# EtherCAT Overview

EtherCAT State Machine

The EtherCAT State Machine (ESM) is required on all EtherCAT devices. The ESM in general

- defines 5 communication states of the slave device
    - Init, Pre-Operational, Safe-Operational, Operational
    - Bootstrap is an optional state for firmware upload
- specifies initialization and error handling of the slave device
- identifies the current communication relationship between the master and slave device
    - requested and current state are accessed through the AL Control and AL Status registers

The ESM states can be transitioned as shown
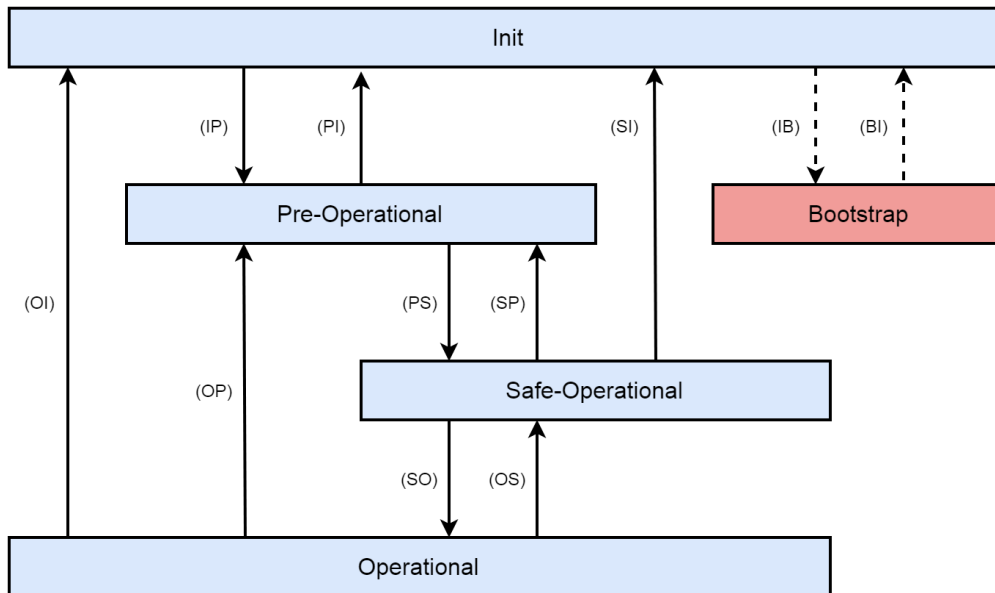
Init State

- No communication to the application layer is allowed
- master only has communication to the data link registers (slave device eeprom, addressing, etc)

Pre-Operational State

- Mailbox (SDO) communication to the application layer is available
- No Process Data (PDO) communication.
- PDO register mapping should be completed. Transition to Safe-Operation will configure mapping.

Safe-Operational State

- Mailbox (SDO) communication to the application layer is available
- Slave output (tx) Process Data (PDO) communication is evaluated

Operational State

- All communication is commenced and valid

Bootstrap State

- The bootstrap state is used when updating EtherCAT firmware.

Explicit Device ID

General Description

The use of EtherCAT Device identification is to identify an EtherCAT slave explicitly. This is necessary for the following use cases:

- Hot Connect applications
  Within some applications it might be useful to connect or disconnect parts of the network. In this case the master must have the possibility to identify which part of the network is available.

- Prevention against cable swapping
  If at least two identical devices are used in one application it might be necessary to prevent the mix-up of these devices by cable swapping. Example Scenario: Within a machining center there might be two identical drives to work in X and Y direction. To avoid that the drives receive wrong process data, for example after a device replacement, an explicit identification of the devices can be used.

The Device Identification value can be used optionally for unique addressing.

Rotary Selectors

The CM1-E uses 2 rotary selectors on the side of the motor to set the ID. These use hexadecimal values to set the range from 0-255. The values are set as follows

	x10	**x1**
Description	Most significant 4 bits	Least significant 4 bits
Example value	B_h	5_h
Combined value	$B5_h$ (181_d)	

ID Range Usage

The following ID range is permissible

ID	**Usage**
0x00 (0)	No ID is set and Explicit Device ID is not used
0x01-0xFE (1-254)	Explicit Device ID has been set
0xFF (255)	Reserved - Value cannot be used and will be read as 0 by the master

Configured Station Alias

For backwards compatibility with certain master controllers the Configured Station Alias Register 0x0012 may be used. The following conditions exist:

Explicit Device ID Value	**Configured Station Alias Value**	**Usage**
0	0	No identification used or expected
>0	0	Explicit Device ID is used
0	>0	Configured Station Alias is used
>0	>0	Internal error generated

PDO Timing

The CM1-E slave will accept a number of PDO rates. The rate is auto-detected and no additional setup is required on the slave.

Accepted rates are

1. 1000s (1ms)
2. 500s
3. 250s
4. 200s

The detected rate can be read in object 0xFE00:1.

PDO Mappings

The Cool Muscle EtherCAT slave has a few static PDO mapping options. It does not use dynamic mapping.

