User's Manual

Ethercat Module Attachment

Manual Code: MB00301E00 V_1.4

INDEX

1 INTRODUCTION

1.1 ABOUT THIS MANUAL

This manual is meant as a brief explanation of how to work new OPDE EtherCAT module. The manual contains the following chapters:

- **Introduction** provides information background about the manual;
- **Mechanical Installation** contains the instructions on mounting the OPDE EtherCAT Module;
- **Electrical Installation** contains cabling instruction and general information about EtherCAT connections;
- **Getting Started** contains a quick guide for setting-up the OPDE with a Master EtherCAT,
- **Protocols** provides the most important informations about EtherCAT protocol, CAN OPEN DSP402 protocols and main CAN OPEN over EtherCAT object used;
- **Diagnostics** provides the information to solve possible problems and wrong configurations;

1.2 COMMON SYMBOLS AND ABBREVIATIONS

Abbreviations	Explanations
AL	Application Layer
CAN	Controller Area Network
CiA	CAN in Automation
CoE	CAN application protocol Over EtherCAT services

Abbreviations	Explanations
DC	Distributed Clock
EIA/TIA	Electronic Industries Association and Telecommunications Industry Association
EMC	Electromagnetc Compatibility
EMCY	Emergency Object or Service
ESC	EtherCAT Slave Controller
EtherCAT	Ethernet for Control Automation Technology
ID	Identifier
IP	Internet Protocol
OPDE	Open Drive Explorer
OPD Explorer	OPD Explorer Supervisory Software
PDI	Process Data Input
PDO	Process Data Output
PI	Proportional Integral
PLL	Phase Locked Loop
SDO	Service Data Object
XML	eXtensive Markup Language

1.3 INTENDED AUDIENCE

The manual is intended for those persons who are responsible for commissioning and using an OPDE EtherCAT Module. The reader should have some basic knowledge of networking, electrical fundamentals, electrical wiring practices and how to work the OPDE drive and OPD Explorer.

1.4 BEFORE YOU START

It is necessary that the drive is installed correctly and ready to use before starting the installation of the OPDE EtherCAT Module.

2 MECHANICAL INSTALLATION

2.1 GENERAL INFORMATION ABOUT OPDE OPTIONAL BOARDS

In the OPDE drive are present three slots where is possible to connect some optional boards (Fig. 2.1). Depending on the slot is allowed to connect only some cards as follows (for more information, see the OPDE installation manual):

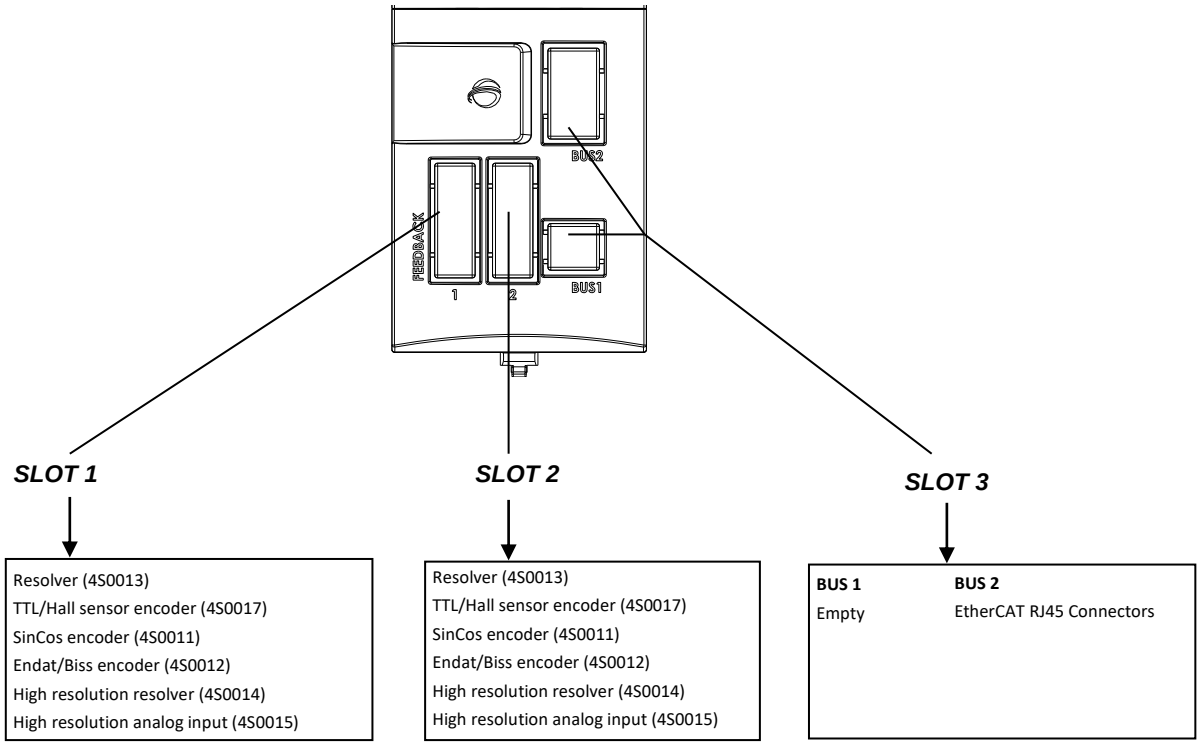


Fig. 2.1 – Slots area in OPDE

2.2 MOUNTING THE OPDE ETHERCAT MODULE

The OPDE EtherCAT Module must be inserted into its specific position in the drive: **SLOT 3**. The following figures show how to install the optional boards (Fig. 2.2).

