



Setup

Operation

Maintenance

In case of an error...

We will cover:

- Machine Setup
- Operational and Online diagnostics
- Maintenance
- In case of an error...



Setup

Operation

Maintenance

In case of an error...

- Check electrical cabling
- Check network topology and identify devices
- Start network

# Straight or Cross-over cable?

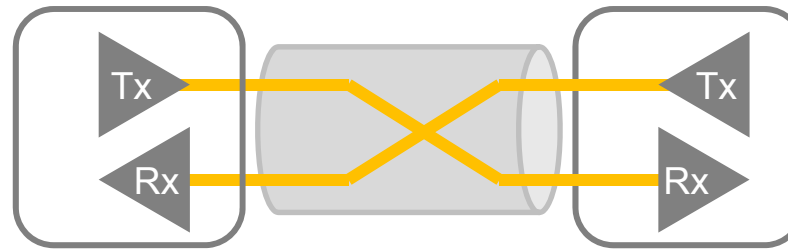
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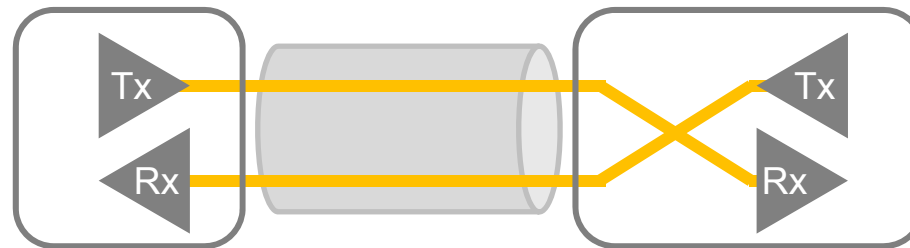
In case of an error...

- The connection between Ethernet devices must ensure that the transmitter of one device is connected to the receiver of the other device
- **Cross-over cable** are used to connect devices directly with each other



Cross-over Cable

- **Straight cable** are used as patch cables, e.g. to connect to a switch device, crossing is done in one device



Straight Cable

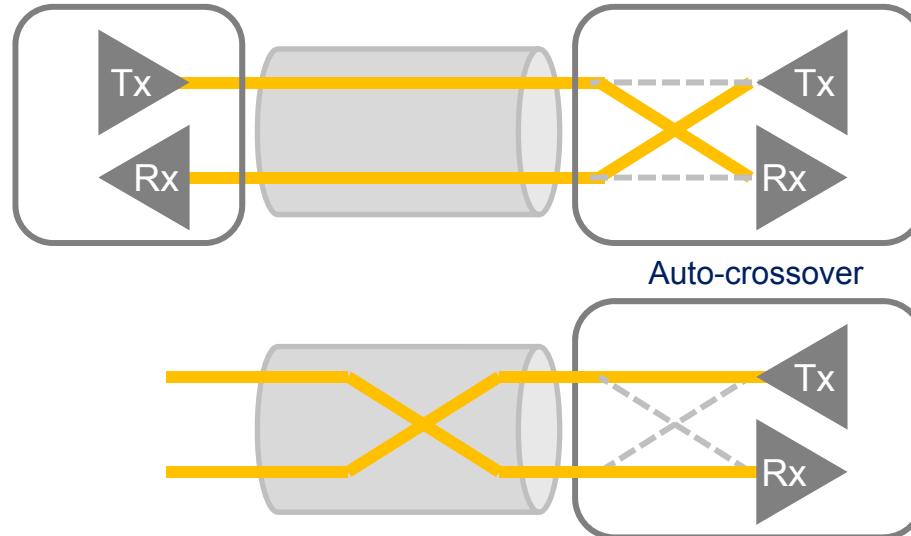
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In case of an error...

- EtherCAT slaves support **Auto-crossover** functionality
  - Each port detects automatically whether the crossing is done on cable or not
  - Cross-over and Straight cable can be used arbitrarily



- And: Ethernet uses Peer-to-Peer connections.
  - Electrical signals are refreshed by each port
  - Full 100 m cable available between two devices

# Is a link established?

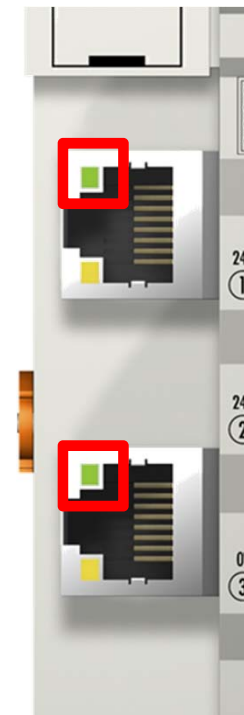
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In case of an error...

- The simplest way of diagnosing an Ethernet connection is to observe the link indicator at both end points
- Each EtherCAT slave with removable connectors, like RJ45, M12 have a **Link/Activity Indicator** per port
  - Activity on the port means that data transfer is available  
For EtherCAT: The Master sends Frames



Link	Activity	Condition	Indicator
Yes	No	Port open	On
Yes	Yes	Port open	Flickering
No	N/A	Port closed	Off

- Additional, the Master can provide these information by reading according registers in the slaves

DLL Status	
Port A:	Carrier / Open
Port B:	Carrier / Open
Port C:	Carrier / Open
Port D:	No Carrier / Closed

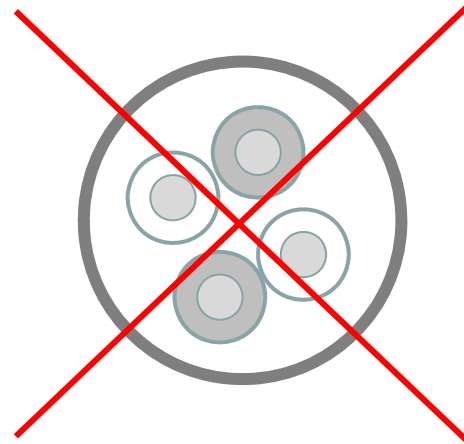
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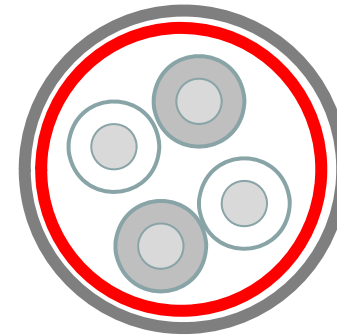
Maintenance

In case of an error...

- According to the installation profile, EtherCAT uses shielded cable for high basic standard of noise immunity
  - The overall shield around the core pairs provides for protection against external electromagnetic interference fields for the enclosed communication cores



UTP  
Unshielded twisted pair



STP  
Shielded twisted pair

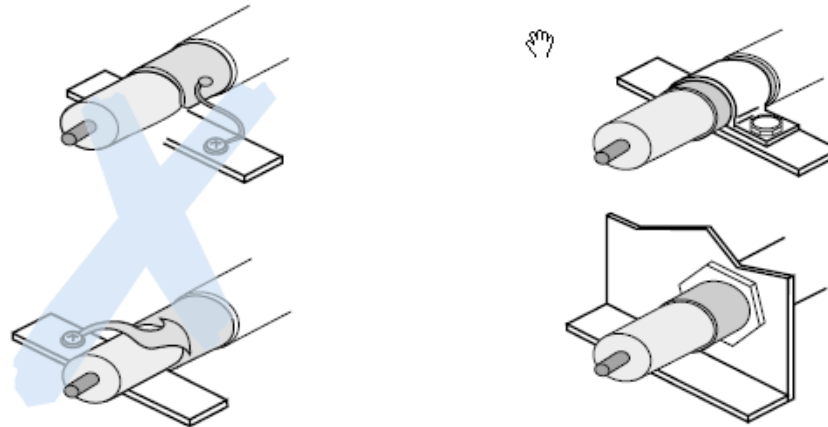
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In case of an error...

- It is important for effectiveness that the shield coverage has a low impedance throughout and that it is also implemented without interruption or holes at transition points
- The shield should be connected at each end of the cable to the machine earth via an electrically conducting connection with a large surface area and low impedance.
  - A pigtail, i.e. the twisting together and point contact of the shield, should be avoided.



ZVEI, EMV leicht gemacht,  
Pocket Guide

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In case of an error...

