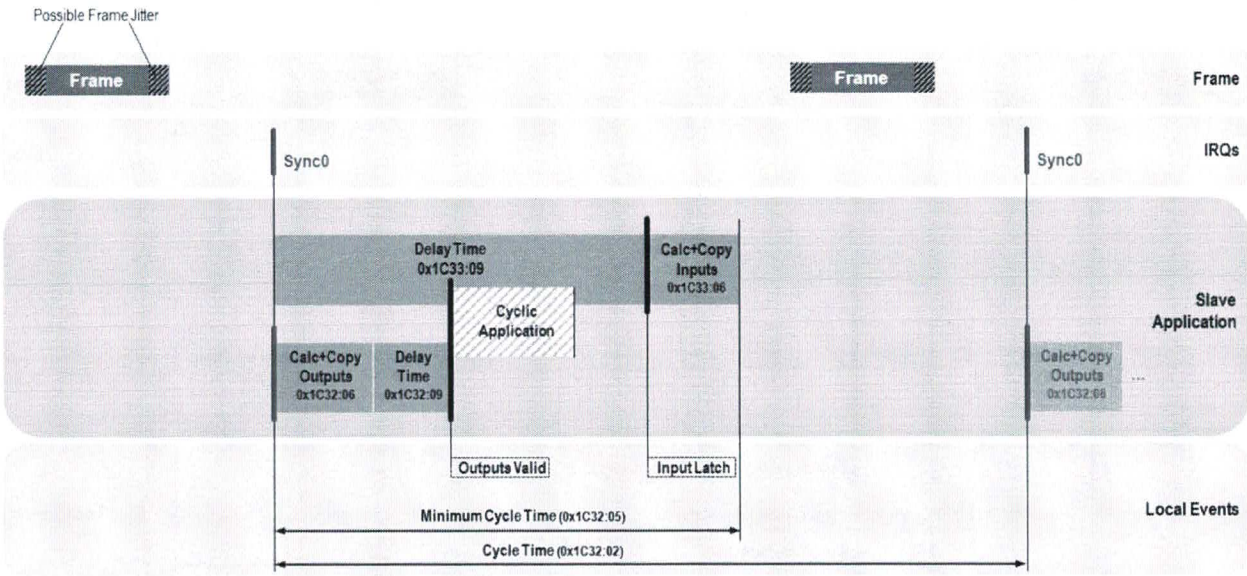
DC Mode 1

Sync0 Event



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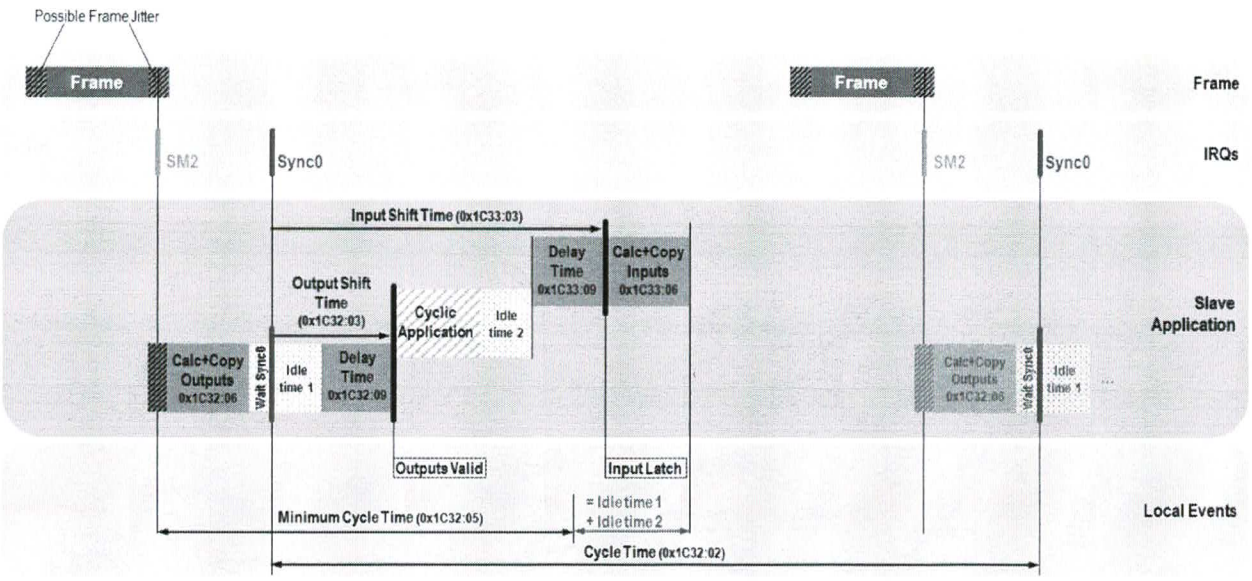
DC-Synchronous

Sync0 Event (Shift of Outputs Valid and/or Input Latch via 0x1C3x:03)



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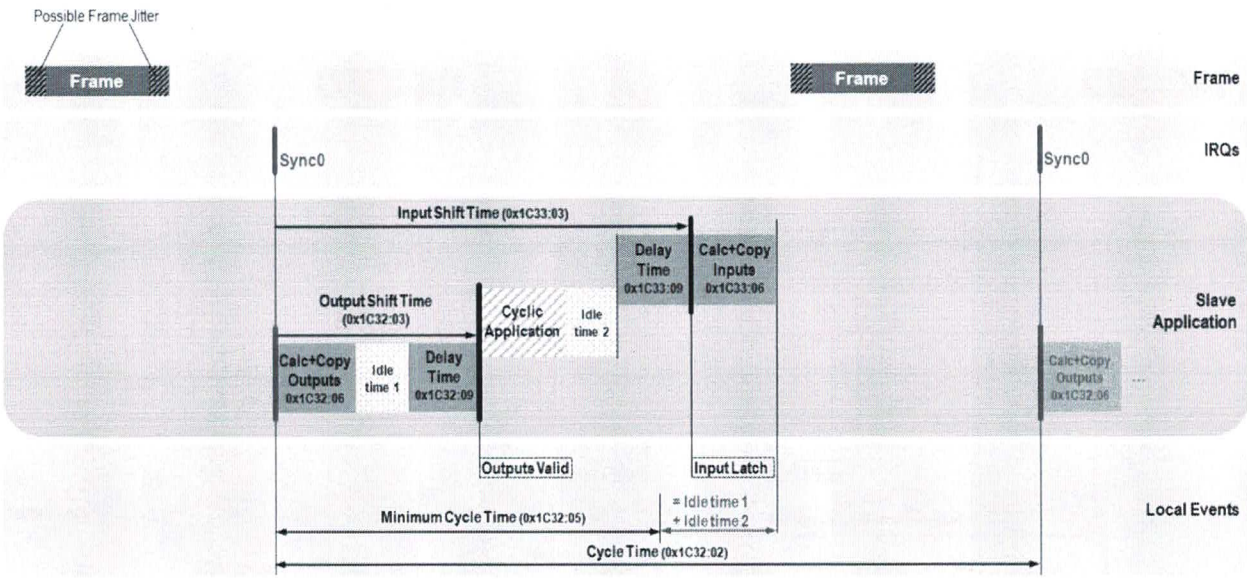
DC-Synchronous