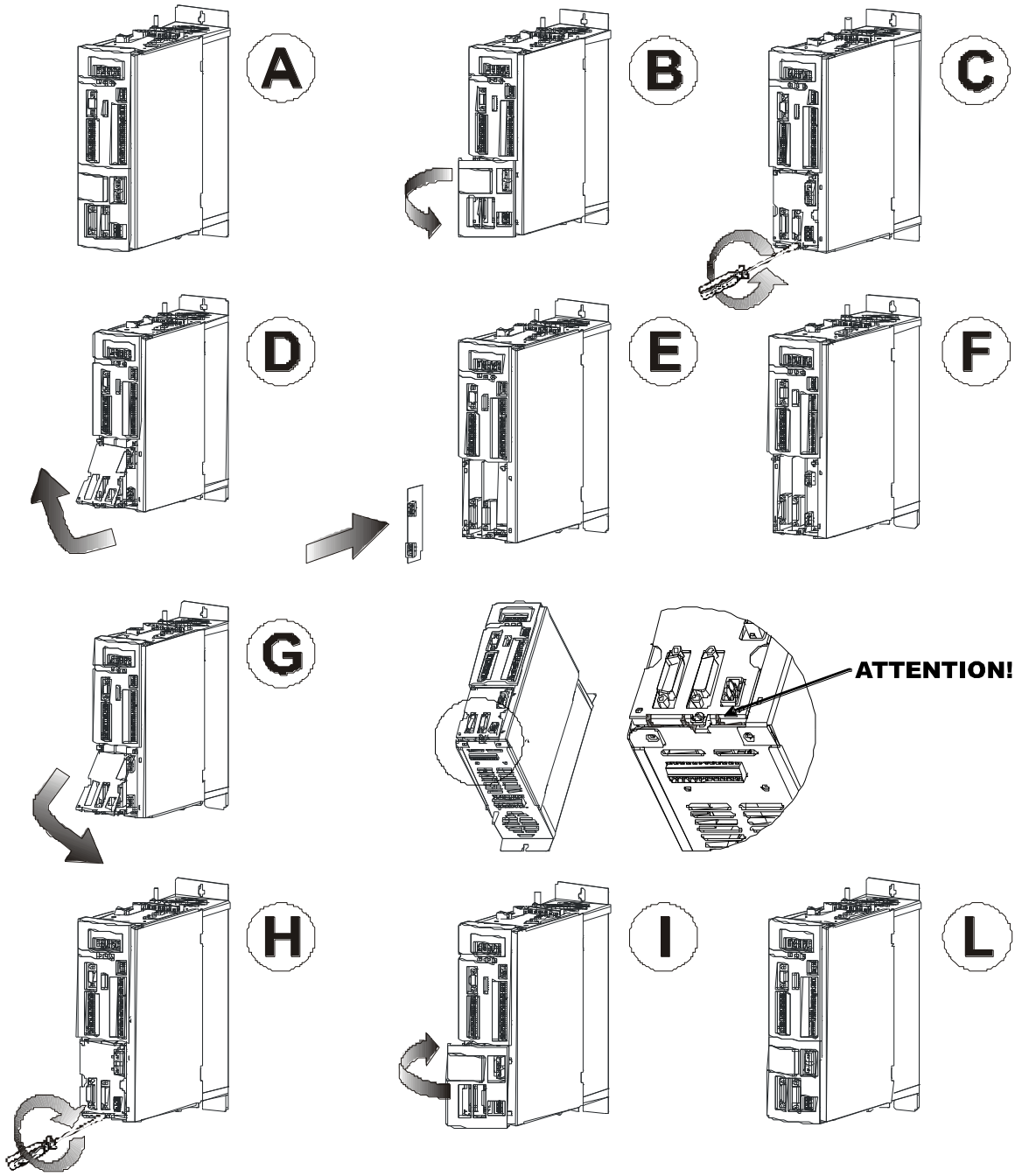


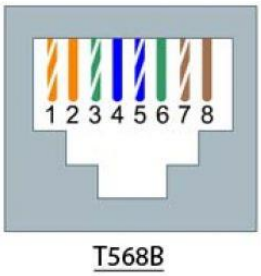
Fig. 2.2 – Optional board installation in OPDE mod 03A ÷ 60A

Pay Attention: before installing or removing the optional boards in the OPDE drive, ensure AC main supply has been disconnected for at least 5 minutes and the drive power supply has been switched-off.

3 ELECTRICAL INSTALLATION

3.1 BUS INTERFACE

The OPDE EtherCAT module incorporates two 10/100 Base TX RJ45 interfaces. The individual contacts of the RJ-45 socket are allocated as per the "T 568-B" standard. In Fig 3.1 are shown the pins and the colour codes of the T 568-B standard.



RJ45 Pin #	Wire Color (T568B)	Wire Diagram (T568B)	10Base-T Signal 100Base-TX Signal	1000Base-T Signal
1	White/Orange		Transmit+	BI_DA+
2	Orange		Transmit-	BI_DA-
3	White/Green		Receive+	BI_DB+
4	Blue		Unused	BI_DC+
5	White/Blue		Unused	BI_DC-
6	Green		Receive-	BI_DB-
7	White/Brown		Unused	BI_DD+
8	Brown		Unused	BI_DD-

Fig. 3.1 – T568-B Standard

3.2 RECOMMENDED CABLES

Ethernet patch or crossover cables in **CAT5e** quality can be used as the connection cable. CAT5e is an Ethernet network cable standard defined by the EIA/TIA. CAT5e is the fifth generation of twisted pair Ethernet technology and the most popular of all twisted pair cables in use today. CAT5e cable runs are limited to a maximum recommended run length of 100m.
Also TDE Macno recommends shielded cables for environments where proximity to power cable, high power or RF equipments may introduce crosstalk.

3.3 ETHERCAT CONNECTIONS

TDE Macno recommends, like EtherCAT network topology, the classic daisy chain (Fig. 3.2). In daisy chain topology the EtherCAT slave (OPDE drive) has an IN and an OUT RJ45 socket. The EtherCAT cable (coming from the direction of the master) is plugged into the IN socket. The OUT socket is connected to the next station.

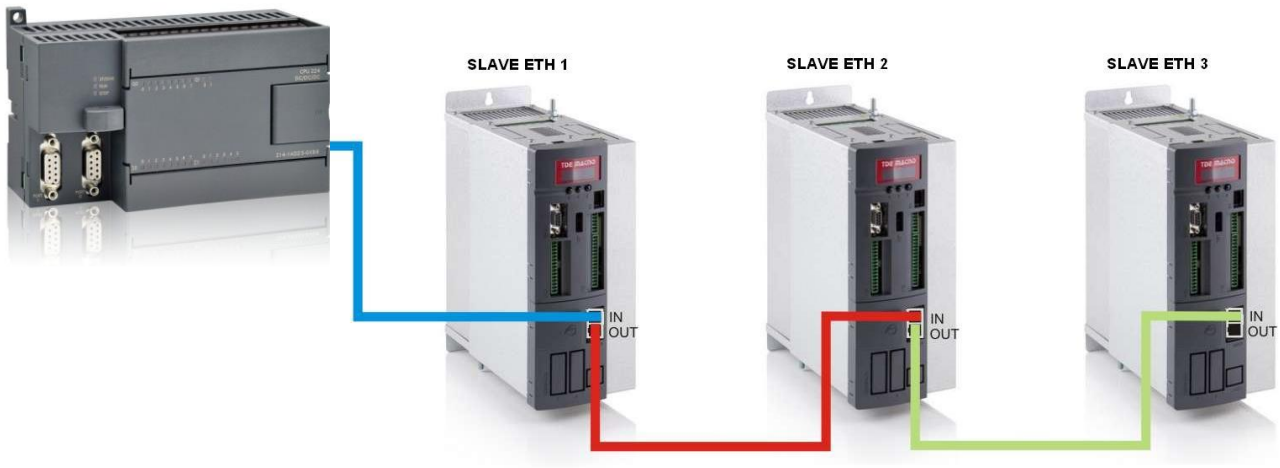


Fig. 3.2 – Daisy chain network

4 GETTING STARTED

4.1 DRIVE CONFIGURATION

After the OPDE EtherCAT module has been mechanically and electrically installed according to the instructions in the previous chapters, the drive must be prepared for communication with the module. Normally, the drive parameters must be adjusted to activate the communication. The parameter values can be changed by using the OPDE keypad or OPD Explorer software.
The principal EtherCAT parameters are those shown in the Tab. 4.1. In OPD Explorer the EtherCAT parameters can be found in the submenu item ***EtherCAT*** (Fig. 4.1).

Name	Description	Min	Max	Default	UM	Scale
EN_SYNC_REG	C23 - Enable CAN Open SYNC tracking loop	0	1	0		1
EN_FLDBUS	C64 - Enable fieldbus manage	0	4	0		1
SYNC_REG_KP	P11 - CanOpen SYNC loop regulator Proportional gain	0	200	2		1
SYNC_REG_TA	P12 - CanOpen SYNC loop regulator lead time constant	0	20000	400		1
SYNC_DELAY	Delay from SYNC reception to Speed routine execution			0	us	1
PWM_SYNC_OFFSET	PWM offset for SYNC delay control			0	pulses	1
STATE_SM	Actual state of the state machine			0		1
CYCLE _TIME	CAN Open: Cycle period in us (Obj 0x1006) - EtherCAT: Sync0 Cycle time			0		1
MAPPING_CONFIG	U03 - Select the mapping configuration			0	Hex	1
ESC_REG_ADDR	Select ESC register address			ffff	Hex	1
PDO_MAPPING	PDO mapping-the value is configured with MAPPING CONFIG			0	Hex	1
EN_PDO	COE: PDO enabled			0	Bin	1
EN_SM_ASSIGN	COE: Sync Manager PDO assigned			0	Bin	1
ESC_DL_STATUS	ESC Data Link status			0	Bin	1
RD_ESC_REGISTER0	Read ESC registers 0			0	Hex	1
RD_ESC_REGISTER1	Read ESC registers 1			0	Hex	1