- The plug connection substantially affects the electrical characteristics of the transmission link, in particular the parameters screening effect, attenuation, crosstalk and return loss
- Shielding and internal signal routing are crucial



RJ45 connector, 4-pin,  
IP 20,  
for field-assembly



M12 connector, 4-pin,  
d-coded, IP67,  
for field-assembly



M12 socket on RJ45  
socket, straight outlet

# Example: poor execution of the cable/connector connection

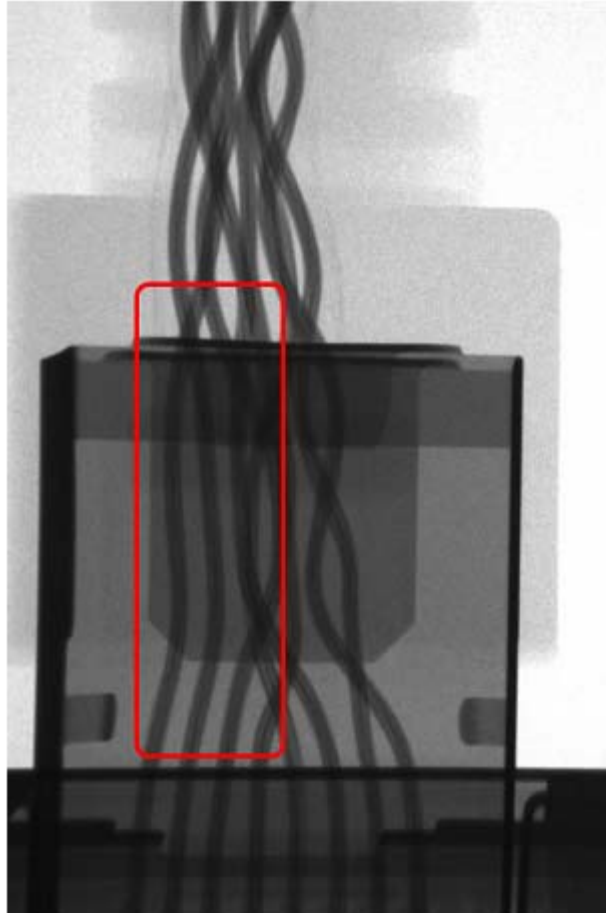
- The core pairs are untwisted over an unnecessarily long distance contrary to the manufacturer's instructions

Setup

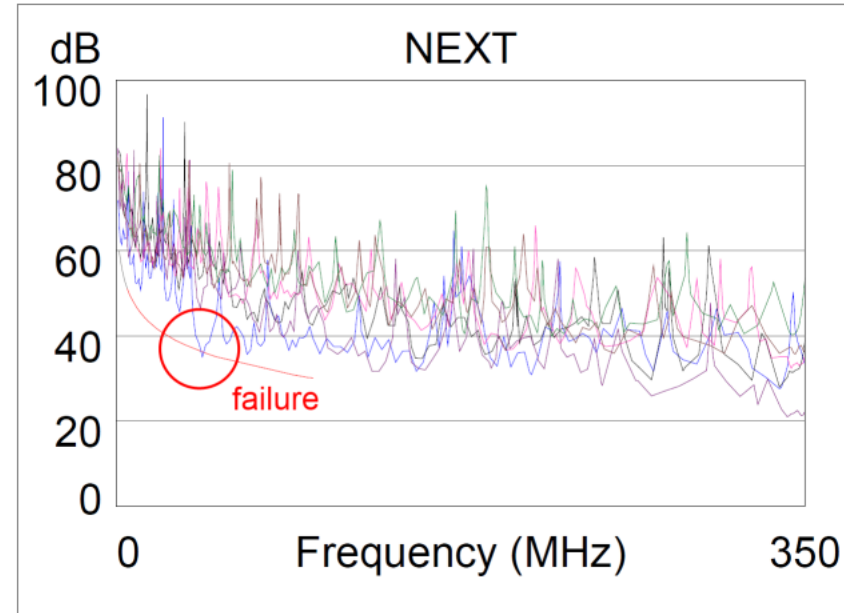
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In case of an error...



X-ray picture of an RJ45 connector



Result of the NEXT test  
(Near End Cross Talk)

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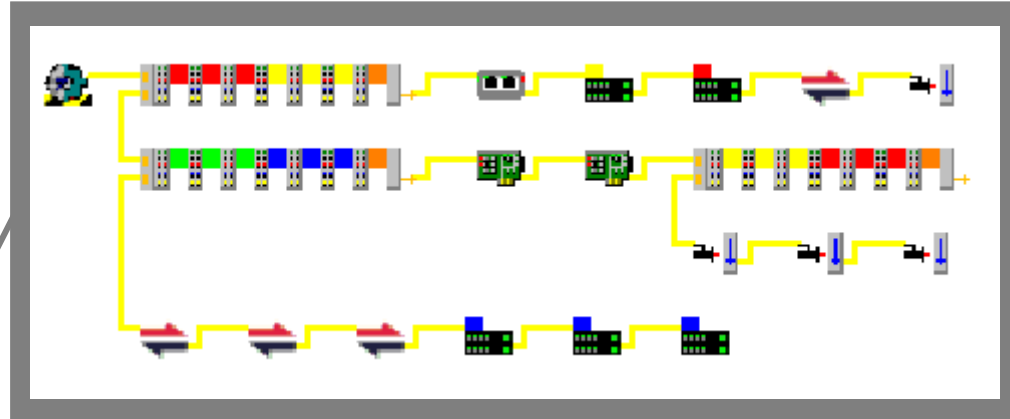
Maintenance

In case of an error...

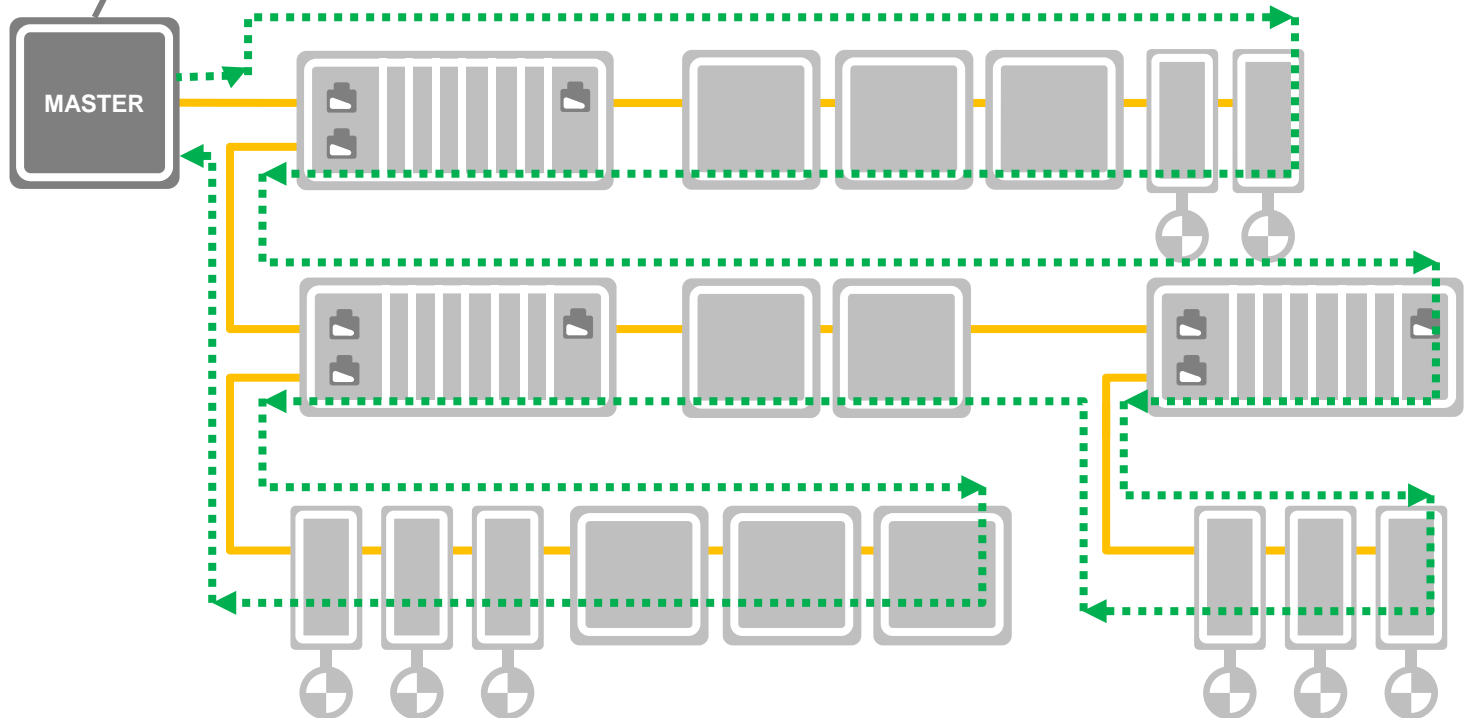
- Incomplete cable screen
  - The cable is only shielded in sections ex-works or is manufactured with insufficient coverage according to EN50288/EN50290.
- Field-configurable plug does not fit the cable used
  - If the core diameter is too small, the insulation displacement contact may not penetrate to the metal conductor and may only cut a little into the insulation.
- Compatibility
  - RJ45 plugs and sockets are not functionally compatible despite normative requirements and are prone to intermittent contacts.
- Wall feed-throughs without earth contact
  - if a metallic double coupler is used as a wall feed-through into a painted housing, the screen contact for system earthing is missing.
- Wrong assembly tool
  - Crimping tool and RJ45 plugs should be approved together by the manufacturer.
- Cable damage
  - An unsuitable cable can be damaged by repetitive movement; this may not be outwardly visible.