Sync0 Event (Shift of Outputs Valid and/or Input Latch via 0x1C3x:03)



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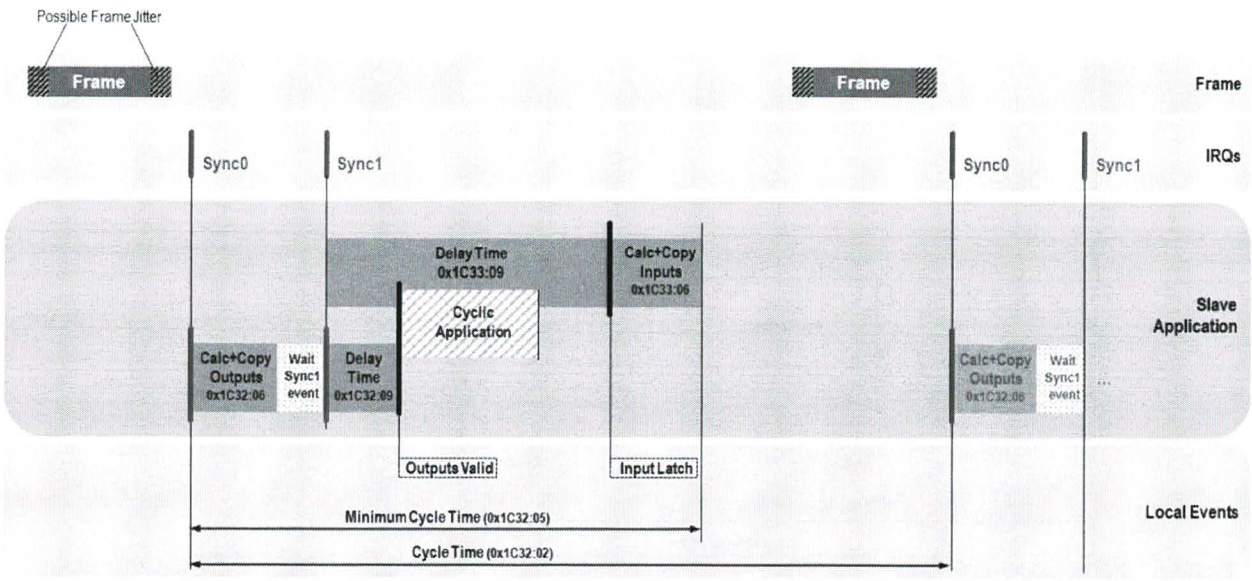
DC-Synchronous

Sync0 Event, Sync1 Event



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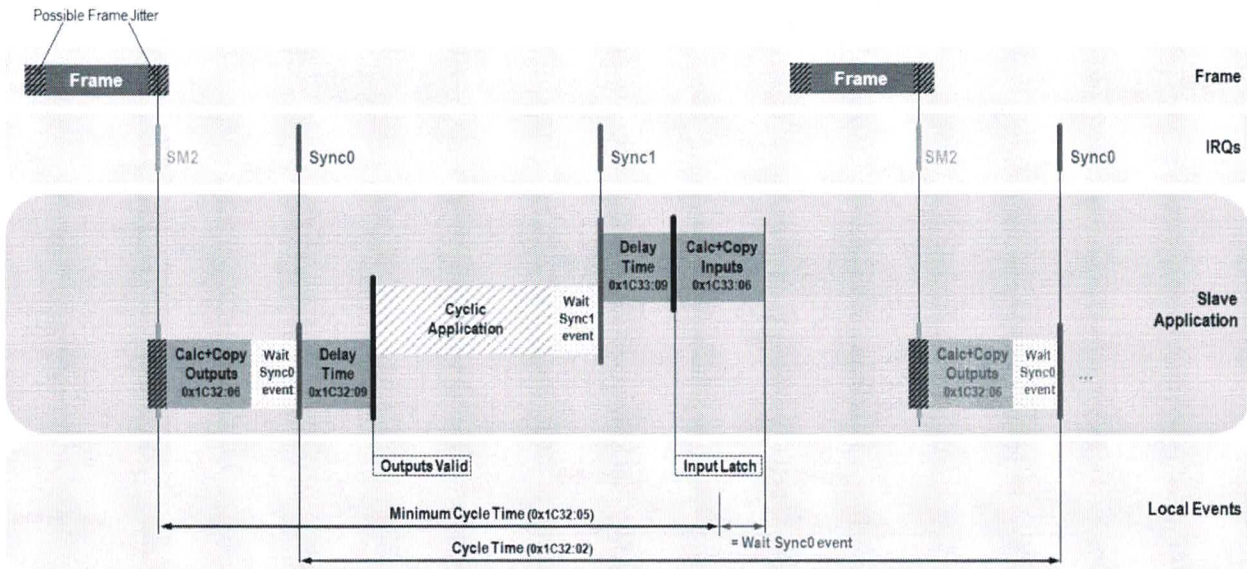
DC-Synchronous

SM Event, Sync0 Event (Shift of Input Latch via Sync1 Event)