Tab. 4.1 - OPDE EtherCAT parameters

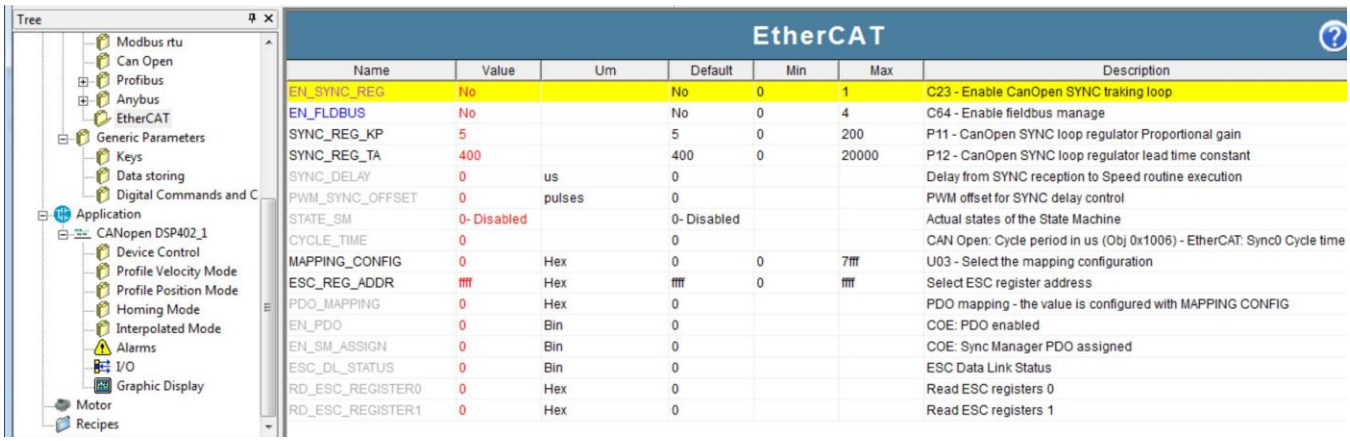


Fig 4.1 - Submenu item EtherCAT

EN_SYNC_REG (C23)

This parameter enables the CAN Open tracking loop and the **Distributed Clock synchronization** (DC synchronization). The CAN Open tracking loop permits to synchronize the CAN Open application with the EtherCAT system time, if the master supports the DC for synchronization of EtherCAT devices (see EtherCAT protocol chapter for more information). The OPDE drive uses a PLL with PI regulator for the synchronization.
To enable the CAN Open tracking loop is necessary to set to “1” the connection parameter C23, if you use the keypad.
To enable the CAN Open tracking loop is necessary to select the value “Yes” from drop-down menu of the EN_SYNC_REG parameter, if you use the supervisory software.
If EN_SYNC_REG (C23) is to “0” (or “No”), the Distributed clock is not active.
The EN_SYNC0_ETH (C23) parameter is a Reserved Parameter (see OPDE Manual for more information).

EN_FLDBUS (C64)

This parameter enables the OPDE EtherCAT Module. To enable the OPDE EtherCAT Module is necessary to set to “4” the connection parameter C64, if you use the keypad.
To enable the OPDE EtherCAT Module is necessary to select the value “EtherCAT” from drop-down menu of the EN_FLDBUS parameter, if you use the supervisory software.
The OPDE EtherCAT module is enabled, if in the *Slot3 FieldBus* field compares the **EtherCAT** sign (the Fig 4.2 is get from the OPD Explorer main page).

Fig. 4.2 - Hardware configuration

The EN_FLDBUS (C64) parameter is a Reserved Parameter (see OPDE Manual for more information).

MAPPING_CONFIG

This parameter configures the shown value on PDO_MAPPING parameter. MAPPING_CONFIG is used for diagnostic troubleshooting. The parameter is expressed in hexadecimal format. The Tab. 4.2 shows the possible MAPPING_CONFIG value.

Name	MAPPING_CONFIG	Description	PDO_MAPPING
0 h	0 h	0 h	0 h
RxPDO 1	10 h	Number of mapped objects	Visualizes the number of mapped objects
	11 h	1st mapped object	Visualizes the 1st mapped object
	1x h	xth mapped object	Visualizes the xth mapped object
	18 h	8th mapped object	Visualizes the 8th mapped object
RxPDO 2	20 h	Number of mapped objects	Visualizes the number of mapped objects
	21 h	1st mapped object	Visualizes the 1st mapped object
	2x h	xth mapped object	Visualizes the xth mapped object
	28 h	8th mapped object	Visualizes the 8th mapped object
RxPDO 3	30 h	Number of mapped objects	Visualizes the number of mapped objects
	31 h	1st mapped object	Visualizes the 1st mapped object
	3x h	xth mapped object	Visualizes the xth mapped object
	38 h	8th mapped object	Visualizes the 8th mapped object
RxPDO 4	40 h	Number of mapped objects	Visualizes the number of mapped objects
	41 h	1st mapped object	Visualizes the 1st mapped object
	4x h	xth mapped object	Visualizes the xth mapped object
	48 h	8th mapped object	Visualizes the 8th mapped object
TxPDO 1	50 h	Number of mapped objects	Visualizes the number of mapped objects
	51 h	1st mapped object	Visualizes the 1st mapped object
	5x h	xth mapped object	Visualizes the xth mapped object
	58 h	8th mapped object	Visualizes the 8th mapped object
TxPDO 2	60 h	Number of mapped objects	Visualizes the number of mapped objects
	61 h	1st mapped object	Visualizes the 1st mapped object
	6x h	xth mapped object	Visualizes the xth mapped object
	68 h	8th mapped object	Visualizes the 8th mapped object
TxPDO 3	70 h	Number of mapped objects	Visualizes the number of mapped objects
	71 h	1st mapped object	Visualizes the 1st mapped object
	7x h	xth mapped object	Visualizes the xth mapped object
	78 h	8th mapped object	Visualizes the 8th mapped object
TxPDO 4	80 h	Number of mapped objects	Visualizes the number of mapped objects
	81 h	1st mapped object	Visualizes the 1st mapped object
	8x h	xth mapped object	Visualizes the xth mapped object
	88 h	8th mapped object	Visualizes the 8th mapped object
SM_CHAN 0	90 h	Number of assigned PDO	Visualizes the number of assigned PDO
	91 h	1st assigned PDO	Visualizes the 1st assigned PDO
	9x h	xth assigned PDO	Visualizes the xth assigned PDO
	94 h	4th assigned PDO	Visualizes the 8th assigned PDO
SM_CHAN 1	A0 h	Number of assigned PDO	Visualizes the number of assigned PDO
	A1 h	1st assigned PDO	Visualizes the 1st assigned PDO
	Ax h	xth assigned PDO	Visualizes the xth assigned PDO
	A4 h	4th assigned PDO	Visualizes the 8th assigned PDO
SM_CHAN 2	B0 h	Number of assigned PDO	Visualizes the number of assigned PDO
	B1 h	1st assigned PDO	Visualizes the 1st assigned PDO
	Bx h	xth assigned PDO	Visualizes the xth assigned PDO
	B4 h	4th assigned PDO	Visualizes the 8th assigned PDO
SM_CHAN 3	C0 h	Number of assigned PDO	Visualizes the number of assigned PDO
	C1 h	1st assigned PDO	Visualizes the 1st assigned PDO
	Cx h	xth assigned PDO	Visualizes the xth assigned PDO
	C4 h	4th assigned PDO	Visualizes the 8th assigned PDO

Tab. 4.2 – Permitted MAPPING_CONFIG values

Number of mapped objects contains the number of valid entries within the mapping record. This number of entries is also the number of the application variables which shall be transmitted/received with the corresponding PDO.
Number of assigned PDO contains the number of valid entries within the mapping record.