# Checking EtherCAT Topology

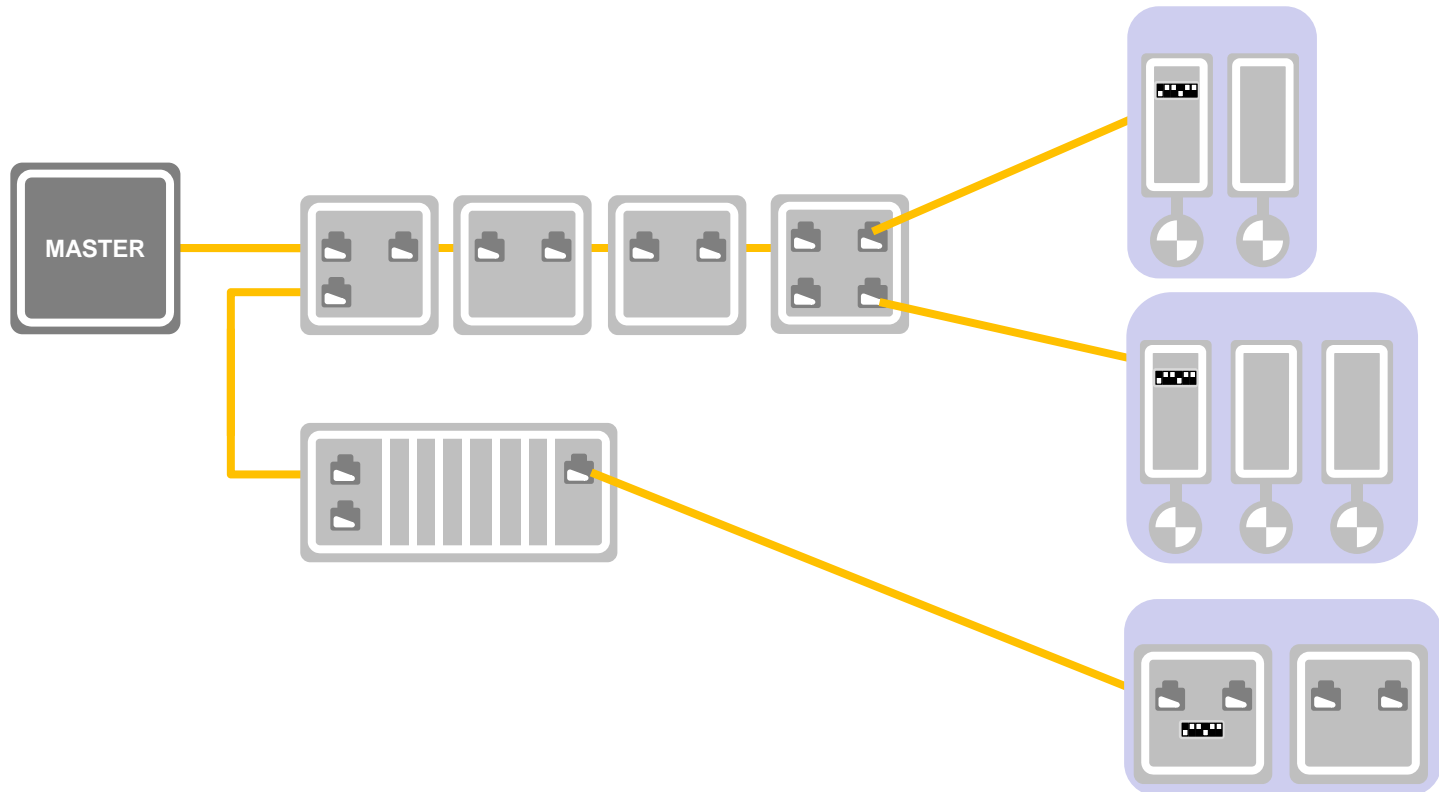
- The EtherCAT network topology can be scanned by Master using Link information of the slaves' ports



Scanned online topology

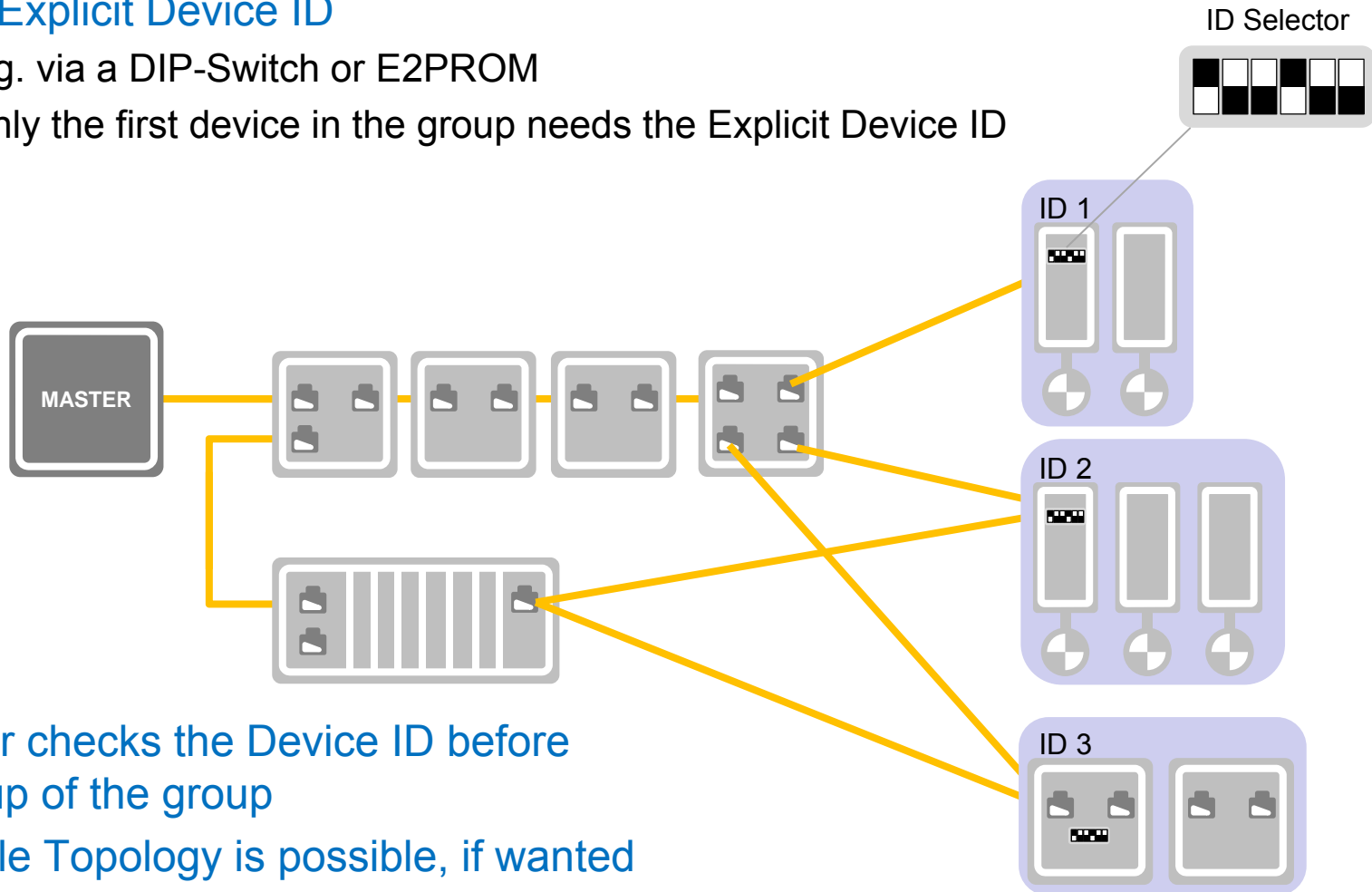


- Optional Machine parts can be connected and dis-connected while the network is running



# Example: Identification of Hot-connect groups

- Hot-connects groups need a non-volatile Identification, we call it **Explicit Device ID**
  - e.g. via a DIP-Switch or E2PROM
  - Only the first device in the group needs the Explicit Device ID



- Master checks the Device ID before boot-up of the group
- Flexible Topology is possible, if wanted

# Monitoring during network running

Online diagnosis, validity of data,  
noise issues, user information

Setup

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In case of an error...