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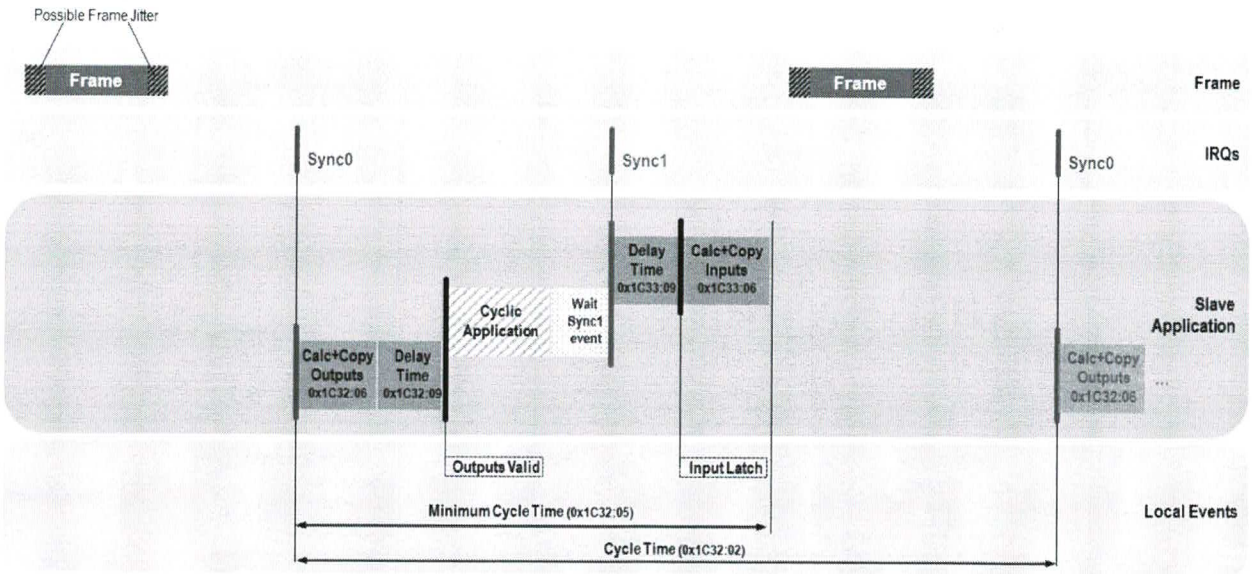
DC-Synchronous

Sync0 Event (Shift of Input Latch via Sync1 Event)



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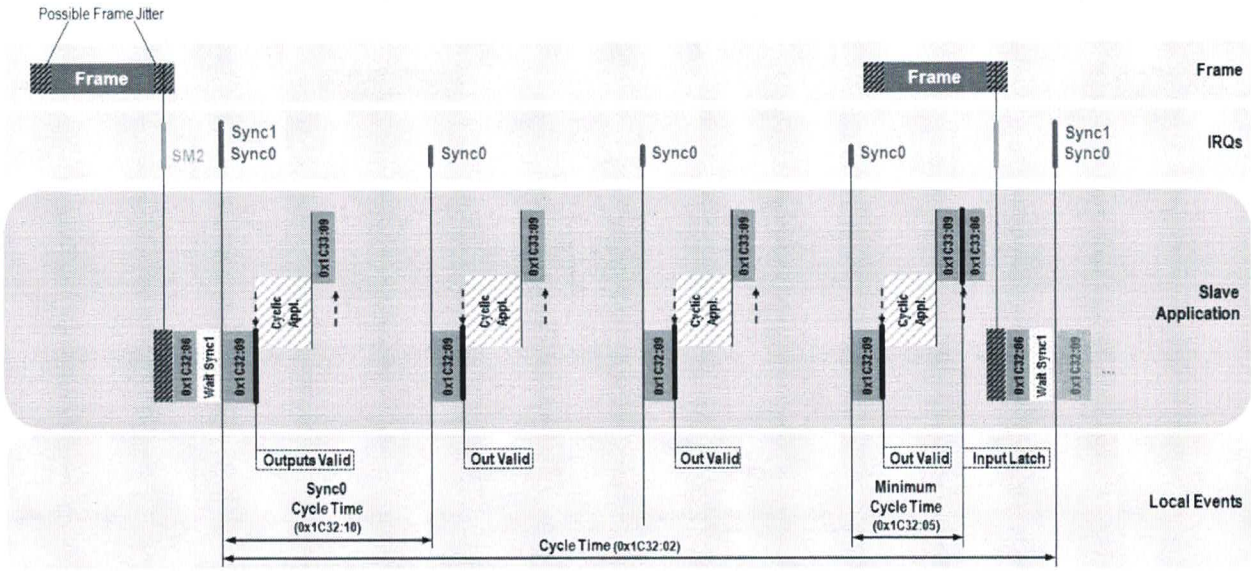
DC-Synchronous

SM Event, Sync1 Event (subordinated cycles via Sync 0)