SYNC_REG_KP (P12)

This parameter configures the PLL proportional gain for the PLL of CAN Open tracking loop.

SYNC_REG_TA (P13)

This parameter configures the PLL lead time constant fo the PLL of CAN Open tracking loop.

SYNC_DELAY (D57)

This parameter visualizes the delay value between SYNC reception and application routine execution in the CAN Open tracking loop modality. The parameter is expressed in microseconds

PWM_SYNC_OFFSET (D58)

This parameter visualizes the target reference for the PLL CAN Open tracking loop. In other words, PWM_SYNC_OFFSET shows the offset time between SYNC reception and application routine execution in the CAN Open tracking loop modality. The parameter is expressed in microseconds.

STATE_SM

This parameter visualizes the actual state of the EtherCAT State Machine. In Tab. 5.3 are shown the OPDE supported states of the EtherCAT State Machine.
NOTE: This parameter is visualized only by supervisory software.

STATE_SM	EtherCAT State
1	INIT
2	PRE-OPERATIONAL
4	SAFE-OPERATIONAL
8	OPERATIONAL

Tab. 4.3 – Supported states of the EtherCAT State Machine

CYCLE_TIME

This parameter visualizes the time between two consecutive SYNC0 pulse in nanoseconds.
NOTE: This parameter is visualized only by supervisory software.

PDO_MAPPING

This parameter visualizes the PDO mapping value. The value depends by MAPPING_CONFIG setting. The parameter is expressed in hexadecimal format.
NOTE: This parameter is visualized only by supervisory software.

EN_PDO

This parameter visualizes the enabled mapped PDO. In Tab. 4.4 are shown the EN_PDO bit descriptions.
NOTE: This parameter is visualized only by supervisory software.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
EN_PDO	TxPDO 4	TxPDO 3	TxPDO 2	TxPDO 1	TxPDO 4	RxPDO 3	RxPDO 2	RxPDO 1

Tab. 4.4 – EN_PDO bit descriptions

SM_ASSIGN

This parameter visualizes the enabled PDO mapping assigned. In Tab. 4.5 are shown the EN_PDO bit descriptions.
NOTE: This parameter is visualized only by supervisory software.

	Bit 1	Bit 0
SM_ASSIGN	PDI Enabled	PDO Enabled

Tab. 4.5 – SM_ASSIGN bit descriptions

ESC_DL_STATUS

This parameter visualizes the ESC Data Link status. In Tab. 4.6 are shown the ESC_DL_STATUS bit descriptions.
NOTE: This parameter is visualized only by supervisory software.

Bit	Description	Access
3:0	Reserved	Read
4	Physical link on Port 0: 0: No link 1: Link detected	Read
5	Physical link on Port 1: 0: No link 1: Link detected	Read
7:6	Reserved	Read
8	Loop Port 0: 0: Open 1: Closed	Read
9	Communication on Port 0: 0: No stable communication 1: Communication established	Read
10	Loop Port 1: 0: Open 1: Closed	Read
11	Communication on Port 1: 0: No stable communication 1: Communication established	Read
15:12	Reserved	Read

Tab. 4.6 – ESC_DL_STATUS bit descriptions

4.2 ETHERCAT DEVICE DESCRIPTION FILE

The EtherCAT Device Description Files are XML files that specify the properties of the slave device for the EtherCAT master and contain information on the supported communication objects. The file can be downloaded from the TDE Macno website. It should be placed in the directory specified by the master e.g. when using TwinCAT software this could be C:\TwinCAT\Io\EtherCAT.

4.3 CONFIGURING OPDE ETHERCAT MODULE FOR CYCLIC COMMUNICATIONS

The EtherCAT protocol supports the auto-configuration, auto-addressing on all the modules connected in the network, this meaning that the protocols does not require other settings in order to achieve communication.
To check that the Ethernet cable is connected to OPDE EtherCAT Module, verify if green LED (link detected LED) on the RJ45 connector is switched on (see Fig. 4.3). If green LED is switched off then check the cabling and also check that the master has started communications.

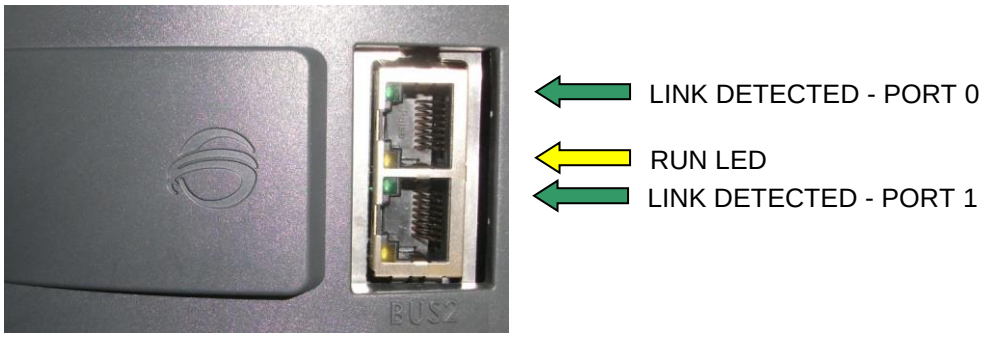


Fig. 4.3-LEDs on the RJ45 connectors

The EtherCAT Master scans the network to check the connected EtherCAT slaves. If the network is configured correctly the OPDE drive should be visible on the master interface.
At this point, to begin the cyclic communications, set the input and output data to send cyclically.
The input and output data are the supported CAN Open objects (CoE objects). OPDE drive supports the objects of Communication Profile Area (1000h – 1FFFh), Manufacturer Specific Profile Area (2000h – 5FFFh) and Standardised Device Profile Area (6000h – 9FFFh), see Protocols chapter for more information.
Cyclic data is implemented on CoE network by using “Process Data Objects”. The Process Data Objects are data packets inserted in the EtherCAT frame.
The input and output data configuration can be shared in two steps:

1. *Process data objects mapping*;
2. *Process data objects assignment*;

4.4 ETHERCAT DEVICE DESCRIPTION FILE

4.4.1 Process Data Objects Mapping

The Process Data Objects Mapping defines the content of the Process Data Objects. There are two Process Data Objects types:

- Receive Process Data Objects (RPDO)
- Transmit Process Data Objects

To execute the RPDO Mapping is necessary to insert in the RPDO Mapping Record the received objects. RPDO Mapping Records are the objects from 1600h to 17FFh.
To execute the TPDO Mapping is necessary to insert in the TPDO Mapping Record the objects to send. TPDO Mapping Records are the objects from 1A00h to 1BFFh.

In Fig. 4.4 is shown the Process Data Objects Mapping (see Protocols chapter for more information).

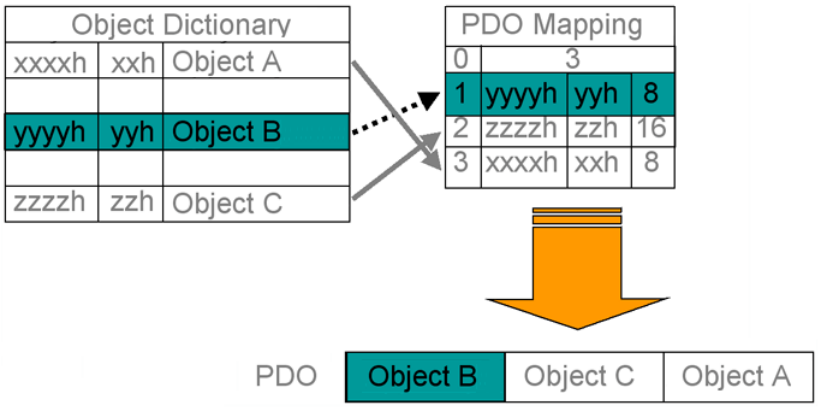


Fig. 4.4-Process Data Objects Mapping

Examples:

- RPDO Mapping for the following objects:
  Index=6040h, sub-index=0h, size: 16bit – Control word;
  Index=60C1h, sub-index=1h, size: 32bit – 1st set-point interpolation data;
  RPDO 1 (1600h) is the Process Data Objects to set.