- All necessary slaves available and running
- Process cyclic data ... .. if valid
- Acyclic access to slaves' parameter
- Fast reaction in case of error

Setup

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In case of an error...

Two main types of diagnostic information can be distinguished

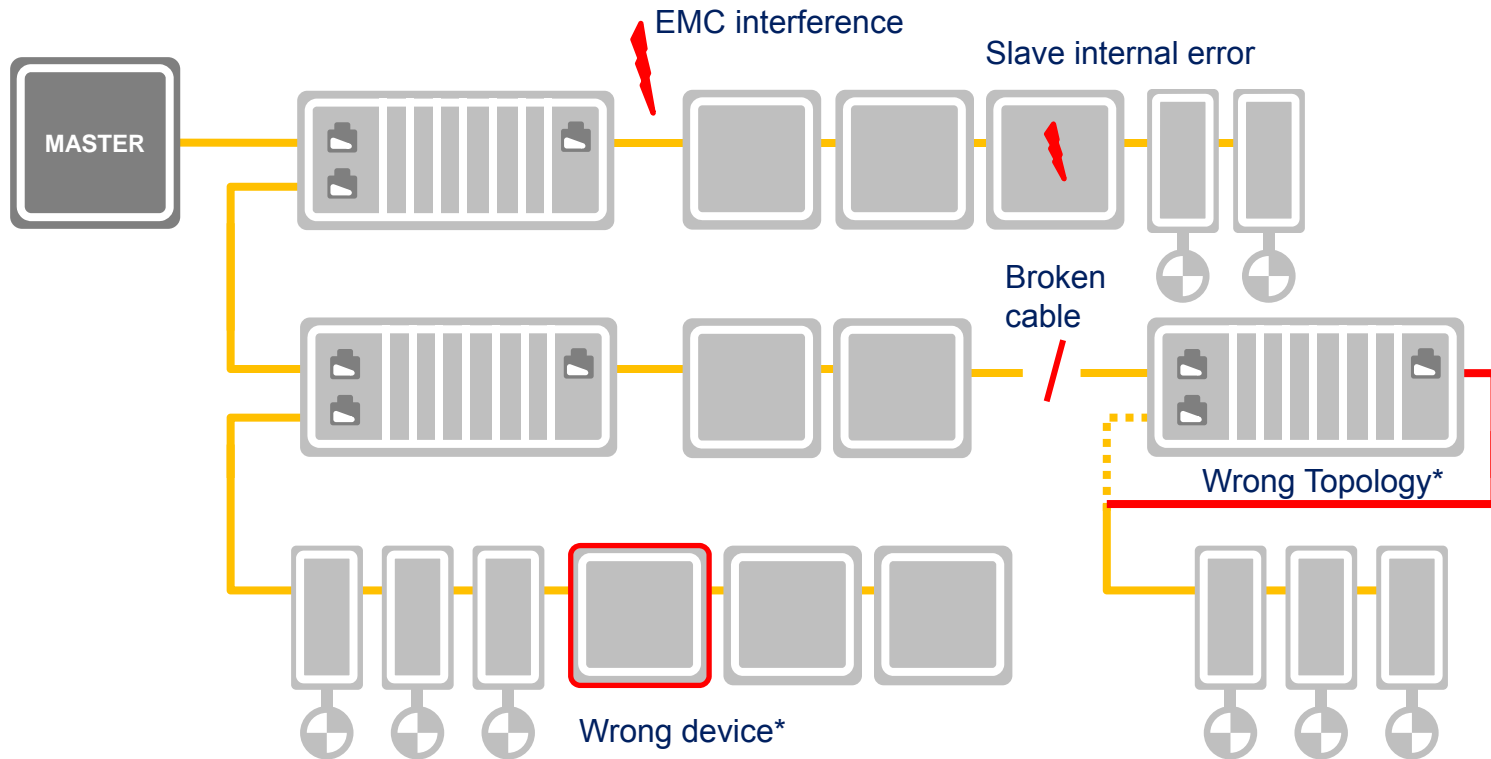
- **Cyclic validity** of process data within each cycle
  - Consistent processing by all addressed slaves
  - Cyclic updating of process data by slaves application
  - Synchronization status
  - Current state of Slave devices
  - Transmission errors
- **Acyclic information** for additional fault diagnostic
  - Network Topology
  - Physical link status and number of link lost events
  - Hardware interface errors
  - Error counter
  - Slave identification
  - Application specific errors

Fast Reaction

Precise analysis

- Setup
- Operation
- Maintenance
- In case of an error...

- Within an EtherCAT Network several diagnosis information are provided



\*checked during boot-up of the network

- For a fast overview of the network behavior Master can provide Online View of all slaves

Example:  
Overview of EtherCAT Slaves  
incl. current State and  
CRC-Error information

No	Addr	Name	State	CRC
1	1001	IO_Station_A (EK1100)	OP	0, 0, 0
2	1002	StationA_DI1 (EL1002)	OP	0, 0
3	1003	StationA_DO1 (EL2202-0100)	OP	0, 0
4	1004	Safety-PLC (EL6930)	OP	0, 0
5	1005	StationA_DI2 (EL1008)	OP	0, 0
6	1006	StationA_SafeOut1 (EL2904)	OP	0, 0
7	1007	Term 7 (EK1110)	OP	0, 0
8	1008	IO_Station_B (EK1101)	OP	0, 0
9	1009	Encoder_Feedback (EL5001)	OP	0, 0
10	1010	StationB_DI1 (EL1004)	OP	0, 0
11	1011	StationB_DO1 (EL2004)	OP	0, 0
12	1012	Term 12 (EK1110)	OP	0, 0
13	1013	IO_Station_C (EK1814)	OP	0, 0
14	1014	Term 14 (EK1110)	OP	0
15	1015	IO_Station_D (EK1101)	OP	0, 0
16	1016	StationD_DI1 (EL1002)	OP	0, 0
17	1017	StationD_DO1 (EL2022)	OP	0, 0
18	1018	Term 18 (EK1110)	OP	0, 0
19	1019	IO_Station_E (EK1100)	OP	0, 0, 0
20	1020	StationE_DI1 (EL1008)	OP	0, 0
21	1021	StationE_SafeInput1 (EL1904)	OP	0, 0
22	1022	StationE_DO1 (EL2008)	OP	0, 0
23	1023	Term 23 (EK1110)	OP	0
24	1024	IO_Station_F(EK1101)	OP	0, 0
25	1025	StationF_DI1 (EL1202)	OP	0, 0
26	1026	StationF_DO1 (EL2202)	OP	0, 0
27	1027	StationF_AI1 (EL3742)	OP	0, 0
28	1028	StationF_AO1 (EL4712)	OP	0, 0
29	1029	Profibus_Gateway (EL6731)	OP	0