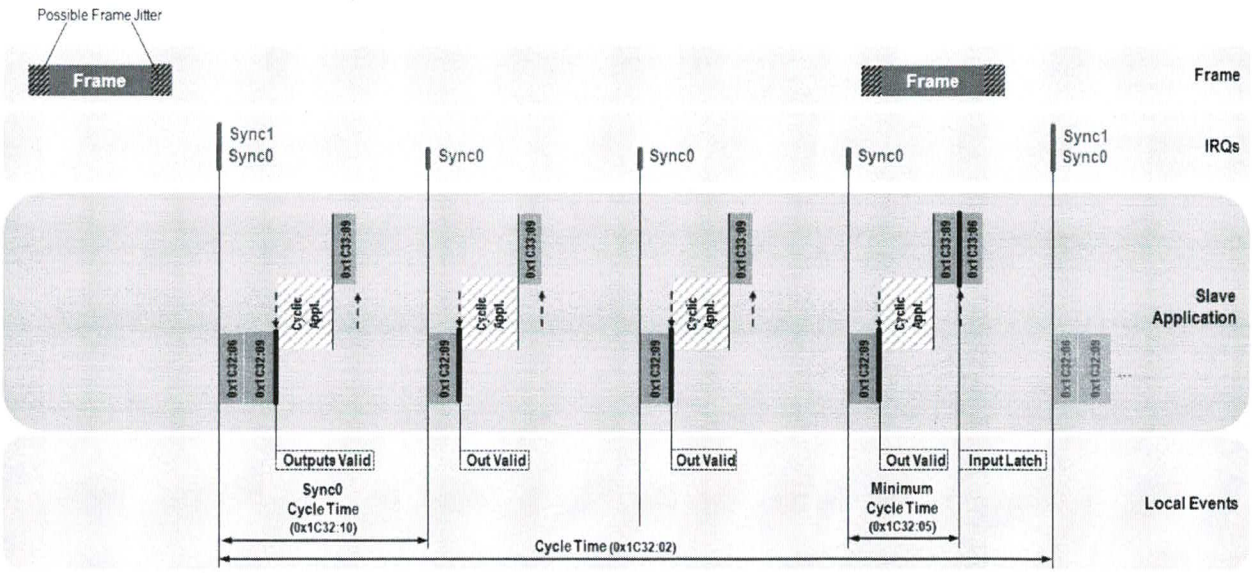


Possible Output Valid /
Input Latch

© EtherCAT Technology Group

DC-Synchronous

Sync1 Event (subordinated cycles via Sync 0)



Possible Output Valid /
Input Latch

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SII | Slave Information Interface

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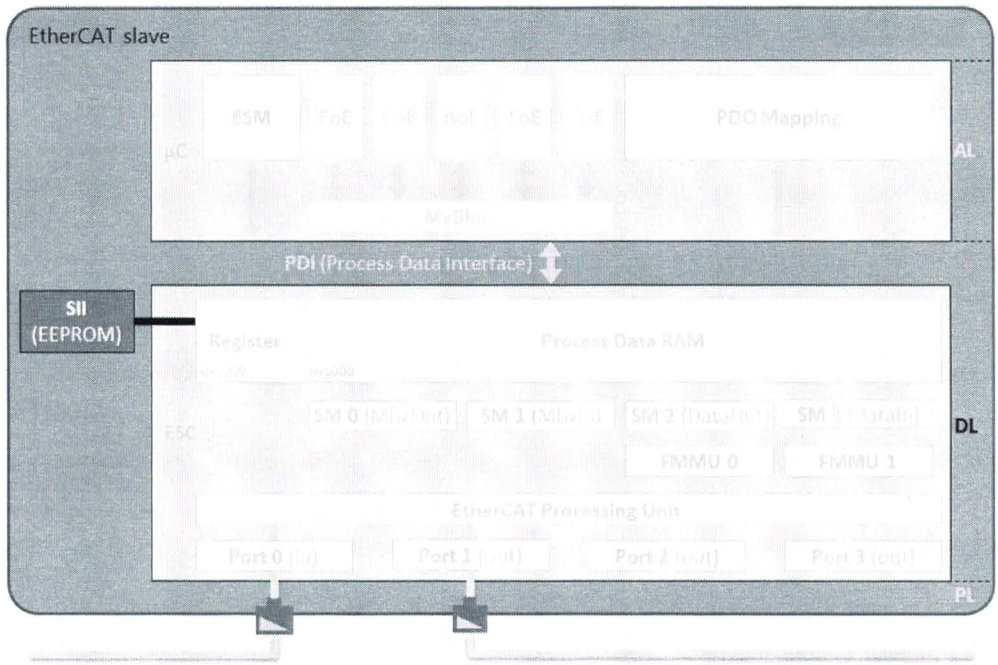

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SII | Slave Information Interface

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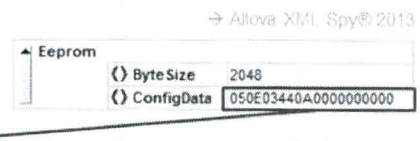
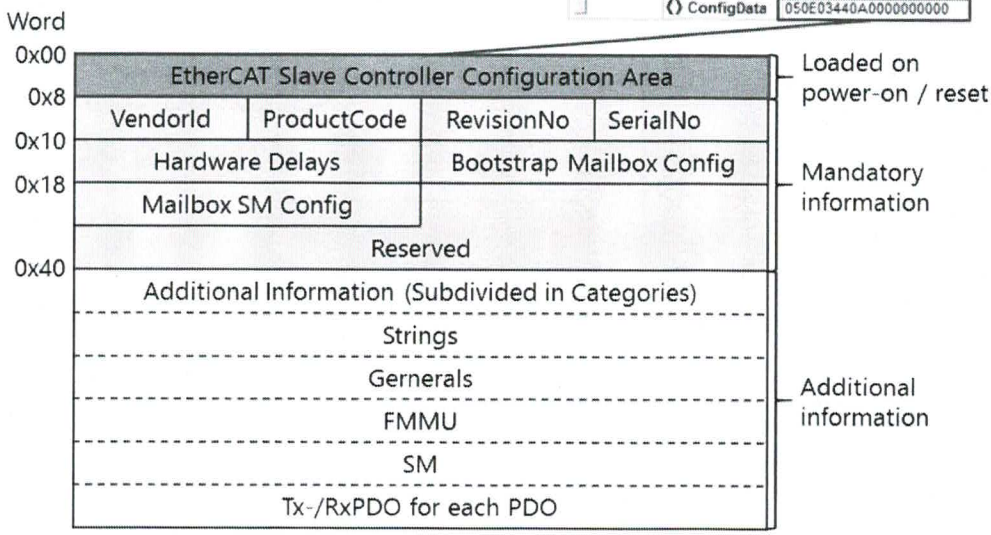
- Contains basic configuration information (mandatory)
  - Physical: EEPROM up to 4 Mbit
  - Emulated: ESC related
- Configurable with converted ESI-file