To configure the RPDO1 follow below steps:

- Index: 1600h
  Sub-index: 0

  Size: 1 byte

  Value: 0

  Deactivate the RPDO1 mapping

- Index: 1600h
  Sub-index: 1

  Size: 4 byte

  Value: 60400010h

  Insert first object of the RPDO1.

  To set the value, see the Object Dictionary description

- Index: 1600h
  Sub-index: 2

  Size: 4 byte

  Value: 60C10120h

  Insert second object of the RPDO1.

  To set the value, see the Object Dictionary description

- Index: 1600h
  Sub-index: 0

  Size: 1 byte

  Value: 2

  Set the number of mapped objects

- TPDO Mapping for the following objects:
  Index=6041h, sub-index=0h, size: 16bit – Status word;
  Index=6064h, sub-index=0h, size: 32bit – Position actual value;
  Index=2018h, sub-index=0h, size: 16bit – Alarms;
  TPDO 2 (1A01h) is the Process Data Objects to set.

To configure the TPDO2 follow below steps:

- Index: 1A01h
  Sub-index: 0

  Size: 1 byte

  Value: 0

  Deactivate the TPDO2 mapping

- Index: 1A01h
  Sub-index: 1

  Size: 4 byte

  Value: 60410010h

  Insert first object of the TPDO2. To set the value, see the Object Dictionary description

- Index: 1A01h
  Sub-index: 2

  Size: 4 byte

  Value: 60640020h

  Insert second object of the TPDO2. To set the value, see the Object Dictionary description

- Index: 1A01h
  Sub-index: 3

  Size: 4 byte

  Value: 20180010h

  Insert third object of the TPDO2. To set the value, see the Object Dictionary description

- Index: 1A01h
  Sub-index: 0

  Size: 1 byte

  Value: 3

  Set the number of mapped objects

4.4.2 Process Data Objects Assignment

The Process Data Objects Assignment is used to control the transmission of Process Data Objects in the EtherCAT network. The Process Data Objects Assignment is supported by SyncManagers (see Protocols chapter for more information) There are two Process Data Objects Assignment types:

- PDO (master to slave);
- PDi;

To execute the PDO assignment is necessary to insert in the Sync Manager Channel 2 the enabled RPDO. Sync Manager Channel 2 is a record object with index 1C12h.

To execute the PDI assignment is necessary to insert in the Sync Manager Channel 3 the enabled TPDO. Sync Manager Channel 3 is a record object with index 1C13h.
In Fig. 4.5 is shown the Process Data Objects Assignment (see Protocols chapter for more information).

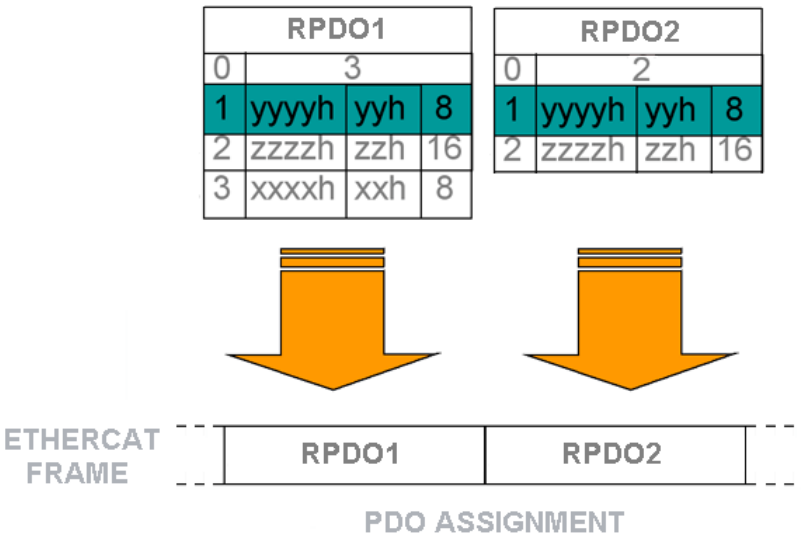


Fig. 4.5-Process Data Objects Assignment

Examples:

- PDO Assignment for the following RPDOs:
  Index=1600h – RPDO1;
  Index=1601h – RPDO2;

  To configure the PDO (1C12h) follow below steps:

  - Index: 1C12h
    Sub-index: 0

    Size: 1 byte

    Value: 0

    Deactivate the PDO assignment

  - Index: 1C12h
    Sub-index: 1

    Size: 2 byte

    Value: 1600h

    Insert the RPDO1 in the PDO. To set the value, see the Object Dictionary description

  - Index: 1C12h
    Sub-index: 2

    Size: 2 byte

    Value: 1601h

    Insert the RPDO2 in the PDO. To set the value, see the Object Dictionary description

  - Index: 1C12h
    Sub-index: 0

    Size: 1 byte

    Value: 2

    Set the number of assigned RPDO

- PDI Assignment for the following TPDO:
  Index=1A01h – TPDO2;

  To configure the PDI (1C13h) follow below steps:

  - Index: 1C13h
    Sub-index: 0

    Size: 1 byte

    Value: 0

    Deactivate the PDI assignment

  - Index: 1C13h
    Sub-index: 1

    Size: 2 byte

    Value: 1A01h

    Insert the TPDO2 in the PDI.

    To set the value,

    see the Object Dictionary description

  - Index: 1C13h
    Sub-index: 0

    Size: 1 byte

    Value: 1

    Set the number of mapped objects

5 PROTOCOLS

5.1 ETHERCAT PROTOCOL

The EtherCAT is a open real-time Ethernet network. Protocol uses a special Ether type inside the Ethernet frame. The Ether type allows transport of control data directly within the Ethernet frame without redefining the standard Ethernet frame. The frame may consist of several sub-telegrams, each serving a particular memory area of the logical process images. Addressing of the EtherCAT terminals can be in any order because the data sequence is independent of the physical order.
The OPDE drive supports the following EtherCAT protocol properties:

- **SyncManager**;
- **Distributed Clock**;
- **EtherCAT State Machine**;
- **CoE**.

5.1.1 Sync Manager

The memory of an ESC can be used for exchanging data between the EtherCAT master and application µ-controller (OPDE drive µ-controller) without any restrictions. SyncManagers enable consistent and secure data exchange of these data. SyncManagers are configured by the EtherCAT master.
SyncManagers support two communication modes:

- Buffered Mode: EtherCAT master or OPDE application can access to the communication buffer at any time. The buffered mode is typically used for cyclic process data.
- Mailbox Mode: EtherCAT master or OPDE application can access to the communication buffer only after the other side has finished its access. In other words, if EtherCAT master is writing/reading on the communication buffer, the OPDE application must wait that the communication buffer is free. The mailbox mode is typically used for application layer protocol.

OPDE drive implements four SyncManagers: two SyncManagers in mailbox mode and two SyncManagers in buffered mode.

- Sync Manager 0 is used like receive mailbox (master to slave);
- Sync Manager 1 is used like transmit mailbox (slave to master);
- Sync Manager 2 is used like process data output (master to slave);
- Sync Manager 3 is used like process data input (slave to master).