- The RxPDO is the PDO received by the motor/slave device
- The TxPDO is the PDO transmitted by the motor/slave device

Position units are in encoder counts (pulses). There are 50,000 encoder counts per revolution.

The following mappings are available.

Dynamic Switching of mode

This mapping is useful as a generic mapping. The master can run in any of the available modes as well as switch dynamically between them. The PDO also offers a lot of feedback information for diagnostics.

RxPDO - 0x1600

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6040	Controlword	-	UINT16	All	The Controlword is used to control the state of the mode of operation.
0x60FE	Digital outputs	-	UINT16	All	Set the state of the digital outputs
0x607A	Target position	units	INT32	CSP, PP	Set the target position of the motor
0x60FF	Target speed	units/ms units/s	INT32	CSV PV	Set the target speed of the motor. Note PV mode and CSV mode have different units.
0x6060	Modes of operation	-	INT8	All	Set the required mode of operation

TxPDO - 0x1A00

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6041	Statusword	-	UINT16	All	The Statusword describes the current state of the mode of operation.
0x603F	Error Code	-	UINT16	All	The actual error code currently active.
0x6064	Position Actual Value	units	INT32	All	The value of the motor's actual position
0x606C	Speed Actual Value	units/ms	INT32	All	The value of the motor's actual speed
0x6077	Torque Actual Value	0.1% rated torque	INT16	All	The value of the motor's actual peak torque
0x60FD	Digital Inputs	-	UINT16	All	Digital inputs status
0x2301	Temperature	°c	INT16	All	The actual motor temperature in °c.
0x6079	DC Voltage	0.1VDC	INT16	All	The actual DC 24V DC bus voltage
0x6061	Modes of operation display	-	INT8	All	The mode of operation currently running.

CSP Mode

This mapping is useful when a minimum amount of data wants to be transferred using CSP mode.

RxPDO - 0x1601

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6040	Controlword	-	UINT16	All	The Controlword is used to control the state of the mode of operation.
0x60FE	Digital outputs	-	UINT16	All	Set the state of the digital outputs
0x607A	Target position	units	INT32	CSP, PP	Set the target position of the motor

TxPDO - 0x1A01

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6041	Statusword	-	UINT16	All	The Statusword describes the current state of the mode of operation.
0x603F	Error Code	-	UINT16	All	The actual error code currently active.
0x6064	Position Actual Value	units	INT32	All	The value of the motor's actual position
0x6077	Torque Actual Value	0.1% rated torque	INT16	All	The value of the motor's actual peak torque
0x606C	Speed Actual Value	units/ms	INT32	All	The value of the motor's actual speed
0x60FD	Digital Inputs	-	UINT16	All	Digital inputs status

CSV Mode

This mapping is useful when a minimum amount of data wants to be transferred using CSP mode.

RxPDO - 0x1602

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6040	Controlword	-	UINT16	All	The Controlword is used to control the state of the mode of operation.
0x60FE	Digital outputs	-	UINT16	All	Set the state of the digital outputs
0x60FF	Target speed	units/ms	INT32	CSV	Set the target speed of the motor. Note PV mode and CSV mode have different units.

TxPDO - 0x1A02

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6041	Statusword	-	UINT16	All	The Statusword describes the current state of the mode of operation.
0x603F	Error Code	-	UINT16	All	The actual error code currently active.
0x6064	Position Actual Value	units	INT32	All	The value of the motor's actual position
0x6077	Torque Actual Value	0.1% rated torque	INT16	All	The value of the motor's actual peak torque
0x606C	Speed Actual Value	units/ms	INT32	All	The value of the motor's actual speed
0x60FD	Digital Inputs	-	UINT16	All	Digital inputs status

Profile Mode

This mapping is useful when profile position or profile velocity mode is used.

RxPDO - 0x1603

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6040	Controlword	-	UINT16	All	The Controlword is used to control the state of the mode of operation.
0x60FE	Digital outputs	-	UINT16	All	Set the state of the digital outputs
0x607A	Target position	units	INT32	CSP, PP	Set the target position of the motor
0x60FF	Target speed	units/ms units/s	INT32	CSV PV	Set the target speed of the motor. Note PV mode and CSV mode have different units.
0x6081	Profile velocity	-	UINT32	PP	Set the required mode of operation

0x6083	Profile acceleration		UINT32	PP, PV	

TxPDO - 0x1A03

Object	Name	Units	Data Type	Applicable Modes of Operation	Description
0x6041	Statusword	-	UINT16	All	The Statusword describes the current state of the mode of operation.
0x603F	Error Code	-	UINT16	All	The actual error code currently active.
0x6064	Position Actual Value	units	INT32	All	The value of the motor's actual position
0x606C	Speed Actual Value	units/ms	INT32	All	The value of the motor's actual speed
0x6077	Torque Actual Value	0.1% rated torque	INT16	All	The value of the motor's actual peak torque
0x60FD	Digital Inputs	-	UINT16	All	Digital inputs status
0x2301	Temperature	°c	INT16	All	The actual motor temperature in °c.
0x6079	DC Voltage	0.1VDC	INT16	All	The actual DC 24V DC bus voltage