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Specified in ETG.2010

EtherCAT Diagnosis Features

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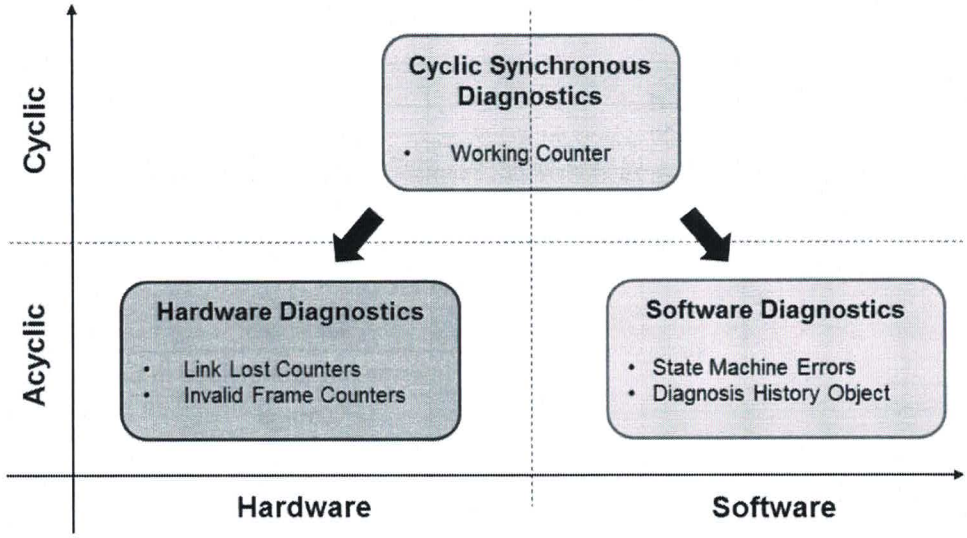
EtherCAT provides extensive **diagnostic information** both at hardware and at software level.



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EtherCAT Diagnosis Features

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Hardware Diagnostics (Physical + Datalink Layer)

- Link Lost Counters
  → incremented every time a port loses the physical link
- Invalid Frame Counters
  → incremented every time a port detects a corrupted frame

Software Diagnostics (Application Layer)

- State Machine Errors
  → are triggered in case of EtherCAT generic software errors
- Diagnosis History Object
  → enables slave to report application specific errors

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EtherCAT Diagnosis Features

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Additional information about EtherCAT diagnostic features is available in the "EtherCAT Diagnosis for Users" document, available in different languages on the ETG website:

EtherCAT Diagnosis for Users

This slide set intends to provide an overview over the diagnostic capabilities provided by EtherCAT. It contains a description of the basic diagnosis functionalities and the most typical error scenarios within an EtherCAT network.

It is primarily intended for end users and plant operators, as well as for machine builders and system integrators. For additional information about EtherCAT diagnostics -including more detailed error scenarios –which could be of interest for EtherCAT master and slave manufacturers, please refer to slide set "EtherCAT Diagnosis For Developers".

For comments regarding the slides please contact info@ethercat.org.

Description	Language	Type	Date	Size	Ver.	Status
EtherCAT Diagnosis for Users	EN	PDF	Sep 21, 2017	1,59 MB		
ユーザ向けEtherCAT診断方法	JP	PDF	Jan 12, 2018	1,55 MB		
Diagnóstico EtherCAT para usuarios	ES	PDF	Sep 21, 2017	1,58 MB		
针对用户的EtherCAT诊断	CN	PDF	Jun 30, 2017	1,86 MB		
EtherCAT-Diagnose für Anwender	DE	PDF	Sep 21, 2017	1,58 MB		
Diagnostica EtherCAT per Utilizzatori	IT	PDF	Sep 21, 2017	1,60 MB		

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Monitoring of EtherCAT Communication

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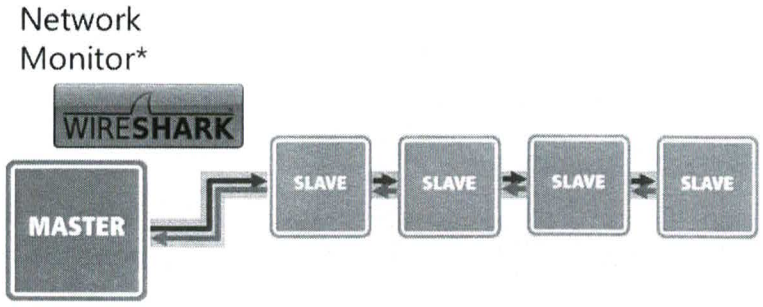
EtherCAT traffic can be traced via freely available software tools like Wireshark.



- Masters sends an EtherCAT Frame (broadcast)
  → Monitor gets the 1st copy (unprocessed)
- Frame returns from EtherCAT Slave Devices
  → Monitor gets the 2nd copy (processed)

*Attention: At low cycle times order of frames might be mixed because of timing restrictions within NDIS protocol driver.

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Monitoring of EtherCAT Communication

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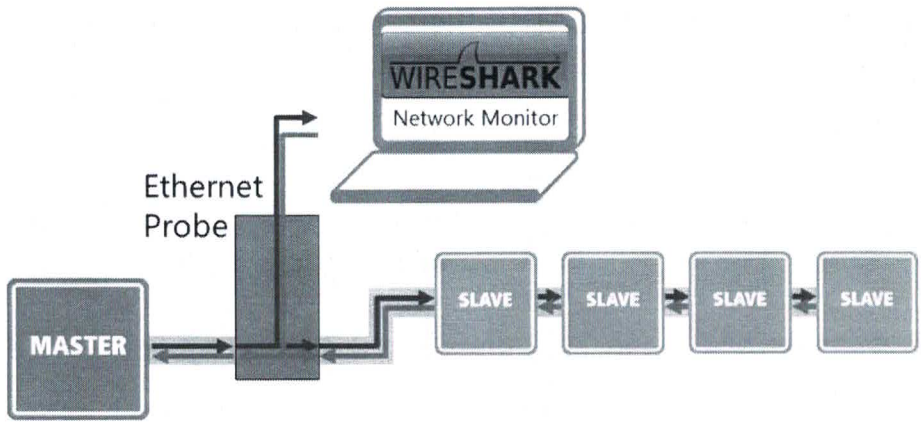

- Masters sends an EtherCAT Frame (broadcast)
  → Monitor gets the 1st copy (unprocessed) w/ Timestamp
- Frame returns from EtherCAT Slave Devices
  → Monitor gets the 2nd copy (processed) w/ Timestamp

☑ Real-time performance is not affected (no jitter, no delay)

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Monitoring of EtherCAT Communication