In Fig. 5.1 is shown the SyncManagers assigning.

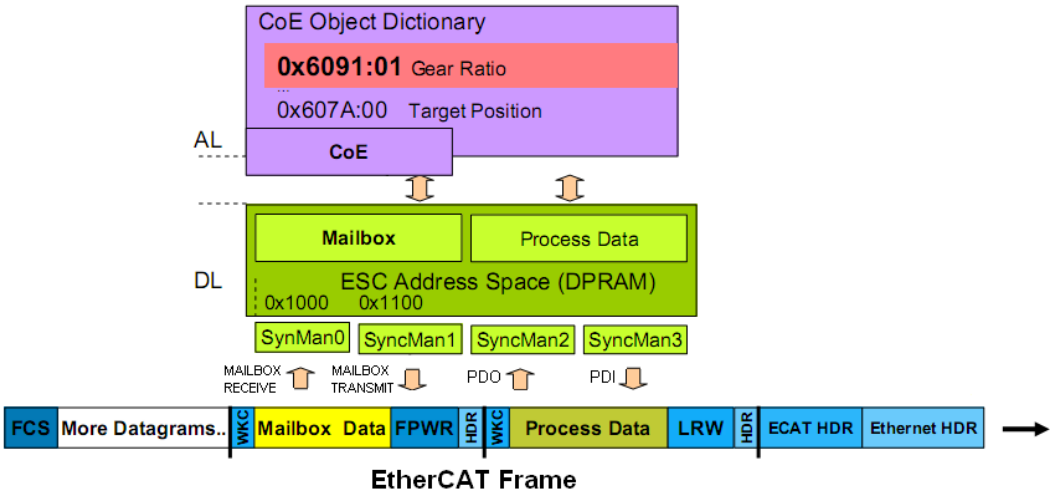


Fig. 5.1-SyncManagers assigning

5.1.2 Distributed Clock

Distributed Clock is a technique of clock synchronization between the slaves and the master. DC clock synchronization enables all EtherCAT devices to share the same EtherCAT system time. In this way is possible to synchronize the local application of each device.
Accurate synchronisation is particularly important in cases where widely distributed processes require simultaneous actions. This may be the case, for example, in applications where several servo axes carry out coordinated movements simultaneously.
OPDE Drive supports the DC technique. To enable the DC, see the paragraph *Drive Configuration* in ***Getting Started*** chapter.

5.1.3 EtherCAT State Machine

ESM is responsible for the coordination of master and slave at start up and during operation. State changes are normally requested by the master.
The OPDE drive supports four states:

- Init: the Init state defines the root of the communication relationship between the master and the slave in application layer. No direct communication between the master and the slave in application layer is possible, in other words, mailbox services and process data services are disabled. The master uses this state to initialize a set of configuration register of the ESC.
- Pre-Operational: in the Pre-Operational state the mailbox services are activated. The master and the slave can use the mailbox to exchange application specific initializations and parameters. No process data communication is possible in this state.
- Safe-Operational: in the Safe-Operational state the application of the slave shall deliver actual input data without manipulating the output data;
- Operational: in the Operational state the application of the slave shall deliver actual input data and the master shall deliver actual output data.
- Init: the Init state defines the root of the communication relationship between the master and the slave in application

In Fig. 5.2 are shown the permitted state transitions of the ESM.

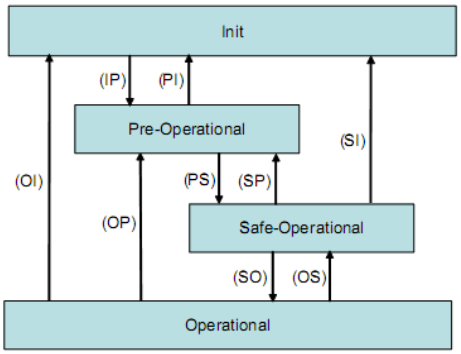


Fig. 5.2- Permitted state transitions of the ESM

5.1.4 CoE

EtherCAT provides the same communication mechanisms as the familiar CAN Open mechanisms: object dictionary, PDO (process data objects) and SDO (service data objects) - even the network management is comparable.
OPDE drive supports the following CoE services:

- SDO Download Expedited Request;
- SDO Upload Expedited Request;
- SDO Upload Expedited Response;
- Abort SDO Transfer Request;
- Emergency Request;
- RxPDO Transmission via mailbox;
- TxPDO Transmission via mailbox;
- RxPDO Remote Transmission Request;
- TPDO Remote Transmission Request;
- Process Data Input;
- Process Data Output;

5.2 OPDE OBJECT DICTIONARY

OPDE drive supports the following objects of the Communication Profile Area (Tab. 5.1).

Index (hex)	Object	Name	Type	Access
1000	VAR	Device type	UNSIGNED32	Reading
1001	VAR	Error register	UNSIGNED8	Reading
1002		Reserved		
-	-	-	-	-
1007		Reserved		
1008	VAR	Manufacturer device name	Vis-String	constant
1009	VAR	Manufacturer hardware version	Vis-String	constant
100A	VAR	Manufacturer software version	Vis-String	constant
100B		Reserved		
-	-	-	-	-
1017		Reserved		
1018	RECORD	Identity Object	Identity (23h)	Reading
1019		Reserved		
-	-	-	-	-
15FF		Reserved		
1600	RECORD	1st receive PDO mapping	PDO Mapping	Reading/writing
1601	RECORD	2nd receive PDO mapping	PDO Mapping	Reading/writing
1602	RECORD	3rd receive PDO mapping	PDO Mapping	Reading/writing
1603	RECORD	4th receive PDO mapping	PDO Mapping	Reading/writing
1604		Reserved		
-	-	-	-	-
19FF		Reserved		
1A00	RECORD	1st transmit PDO mapping	PDO Mapping	Reading/writing
1A01	RECORD	2nd transmit PDO mapping	PDO Mapping	Reading/writing
1A02	RECORD	3rd transmit PDO mapping	PDO Mapping	Reading/writing
1A03	RECORD	4th transmit PDO mapping	PDO Mapping	Reading/writing
1A04		Reserved		
-	-	-	-	-
1BFF		Reserved		
1C00	ARRAY	Sync Manager Communication Type	UNSIGNED8	Reading

Index (hex)	Object	Name	Type	Access
1C01		Reserved		
-	-	-	-	-
1C0F		Reserved		
1C10	ARRAY	Sync Manager 0 PDO Assignment	UNSIGNED16	Reading/writing
1C11	ARRAY	Sync Manager 1 PDO Assignment	UNSIGNED16	Reading/writing
1C12	ARRAY	Sync Manager 2 PDO Assignment	UNSIGNED16	Reading/writing
1C13	ARRAY	Sync Manager 3 PDO Assignment	UNSIGNED16	Reading/writing
1C14		Reserved		
-	-	-	-	-
1FFF		Reserved		

Tab. 5.1- OPDE Communication Profile Area

OPDE drive supports the following objects of the Manufacturer Specific Profile Area (Tab. 5.2).