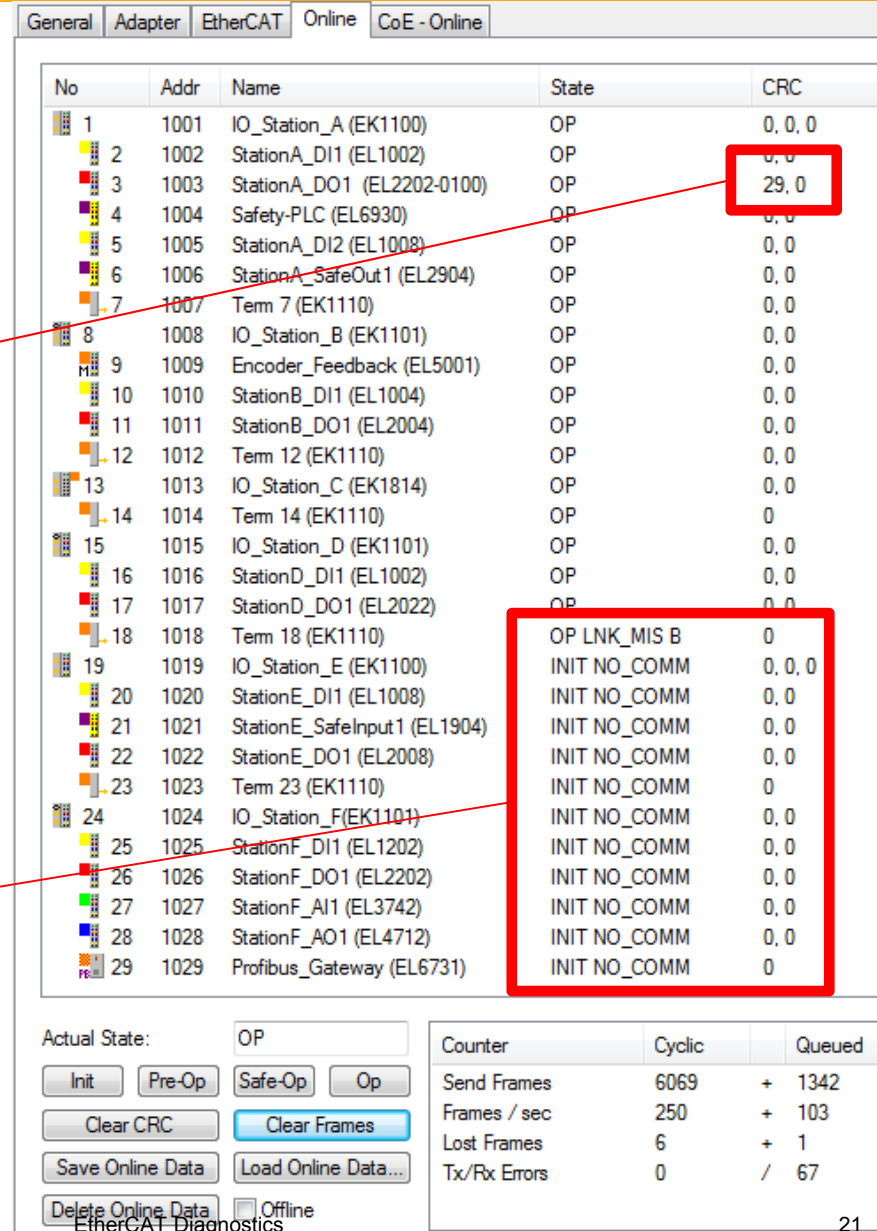
  

Actual State: <input type="text" value="OP"/>		Counter	Cyclic	Queued
<input type="button" value="Init"/>	<input type="button" value="Pre-Op"/>	Send Frames	2264595	+ 792381
<input type="button" value="Clear CRC"/>	<input type="button" value="Clear Frames"/>	Frames / sec	250	+ 3
<input type="button" value="Save Online Data"/>	<input type="button" value="Load Online Data..."/>	Lost Frames	2438	+ 607
<input type="button" value="Delete Online Data"/>	<input type="checkbox"/> Offline	Tx/Rx Errors	0	/ 3398

- Misbehavior in the network can easily be identified and located

CRC error on Port A

Term 18 in Operational, but **Missing Link on Port B**  
 → IO\_Station\_E and rest of network not available (No\_Comm)



No	Addr	Name	State	CRC
1	1001	IO_Station_A (EK1100)	OP	0, 0, 0
2	1002	StationA_DI1 (EL1002)	OP	29, 0
3	1003	StationA_DO1 (EL2202-0100)	OP	0, 0
4	1004	Safety-PLC (EL6930)	OP	0, 0
5	1005	StationA_DI2 (EL1008)	OP	0, 0
6	1006	StationA_SafeOut1 (EL2904)	OP	0, 0
7	1007	Term 7 (EK1110)	OP	0, 0
8	1008	IO_Station_B (EK1101)	OP	0, 0
9	1009	Encoder_Feedback (EL5001)	OP	0, 0
10	1010	StationB_DI1 (EL1004)	OP	0, 0
11	1011	StationB_DO1 (EL2004)	OP	0, 0
12	1012	Term 12 (EK1110)	OP	0, 0
13	1013	IO_Station_C (EK1814)	OP	0, 0
14	1014	Term 14 (EK1110)	OP	0
15	1015	IO_Station_D (EK1101)	OP	0, 0
16	1016	StationD_DI1 (EL1002)	OP	0, 0
17	1017	StationD_DO1 (EL2022)	OP	0, 0
18	1018	Term 18 (EK1110)	OP	0
19	1019	IO_Station_E (EK1100)	OP LNK_MIS B	0
20	1020	StationE_DI1 (EL1008)	INIT NO_COMM	0, 0, 0
21	1021	StationE_SafeInput1 (EL1904)	INIT NO_COMM	0, 0
22	1022	StationE_DO1 (EL2008)	INIT NO_COMM	0, 0
23	1023	Term 23 (EK1110)	INIT NO_COMM	0
24	1024	IO_Station_F (EK1101)	INIT NO_COMM	0, 0
25	1025	StationF_DI1 (EL1202)	INIT NO_COMM	0, 0
26	1026	StationF_DO1 (EL2202)	INIT NO_COMM	0, 0
27	1027	StationF_AI1 (EL3742)	INIT NO_COMM	0, 0
28	1028	StationF_AO1 (EL4712)	INIT NO_COMM	0, 0
29	1029	Profibus_Gateway (EL6731)	INIT NO_COMM	0

Counter	Cyclic	Queued
Send Frames	6069	+ 1342
Frames / sec	250	+ 103
Lost Frames	6	+ 1
Tx/Rx Errors	0	/ 67

- Topology View can also be used for network overview

Example:  
Online Topology View

**Online Configuration**

All green – all in operational

EtherCAT	
Name:	Term 9 (EL5001)
Type:	EL5001
EtherCAT Addr:	1009
Auto Inc Addr:	FFF8
Identity	
Vendor Id:	2
Revision No:	0x03f90000
Product Code:	0x13893052
Serial No:	0x00000000
Product/Revision:	EL5001-0000-1017

- Topology View can also be used for network overview

Example:  
Online Topology View

The screenshot displays the 'Online Topology View' window. The main area shows a network diagram with several nodes connected by yellow lines. A red dot is visible on one of the nodes, with a red line pointing to it and the text 'Red dot - CRC error'. Another red line points to a node with a red status bar, labeled 'No Comm'. A legend on the right side of the diagram maps colors to operational states: Green for 'Op', Yellow for 'PreOp', Yel/Green for 'SafeOp', and Red for 'Init'. Below the diagram is a configuration panel for the selected node, 'Term 9 (EL5001)'. The panel includes fields for Name, Type, EtherCAT Addr, Auto Inc Addr, Vendor Id, Revision No, Product Code, Serial No, and Product/Revision.

**Online Configuration**

Green	Op
Yellow	PreOp
Yel/Green	SafeOp
Red	Init

No Comm

Red dot - CRC error

**EtherCAT Online Process Data**

Name: Term 9 (EL5001)

Type: EL5001

EtherCAT Addr: 1009

Auto Inc Addr: FFF8

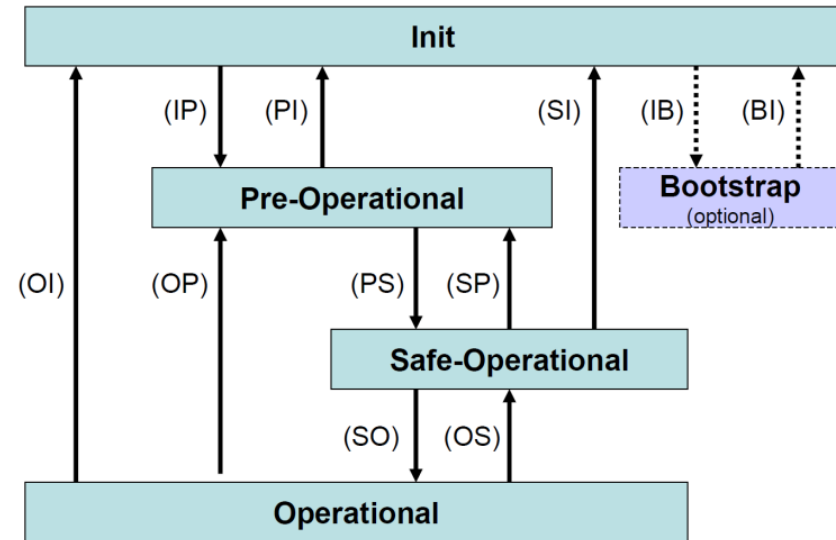
Identity

Vendor Id: 2      Revision No: 0x03f90000

Product Code: 0x13893052      Serial No: 0x00000000

Product/Revision: EL5001-0000-1017

- EtherCAT State Machine (ESM) defines the operating states of each single Slave
- State Transitions to an upper state are requested by the Master
  - Master configures the slave according to the application settings and requests next state in AL Control
  - Slave checks the settings and confirms new state in AL Status
- Input and Output data are only valid in Operational state
- In case of errors the slave can
  - Refuse a state transition requested by the Master
  - Step spontaneously to a lower state
- The error is indicated in an Error flag and the error code is given in AL Status Code register