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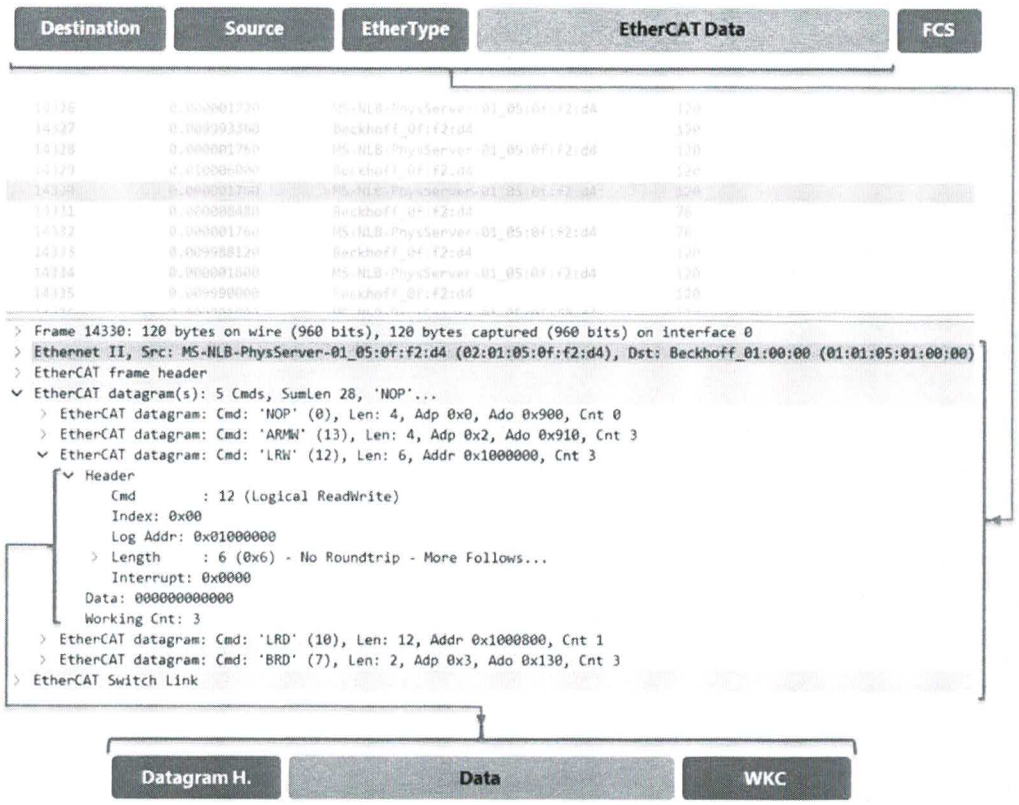

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Standards and References

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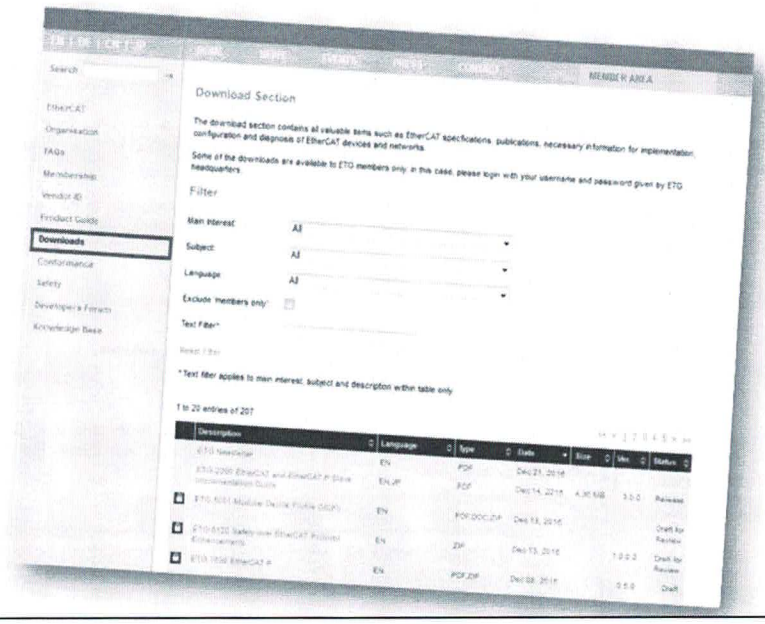
- Specification of EtherCAT is done in the EtherCAT Technology Group (ETG)
- Specifications available at www.ethercat.org/download
- International standardization



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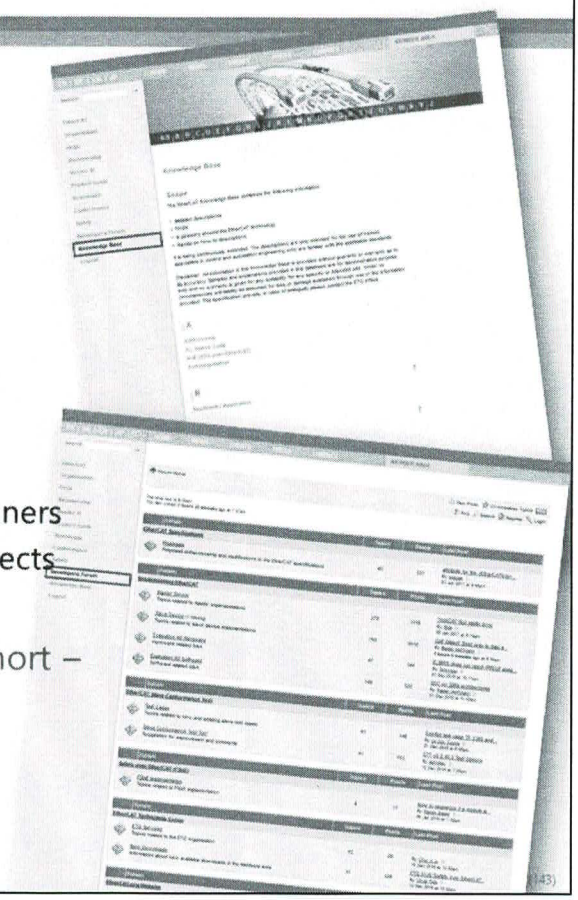
Standards and References