Index (hex)	Object	Type	Name	Description	Access
2000	VAR	INTEGER16	Block size	SDO Block size Block Download	Reading/writing
2001	VAR	DOMAIN	Tab_formati	Formats of the 200 parameters	reading
2002	VAR	DOMAIN	Tab_con_formati	Formats of the 100 connections	Reading
2003	VAR	DOMAIN	Tab_exp_int	Formats of the 64 internal values	reading
2004	VAR	DOMAIN	Tab_exp_osc	Formats of the 64 monitor's sizes	Reading
2005	VAR	DOMAIN	Tab_par_def	Values of the default parameters	Reading
2006	VAR	DOMAIN	Tab_con_def	Values of the default connections	Reading
2007	VAR	INTEGER16	hw_software	Sensor managed by the firmware	Reading
2008	VAR	INTEGER16	hw_sensore	Sensor managed by electronic card	Reading
2009	VAR	INTEGER16	K_zz	Monitor counter	Reading
200A	VAR	INTEGER16	Via_alla_conta	Monitor trigger	Reading
200B	VAR	DOMAIN	Tab_monitor_A	Data saved in the channel A of the monitor	Reading
200C	VAR	DOMAIN	Tab_monitor_B	Data saved in the channel B of the monitor	Reading
200D	ARRAY	INTEGER16	Tab_par [200]	Actual values of the parameters	Reading/writing
200E	ARRAY	INTEGER16	Tab_con [100]	Actual values of the connection	Reading/writing
200F	ARRAY	INTEGER16	Tab_int [64]	Actual values of the internal words	Reading
2010	VAR	UNSIGNED 32	Tab_inp_dig	Actual values of the logical input's functions	Reading

Index (hex)	Object	Type	Name	Description	Access
2011	VAR	UNSIGNED 32	Tab_out_dig	Actual values of the logical output's functions	Reading
2012	ARRAY	INTEGER16	Tab_osc [64]	Actual values of the checked words	Reading
2013	VAR	UNSIGNED16	ingressi	Logical status of the 8 inputs of the terminal board	Reading
2014	VAR	UNSIGNED16	ingressi_hw	Logical status of the 3 inputs from the power	Reading
2015	VAR	UNSIGNED16	uscite_hw	Logical status of the 4 digit outputs	Reading
2016	VAR	UNSIGNED 32	Tab_inp_dig_field	Values set by CAN of the output logical function	Reading/writing
2017	VAR	UNSIGNED16	stato	Variable of the drive's status	Reading
2018	VAR	UNSIGNED16	allarmi	Drive alarms' status	Reading
2019	VAR	UNSIGNED16	abilitazione_allarmi	Word for enabling drive's alarms	Reading
201A	VAR	INTEGER16	f_fieldbus	Speed reference in % of n_{MAX} in 16384	Reading/writing
201B	VAR	INTEGER16	limit_fieldbus	torque limit in % di Tnom in 4095	Reading/writing
201C	VAR	INTEGER16	trif_fieldbus	torque reference in % di Tnom in 4095	Reading/writing
201D	VAR	INTEGER16	theta_fieldbus	Speed reference in electr. pulses x Tpwm	Reading/writing
201E	ARRAY	INTEGER16	Tab_dati_applicazione [100]	Data Area available for the application	Reading/writing
201F	VAR	UNSIGNED32	Ingressi_wr	Writing standard logical inputs	Reading/writing
2020	VAR	UNSIGNED32	Ingressi	Writing application logical inputs	Reading
2021	VAR	UNSIGNED32	Uscite_standard_rd	Reading standard inputs	Reading
2022	VAR	UNSIGNED16	word_vuota	Unused Word	Reading/writing
2023	VAR	UNSIGNED32	double_vuota	Unused Double word	Reading/writing
2024	VAR	DOMAIN	Tab_formati_extra	Formats of extra parameters	Reading

Tab. 5.2- OPDE Manufacturer Specific Profile Area

5.3 CAN OPEN DEVICE PROFILE CIA 402

In OPDE drive are implemented the following CAN Open DSP 402 profiles:

- Device Control;
- Profile Velocity Mode;
- Profile Position Mode;
- Interpolation Position Mode
- Homing Mode;

The units of measurement used by CAN Open DSP 402 are the following:

- Positions are expressed in "ie" (encoder pulse). One mechanical motor revolution is 65536 ie (or encoder pulses);
- Speed are expressed in "ie/s". One revoltions-per-second is 65536 ie/s;
- Accelerations are expressed in "ie/s^2". One revolutions-per-second^2 is 65536 ie/s^2;

For more information, see CiA Draft Standard Proposal 402 specifications.

5.3.1 Device Control

Device controls is a profile that define the behaviour of the control device. The master controls the slave with the following objects:

- Control Word;
- Status Word;
- Modes of operation;
- Modes of operation display;
- Quick stop option code;
- Quick stop deceleration;

The object descriptions are in Tab. 5.3

Index (hex)	Object	Type	Name	Description	PDO Mapping	Access
6040	VAR	UNSIGNED16	Control word	This object controls the Finite State Machine of DSP 402. OPD Explorer Parameter: **E00**	Yes	Reading/writing
6041	VAR	UNSIGNED16	Status word	This object provides the status of Finite State Machine of DSP 402. OPD Explorer Parameter: **D64**	Yes	reading
6060	VAR	INTEGER8	Modes of operation	This object indicates the requested operation modes. OPDE drive supports the following modes: **1. Profile position mode;** **3. Profile velocity mode;** **6. Homing mode;** **7. Interpolation position mode.** OPD Explorer Parameter: **E01**	Yes	Reading/writing
6061	VAR	INTEGER8	Modes of operation display	This object provides the actual operation mode OPD Explorer Parameter: **D65**	Yes	reading
605A	VAR	INTEGER16	Quick stop option code	This object indicates what action is performed when the quick stop function is executed. OPDE drive supports the following codes: **1. Slow down on quick stop ramp and transit into Switch On Disabled;** **6. Slow down on quick stop ramp and stay in Quick Stop Active;** **Note:** if the inserted code is not expected, the quick stop option code executes the code 1. OPD Explorer Parameter: **E38**	No	Reading
6085	VAR	UNSIGNED32	Quick stop deceleration	This object configures the deceleration used to stop the motor when the quick stop function is activated. OPD Explorer Parameters: **E08-E09**	Yes	Reading

Tab. 5.3- Device Control Objects

5.3.2 Profile Velocity Mode

The profile velocity mode covers the following sub-functions:

- Demand value input via trajectory generator;
- Velocity capture using position sensor or velocity sensor;
- Velocity control function with appropriate input and output signals;
- Monitoring of the profile velocity using a window-function;
- Monitoring of velocity actual value using a threshold.

OPDE drive supports the following Profile Velocity Mode objects (Tab. 5.4).

Index (hex)	Object	Type	Name	Description	PDO Mapping	Access
606C	VAR	INTEGER32	Velocity actual value	This object provides the actual velocity. OPD Explorer Parameters: **D68-D69**	Yes	Reading
606D	VAR	UNSIGNED32	Velocity window	This object indicates the configured velocity window. OPD Explorer Parameter: **E22-E23**	Yes	Reading/writing
606E	VAR	UNSIGNED16	Velocity window time	This object indicates the configured velocity window time. OPD Explorer Parameter: **E24**	Yes	Reading/writing
606F	VAR	UNSIGNED32	Velocity threshold	This object indicates the configured velocity threshold. OPD Explorer Parameter: **E18-E19**	Yes	Reading/writing
6070	VAR	UNSIGNED16	Velocity threshold time	This object indicates the configured velocity threshold time. OPD Explorer Parameter: **E20**	Yes	Reading/writing
6083	VAR	UNSIGNED32	Profile acceleration	This object indicates the configured acceleration. OPD Explorer Parameter: **E04-E05**	Yes	Reading/writing
6084	VAR	UNSIGNED32	Profile deceleration	This object indicates the configured deceleration OPD Explorer Parameter: **E06-E07**	Yes	Reading/writing
60FF	VAR	INTEGER32	Target velocity	This object indicates the configured target velocity. OPD Explorer Parameter: **E02-E03**	Yes	Reading/writing

Tab. 5.4- Profile Velocity Mode Objects

5.3.3 Profile Position Mode

In profile position mode a target position is applied to the trajectory generator. The trajectory generator produces a position demand value for the position control loop.

OPDE drive supports the following Profile Position Mode objects (Tab. 5.5).