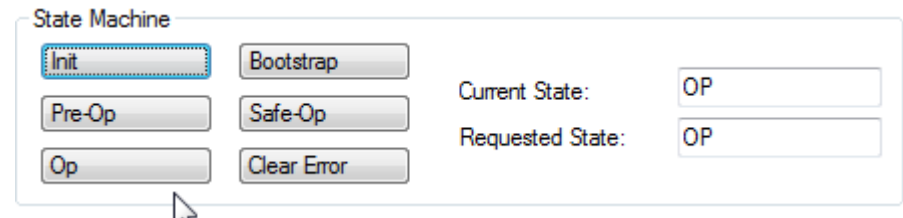


- Current state of the device is displayed at **RUN Indicator** on the device



State	RUN Indicator
Boot	Flickering
Init	Off
PreOp	Blinking
SafeOp	Flashing
Op	On

- Of course, the state information is also available in the master



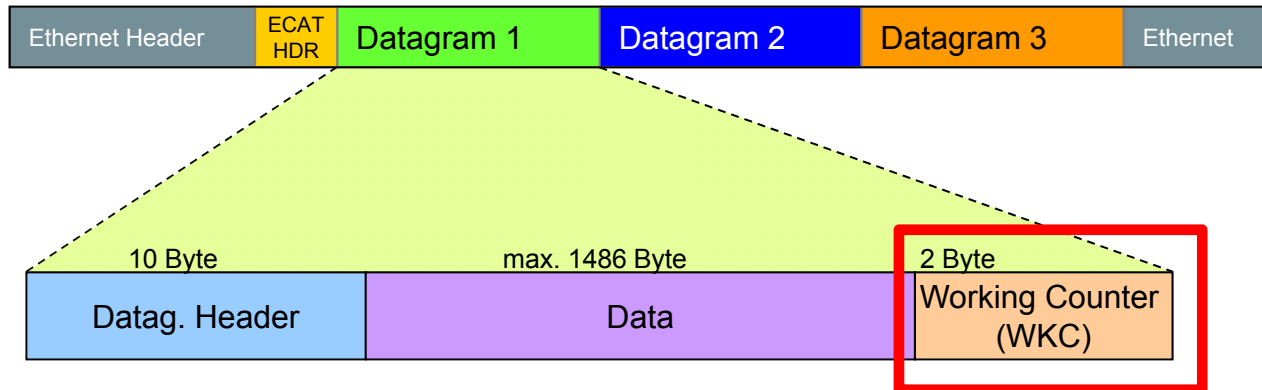
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In case of an error...

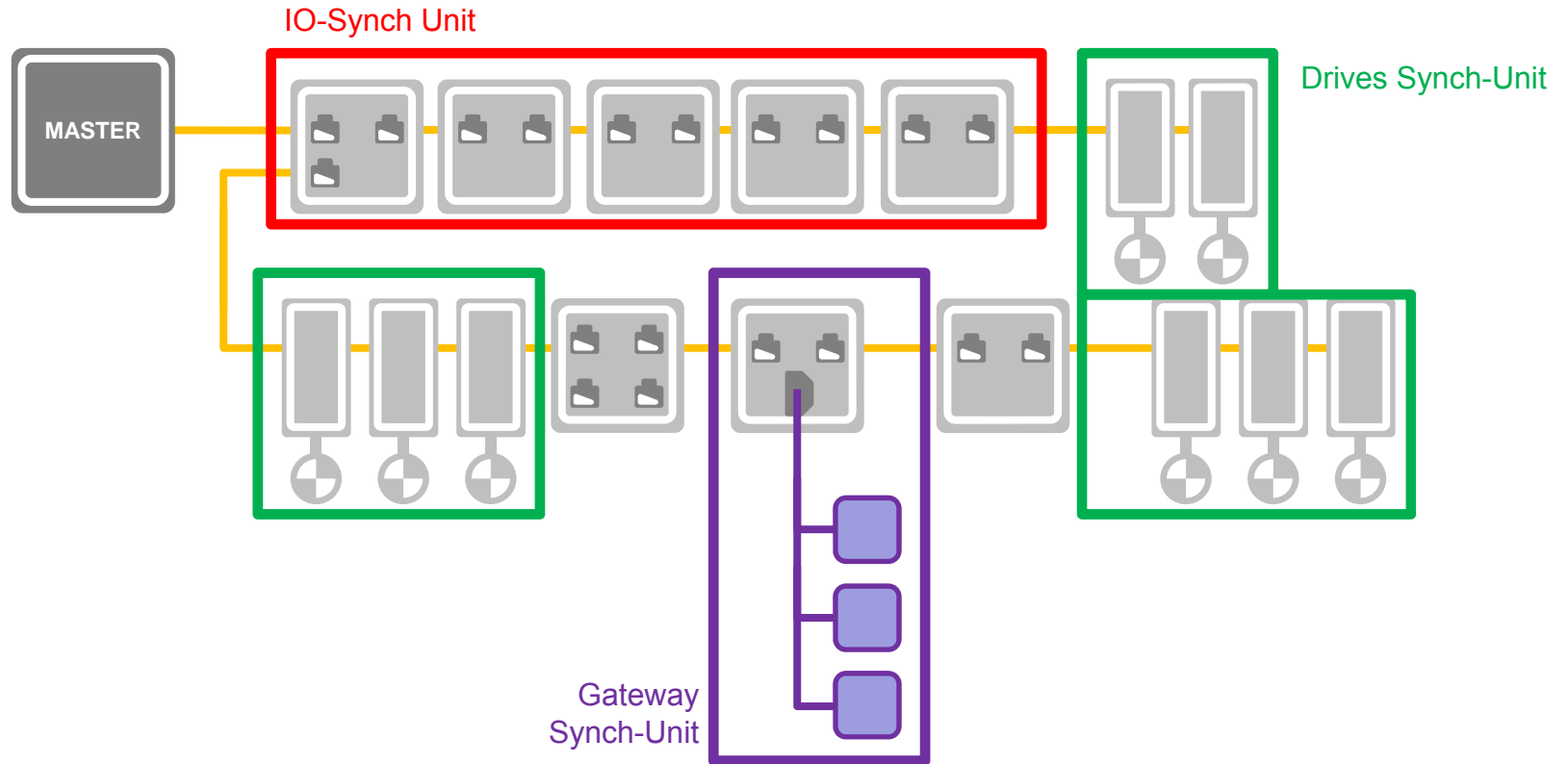
- Each EtherCAT Datagram terminates with a **Working Counter**
  - This counter enables the Master to monitor the number of **successful memory interactions** of a specific Datagram with the Slaves addressed by the Datagram itself.



- Every slave increments the Working Counter in Hardware, if
  - Slave is addressed in Datagram Header
  - Addressed memory space is available to be read / written

# Purpose of EtherCAT Working Counter

- Monitor consistent update of data units, within each Cycle



# Example: Check Op state of all slaves

- The Master can send a **BRD command** (broadcast read) as an additional datagram in the frame on AL Status register in each cycle



- Since each slave always supports the read access to this register, the received Working Counter reflects the **number of nodes** in the network
  - Missing nodes can be detected immediately in each cycle
- The data of the BRD command reflects the **states of the slaves**
  - The states are bit-coded in AL Status register
  - If all nodes are in Op state, only Bit 3 is set
  - If BRD data is  $\neq 8$ , at least one node is not in Op Master can start diagnosis process

AL Status 0x0130 Bit 3:0	Description
1 = 0001 <sub>b</sub>	Init State
2 = 0010 <sub>b</sub>	PreOp state
4 = 0100 <sub>b</sub>	SafeOp state
8 = 1000 <sub>b</sub>	Op state