- EtherCAT Knowledge Base
  www.ethercat.org/kb
  - Glossary to find documentation
  - Technical descriptions which explain or supplement the technical specification
  - How-To's and answers

- EtherCAT Developers Forum
  www.ethercat.org/forum
  - Crossroad of EtherCAT experts and beginners
  - Multiple topics covering all EtherCAT aspects

- Please help us to keep response times short – check our online information first



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IEC 61158 / ETG.1000

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- Digital data communication for measurement and control – Fieldbus for use in industrial control systems
- *The* communication standard
- EtherCAT is named Type 12 in IEC 61158 (no brand names allowed)
- Transformation of the communication protocol to a common model
- ETG document with same content: **ETG.1000**

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IEC 61158 – DL/AL services and protocols

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Users	Implementers
AL Services **Part 5 in IEC 61158** • Model and Concepts • Data type definitions • Application Objects • Service description • Communication Management	**AL Protocol** **Part 6 in IEC 61158** • Syntax definition and Coding • Application Relationship Procedures • State Machines
DL Services **Part 3 in IEC 61158** • Model and Concepts • Service description • Register Description (DL objects)	**DL Protocol** **Part 4 in IEC 61158** • Coding • Medium Access • State Machines

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Further EtherCAT standards

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Additional important specifications are:

- **ETG.1300** Indicator and Labeling specification
  - defines the implementation of indicators signaling the EtherCAT communication state, errors and the link status.
  - the location, labeling and blink codes of the indicators are defined
  - defines the labeling of the EtherCAT Ports
- **ETG.9001** Marking Rules
  - specifies the marking rules for products and the corresponding documentation using the EtherCAT technology
  - Use of trademarks and logo EtherCAT

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These specifications can be found on the ETG Website
http://www.ethercat.org/en/publications.html#members_area

EtherCAT Technology Group

EtherCAT P | Related documentation - ETG

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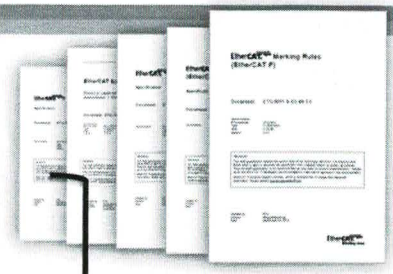
Specifications:



ETG.1030
EtherCAT P

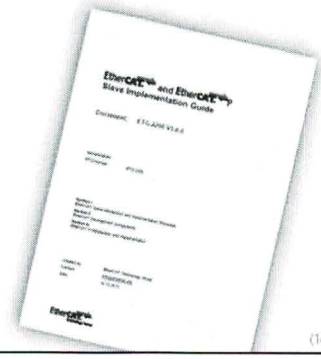
ETG.1000.2P
Physical Layer

ETG.1030.1
EtherCAT P Connector

ETG.2000
EtherCAT Slave Information
- ESI Schema

ETG.9001
Marking Rules

Overview in:
EtherCAT and EtherCAT P Implementation Guide (ETG.2200)



- Landing site: www.ethercat.org/p

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EtherCAT Vendor ID

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Vendor ID in IEC 61158-6-12 (EtherCAT Standard)

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5.6.7.4.6 Identity Object

The Identity Object dictionary entry (index 0x1018) is specified in Table 72.

Table 72 – Identity Object

Sub-Index	Description	Data type	M/O/C	Access	PDO Mapping	Value
0	Number of entries	UNSIGNED8	M	R	No	4
1	Vendor ID	UNSIGNED32	M	R	No	Assigned uniquely by ETG
2	Product Code	UNSIGNED32	M	R	No	Assigned uniquely by Vendor
3	Revision Number	UNSIGNED32	M	R	No	Assigned uniquely by Vendor Bit 0-15: Minor Revision Number of the device Bit 16-31: Major Revision Number of the device
4	Serial Number	UNSIGNED32	M	R	No	Assigned uniquely for this device by Vendor 0 if there is no serial number given

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Vendor ID Principles

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- End users do not have to be ETG member and do not need an ETG vendor ID – even though they are welcome to join ETG and also may get a vendor ID.
- Each vendor of an EtherCAT Device shall be an ETG member and shall obtain and maintain a Vendor ID from the EtherCAT Technology Group.
- The Vendor ID is free of charge.
- The vendor shall implement the Vendor ID in each EtherCAT Device prior to making it available on the market.
- Manufacturers of Communication Devices shall distribute those Communication Devices using their Secondary Vendor ID (range 0xE0000000:0xEFFFFFFF). Optionally they may also use their Vendor ID, e.g. for conformance testing. Use of a Secondary Vendor ID in an Automation Device is prohibited.

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How to obtain an EtherCAT Vendor ID?

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https://www.ethercat.org/memberarea/vendorid/

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Vendor ID Assignment Form

Each EtherCAT compliant device has to implement the worldwide unique Vendor ID assigned by ETG. The EtherCAT Vendor ID Usage is governed by the ETG Vendor ID Policy and the corresponding Vendor ID agreement, which asks for conformance with the EtherCAT specifications. In order to clarify this policy, the general rules are repeated below.

- Each vendor of an EtherCAT device has to be an ETG member and has to obtain and maintain a valid Vendor ID from the EtherCAT Technology Group
- The Vendor ID is free of charge
- The vendor has to implement the Vendor ID in each EtherCAT device prior to making it available on the market
- Manufacturers of machines, which integrate and use EtherCAT devices in combination with or in such machines, are not required to apply for and use a Vendor ID

Vendor ID assignment is free of charge

(→) required field

Company: Beckhoff Automation GmbH & Co. KG

☐ Please check this box and fill out „Department/Branch" field only, if you need several Vendor IDs for your company. In this case please pick a specific name, i.e. "Germany", "Medical", etc. Names like "R&D", "Development" or "Manufacturing" may not be accepted due to their broad range within the company. Note that bit 24 ..27 will be assigned automatically by ETG when "Department/Branch" field is filled out.