Index (hex)	Object	Type	Name	Description	PDO Mapping	Access
6064	VAR	INTEGER32	Position actual value	This object provides the actual position. OPD Explorer Parameters: **D66-D67**	Yes	Reading
6065	VAR	UNSIGNED32	Following error window	This object indicates the configured range of tolerant position values symmetrically to the position demand value. OPD Explorer Parameters: **E16-E17**	Yes	Reading/writing
6067	VAR	UNSIGNED32	Position window	This object indicates the configured symmetrical range of accepted positions relative to the target position. OPD Explorer Parameter: **E14-E15**	Yes	Reading/writing
606F	VAR	UNSIGNED32	Velocity threshold	This object indicates the configured velocity threshold. OPD Explorer Parameter: **E18-E19**	Yes	Reading/writing
607A	VAR	INTEGER32	Target position	This object indicates the commanded position that the drive should move to in position profile mode. OPD Explorer Parameter: **E10-E11**	Yes	Reading/writing
607D	ARRAY	UNSIGNED8	Highest sub-index supported (Sub-index 0)	Highest sub-index supported	No	Reading
		INTEGER32	Min position limit (Sub-index 1)	This object indicates the maximal software position limit. OPD Explorer Parameter: **E40-PE41**	Yes	Reading/writing
		INTEGER32	Max position limit (Sub-index 2)	This object indicates the maximal software position limit. OPD Explorer Parameter: **E42-E43**	Yes	Reading/writing
6081	VAR	UNSIGNED32	Profile velocity	This object indicates the configured velocity normally attained at the end of the acceleration ramp during a profiled motion. OPD Explorer Parameter: **E12-E13**	Yes	Reading/writing
6083	VAR	UNSIGNED32	Profile acceleration	This object indicates the configured acceleration. OPD Explorer Parameter: **E04-E05**	Yes	Reading/writing
6084	VAR	UNSIGNED32	Profile deceleration	This object indicates the configured deceleration OPD Explorer Parameter: **E06-E07**	Yes	Reading/writing

Tab. 5.5 - Profile Position Mode Objects

5.3.4 Interpolated Position Mode

Interpolated position mode is used to control multiple coordinated axes or a single axis with the need for time-interpolation of set-point data. The interpolated position mode normally uses time synchronisation mechanisms for a time coordination of the related drive units (e.g. Distributed Clock in EtherCAT protocol).

OPDE drive supports the following Interpolated Position Mode objects (Tab. 5.6).

Index (hex)	Object	Type	Name	Description	PDO Mapping	Access
6064	VAR	INTEGER32	Position actual value	This object provides the actual position. OPD Explorer Parameters: **D66-D67**	Yes	Reading
606F	VAR	UNSIGNED32	Velocity threshold	This object indicates the configured velocity threshold. OPD Explorer Parameter: **E18-E19**	Yes	Reading/writing
60C1	ARRAY	UNSIGNED8	Highest sub-index supported (Sub-index 0)	Highest sub-index supported	No	Reading
		INTEGER32	Interpolated data – 1st set-point (Sub-index 1)	This object indicates data words, which are necessary to perform the interpolation algorithm. OPD Explorer Parameter: **E24-E25**	Yes	Reading/writing

Tab. 5.6 - Interpolated Position Mode Objects

6... Homing Mode

Homing Mode implements the methods which a drive seeks the home position, or initial reference point (also called, the datum or zero point). There are various methods of achieving this using limit switches at the ends of travel or a home switch (zero point switch) in mid-travel, most of the methods also use the index (zero) pulse train from an incremental encoder.

OPDE drive supports the following methods:

1. ***Homing on negative limit switch and index pulse****;*
2. ***Homing on positive limit switch and index pulse****;*
3. ***Homing on positive home switch and index pulse.*** *The home position is at the left of the point where the home switch changes state;*
4. ***Homing on positive home switch and index pulse.*** *The home position is at the right of the point where the home switch changes state;*
5. ***Homing on negative home switch and index pulse.*** *The home position is at the right of the point where the home switch changes state;*
6. ***Homing on negative home switch and index pulse.*** *The home position is at the left of the point where the home switch changes state;*
7. ***Homing on home switch and index pulse with positive limit switch.*** *The home position is at the left of the point where the home switch has falling edge;*
8. ***Homing on home switch and index pulse with positive limit switch.*** *The home position is at the right of the point where the home switch has rising edge;*
9. ***Homing on home switch and index pulse with positive limit switch.*** *The home position is at the left of the point where the home switch has rising edge;*
10. ***Homing on home switch and index pulse with positive limit switch.*** *The home position is at the right of the point where the home switch has falling edge;*
11. ***Homing on home switch and index pulse with negative limit switch.*** *The home position is at the right of the point where the home switch has falling edge;*

12. ***Homing on home switch and index pulse with negative limit switch.*** *The home position is at the left of the point where the home switch has rising edge;*
13. ***Homing on home switch and index pulse with negative limit switch.*** *The home position is at the right of the point where the home switch has rising edge;*
14. ***Homing on home switch and index pulse with negative limit switch.*** *The home position is at the left of the point where the home switch has falling edge;*
17. ***Homing on negative limit switch without index pulse;***
18. ***Homing on positive limit switch without index pulse;***
19. ***Homing on positive home switch without index pulse.*** *The home position is at the left of the point where the home switch changes state;*
21. ***Homing on negative home switch without index pulse.*** *The home position is at the right of the point where the home switch changes state;*
23. ***Homing on home switch and index pulse without positive limit switch.*** *The home position is at the left of the point where the home switch has falling edge;*
26. ***Homing on home switch without index pulse with positive limit switch.*** *The home position is at the right of the point where the home switch has falling edge;*
27. ***Homing on home switch without index pulse with negative limit switch.*** *The home position is at the right of the point where the home switch has falling edge;*
30. ***Homing on home switch without index pulse with negative limit switch.*** *The home position is at the left of the point where the home switch has falling edge;*
33. ***Homing on index pulse.*** *The home position is at first index pulse found on the left;*
34. ***Homing on index pulse.*** *The home position is at first index pulse found on the right;*
35. ***Homing on index pulse.*** *The home position is the current position.*

OPDE drive supports the following Homing Mode objects (Tab. 5.7).

Index (hex)	Object	Type	Name	Description	PDO Mapping	Access
606F	VAR	UNSIGNED32	Velocity threshold	This object indicates the configured velocity threshold. OPD Explorer Parameter: **E18-E19**	Yes	Reading/writing
607C	VAR	INTEGER32	Home offset	This object indicates the configured difference between the zero position for the application and the machine home position. OPD Explorer Parameters: **E28-E29**	Yes	Reading/writing
6098	VAR	INTEGER8	Homing method	This object indicates the configured homing method The supported methods are those descripted above. OPD Explorer Parameters: **E26**	Yes	Reading/writing
6099	ARRAY	UNSIGNED8	Highest sub-index supported (Sub-index 0)	Highest sub-index supported	No	Reading
		UNSIGNED32	Speed during search for switch (Sub-index 1)	This object indicates the configured speed during search for switch. OPD Explorer Parameter: **E30-E31**	Yes	Reading/writing
		UNSIGNED32	Speed during search for zero (Sub-index 2)	This object indicates the configured speed during search for zero. OPD Explorer Parameter: **E32-E33**	Yes	Reading/writing

609A	VAR	UNSIGNED32	Homing acceleration	This object indicates the configured acceleration and deceleration to be used during homing operation. OPD Explorer Parameters: **E34-E35**	Yes	Reading/writing

Tab. 5.7 - Homing Mode Objects

The **positive limit switch** is the input logic functions **I28.**
The **negative limit switch** is the input logic functions **I29.**
The **home switch** is the input logic functions **I30.**

For more information about input logic functions, see OPDE manual.

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