# Maintenance cycle

Machine history,  
connection deterioration

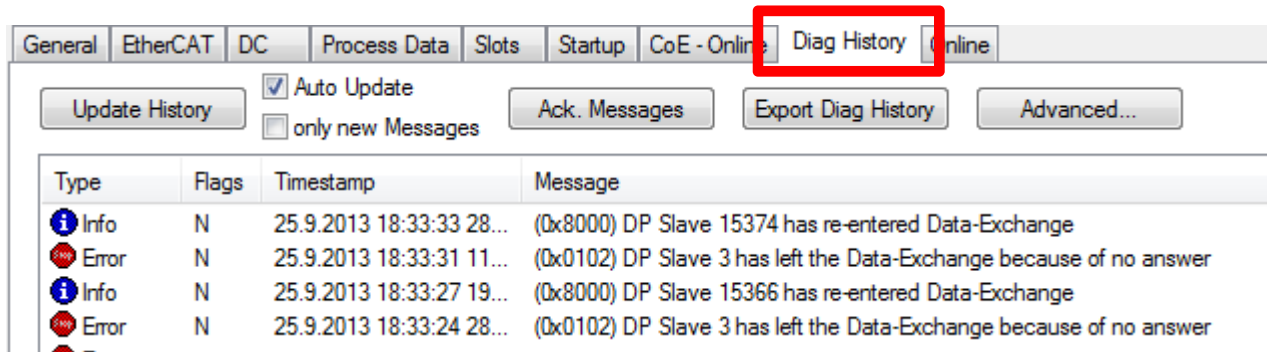
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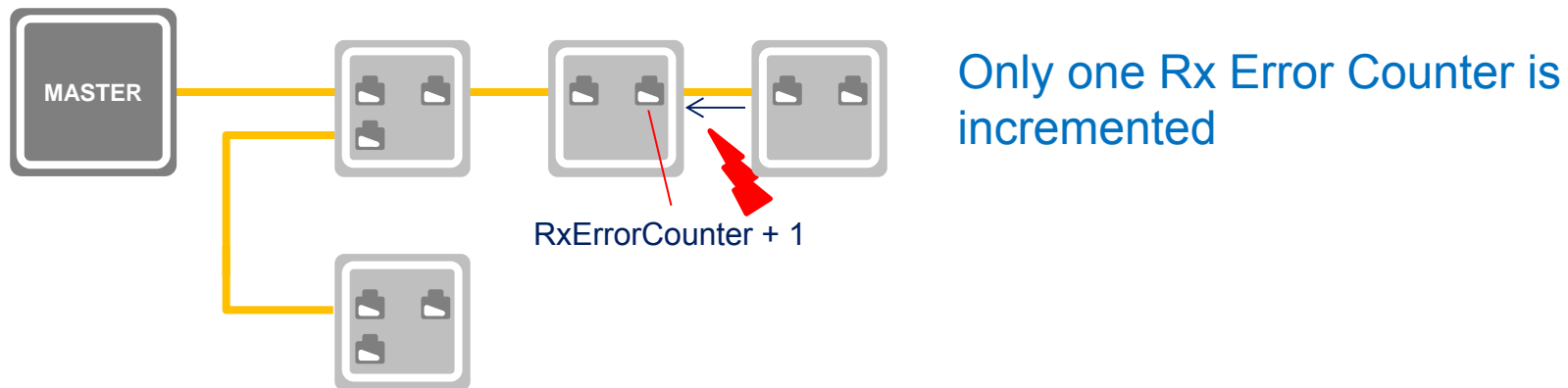
In case of an error...

- Check history of the machine
- Check cabling



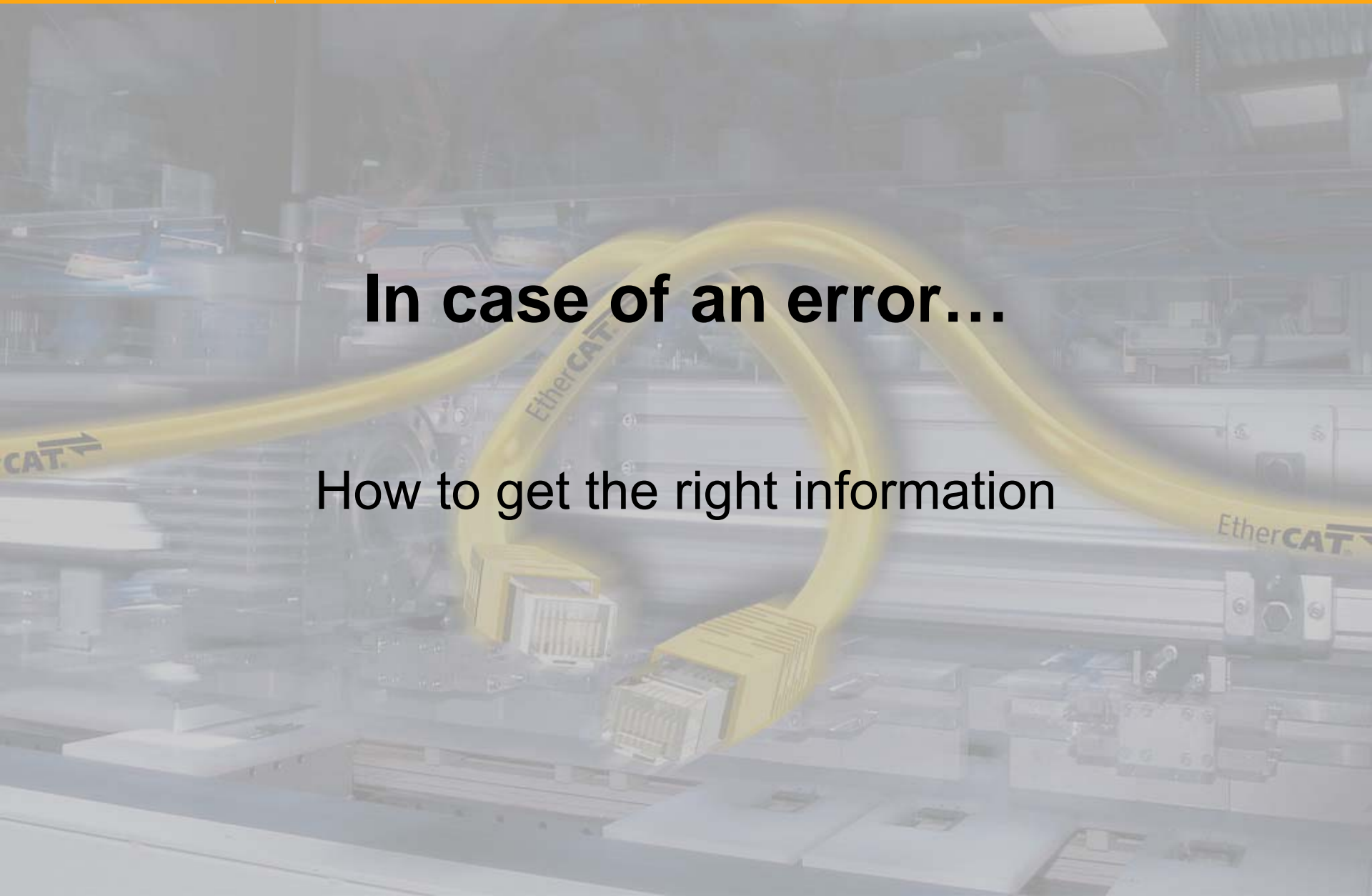
- **Diagnosis History Object** on slave can provide up to 249 Diagnosis Messages, with each containing
  - Diagnosis Code to identify the diagnosis message
  - Diag Type Info, Warning, Error
  - Text ID Reference to ESI File → Plain diagnosis message
  - Time Stamp sample time (optional)
- Single Bit „New Message available“ can be mapped into PDO to signal that new messages are available
- Advantage according to Emergency-Message:
  - Information is stored in the slave and can be read at any time, e.g. during inspection of machine Information can be read by Master Application, e.g. PLC program

- Each port of the ESC performs CRC evaluation of the incoming frame
- Rx Error Counter counts errors with wrong CRC
- If an RX error is detected, the frame is marked as corrupted, so that following slaves does not increment the Rx Error Counter  
→ Error localization is possible
- If an Rx Error Counter is increased it indicates that the electrical connection is disturbed. Possible reasons are
  - Bad shielding
  - Excessive noise
  - Loose connector
  - poor grounding



**In case of an error...**

**How to get the right information**



# In case of an error in a running machine...

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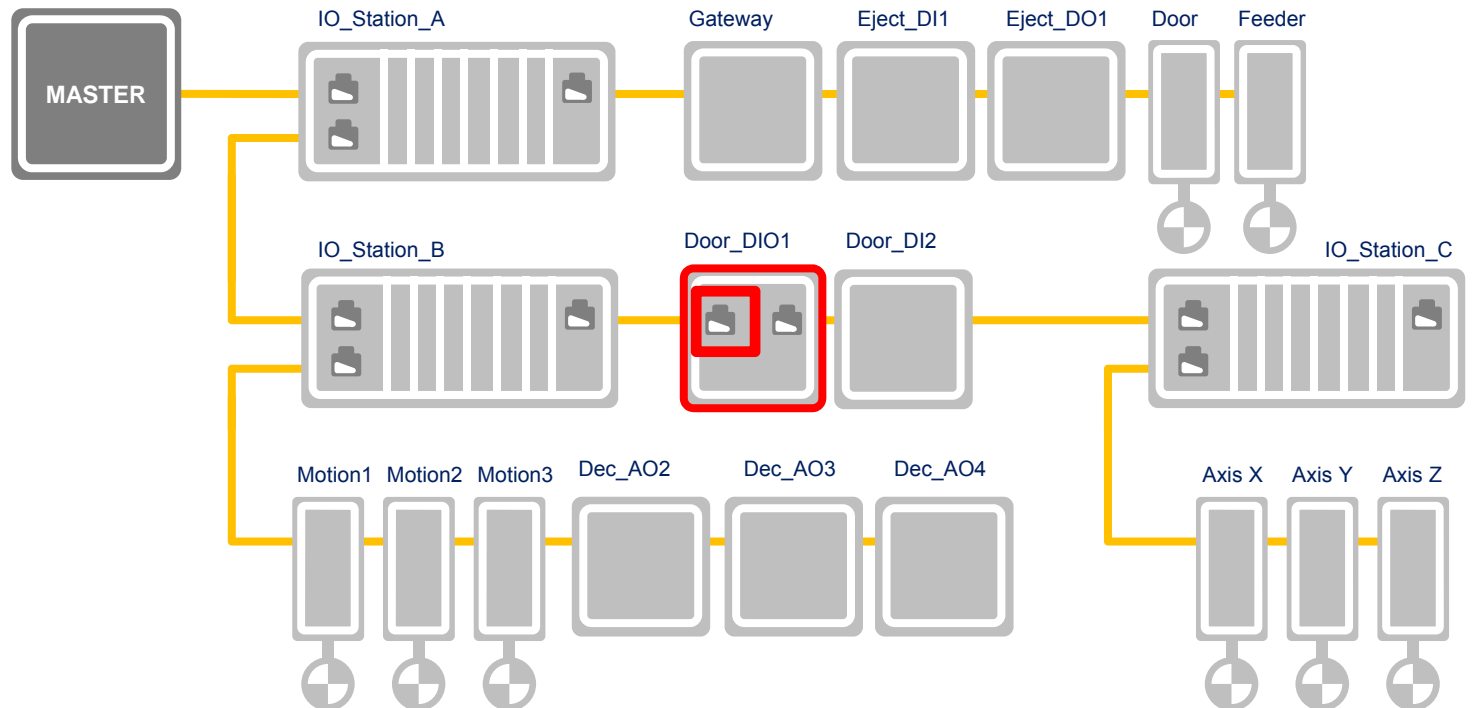
Maintenance