31 … 28	27 … 24	23 … 0
Reserved	Department	Company

MSB … LSB

Department/Branch:
Address: →
ZIP: →
City: →
Country: →
Contact Person: →
Phone: →
Fax:
Email: →

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EtherCAT Vendor ID Agreement

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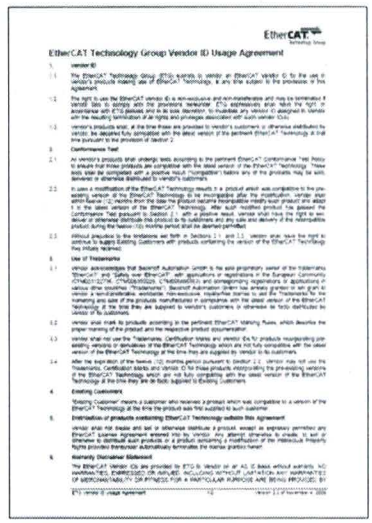
- Applicants for an EtherCAT Vendor ID have to accept the Vendor ID Agreement

- **The Vendor ID Agreement:**
- Demands Conformance for EtherCAT products
- Governs the use of the EtherCAT Trademarks (including reference to the EtherCAT Marking Rules)
- Contains a Disclaimer ("Technology provided "as is", with no warranty implied...)


EtherCAT Technology Group Vendor ID Usage Agreement

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Conformance Testing
+
Product Certification

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Conformance Test Tool (CTT)

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- Test Tool
  - Validates conformity for protocol layer
  - Helps to find errors during development due to detailed error description
  - Helps to improve support: detailed information saved with CTT project file
- I am an EtherCAT device vendor. Do I have to license the conformance test tool?
  - Yes. The ETG takes conformance very seriously, and the availability of the conformance test tool at each and every device vendors R&D lab is an important cornerstone in this process

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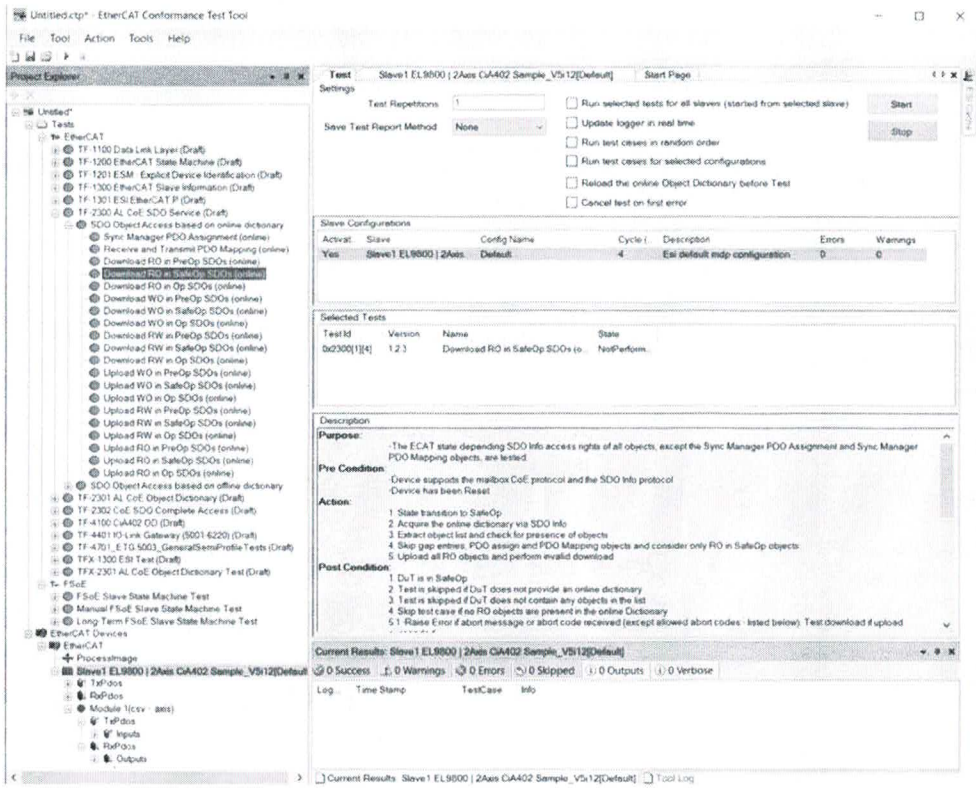

Frequently Asked Questions (I)

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- Do I have to submit my EtherCAT device to the EtherCAT Test Center for testing?
  - No. Conformance Testing with the Test Tool „at home" is sufficient to meet the minimum requirements of the Vendor ID agreement.
- Can I get a Conformance Certificate based on the test results obtained in my R&D lab?
  - No. The Conformance Certificate can only be issued after successfully passing the test at an accredited EtherCAT Test Center.
- Does the test in the EtherCAT Test Center exceed the test done with the Conformance Test Tool (at home)?
  - Yes. The test in the EtherCAT Test Center also includes an interoperability test, checking for conformance regarding the indicator and labeling spec, the marking rules etc.

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Frequently Asked Questions (II)

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- Does the Certificate expire?
  - No. The Certificate confirms that a device of a certain release has passed the current test version in the EtherCAT Test Center. Of course the Certificate can neither confirm that all future releases of the device will also pass, nor that the current device release will pass all future enhancements of the EtherCAT Conformance Test.
- Do I have to submit my device again once I released a newer version?
  - No. However, according to the Vendor ID agreement, you will have to test future releases of your product against the conformance test tool in your R&D lab. Of course you may also submit your device again to the EtherCAT Test Center and obtain a new certificate!

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Conformance Testing Procedure

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- Vendor contacts ETG office if he wants EtherCAT CT
- ETG checks Vendor ID and provides Test Contract – which also allows one to select the EtherCAT Conformance Test Center (ETC).
- Based on choice of vendor, ETG office forwards request to ETC
- ETC provides formal offer to vendor (ETG is not involved in any financial transaction)
- ETC provides checklist to vendor (how to prepare, what to send, etc.)
- Vendor sends device to ETC (or brings it there) .
- ETC tests device.
- ETC sends Test Report to Vendor and to ETG office.
- If test was passed successfully, ETG provides Certificate.

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Conformance Test Mark

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- Devices that have passed the ETC Conformance Test may carry the official conformance test mark
- End users are encouraged to include the availability of the conformance test mark in their vendor and device selection process.

EtherCAT®
Conformance tested

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Official Conformance Test Centers

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Thank you for your attention!
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