In case of an error...

Next to the error indication, these questions need to be answered in case of error:

- **What** has happened?
- **Who** is affected?
- **Where** is it located?

Example scenario: Bad cable connection at device “Door\_DIO1”



# Diagnosis Sequence

Setup  
Operation  
Maintenance

In case of an error...

## Bad cable connection at device "Door\_DIO1"

- Several CRC-Errors detected in slave *Door\_DIO1*  
→ Rx Error counter increments
- Slave detects input/output update error, since no data provided by ESC  
→ Slave steps back to SafeOp state and disables SyncManager

- LRW command including *Door\_DIO1* device:  
→ Master detects Working Counter error, since SyncManager is disabled  
→ Master discards Input data immediately
- Broadcast-Read command on AL Status:  
→ Master detects at least one slave not in OP

- Master reads AL Status register of all slaves  
→ slave *Door\_DIO1* not in OP

- Master reads AL Status Code register of *Door\_DIO1*  
→ Error reason: No valid inputs and outputs

- Master reads Error-Register set of slave *Door\_DIO1*  
→ Rx Error Counter of Port 0 (IN Port) incremented → **failure location**

Supervision



Error!

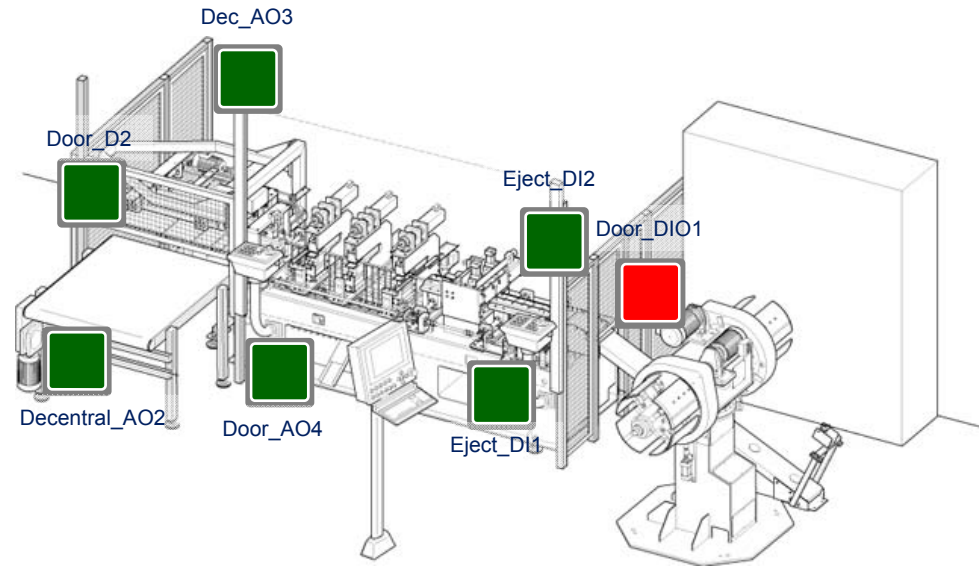
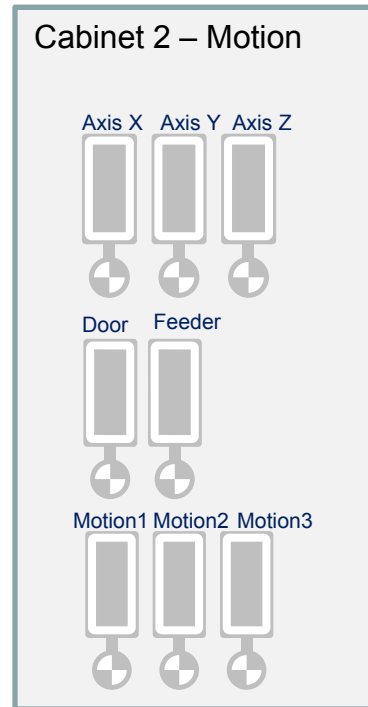
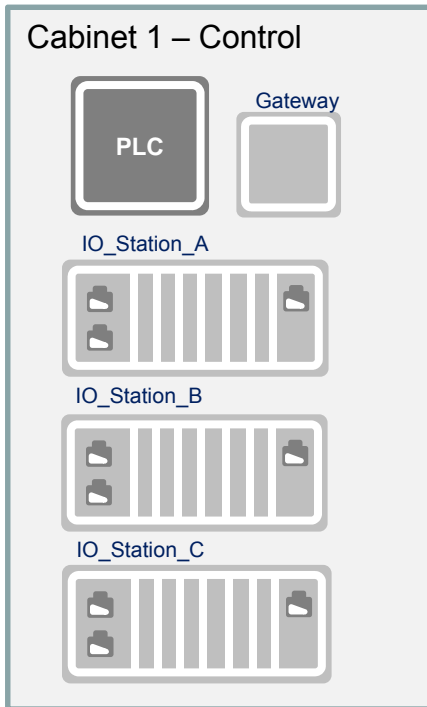
Slave *Door\_DIO1* not in Operational.

Error information No valid inputs and outputs

Possible reason Bad connection on IN-Port of the device.

Proposed action Please check cable or connector.

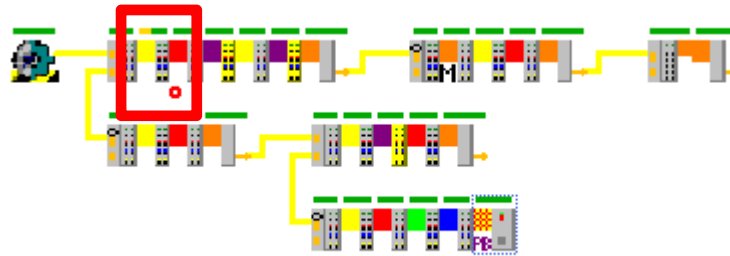
Example:  
Machine Overview



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In case of an error...

- Topology view



- Online view

No	Addr	Name	State	CRC
1	1001	IO_Station_A (EK1100)	OP	0.0.0
2	1002	StationA_DI1 (EL1002)	OP	0.0
3	1003	StationA_DO1 (EL2202-0100)	SAFEOP	29.0
4	1004	Safety-PLC (EL6930)	OP	0.0
5	1005	StationA_DI2 (EL1008)	OP	0.0
6	1006	StationA_SafeOut1 (EL2904)	OP	0.0
7	1007	Term 7 (EK1110)	OP	0.0
8	1008	IO_Station_B (EK1101)	OP	0.0
9	1009	Encoder_Feedback (EL5001)	OP	0.0
10	1010	StationB_DI1 (EL1004)	OP	0.0
11	1011	StationB_DO1 (EL2004)	OP	0.0
12	1012	Term 12 (EK1110)	OP	0.0
13	1013	IO_Station_C (EK1814)	OP	0.0
14	1014	Term 14 (EK1110)	OP	0
15	1015	IO_Station_D (EK1101)	OP	0.0
16	1016	StationD_DI1 (EL1002)	OP	0.0
17	1017	StationD_DO1 (EL2022)	OP	0.0

# QUESTIONS?