



EtherCAT for PM Ctendo DD5 and PM Cprotego D

PILZ
THE SPIRIT OF SAFETY

► Servo amplifiers

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SD means Secure Digital

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1 General information

1.1 About this manual

This manual describes the assembly, installation and commissioning of the "Expansion card EtherCAT" for servo amplifiers of the PMCprotego D series and a reference of the commands that are supported by these servo amplifiers.

The "Expansion card EtherCAT" provides an EtherCAT interface to this servo amplifier. The operating manual describes the card and its installation at a later stage.

In PMCprotego D the EtherCAT functionality is already integrated. The servo amplifier has an onboard Ethernet- interface that has been configured in the standard version for the EtherCAT protocols. This manual is a component of the overall documentation of the digital servo amplifiers. Installation and commissioning of the servo amplifiers and all the standard functions are described in the relevant operating manual.

1.2 Target group

This manual is aimed at qualified personnel with the following requirements:

Transport	Only by personnel with knowledge of managing electrostatically sensitive assemblies
Unpacking	Only by specialists with electrotechnical qualification
Installation	Only by specialists with electrotechnical qualification
Commissioning	Only by specialists with extensive knowledge of electrical engineering and drive technology
Programming	Software developer, EtherCAT design engineers

The qualified staff must know and observe the following standards:

- ▶ IEC 60364 and IEC 60664
- ▶ National accident prevention regulations

1.3 Definition of symbols

Information that is particularly important is identified as follows:



DANGER!

This warning must be heeded! It warns of a hazardous situation that poses an immediate threat of serious injury and death and indicates preventive measures that can be taken.



WARNING!

This warning must be heeded! It warns of a hazardous situation that could lead to serious injury and death and indicates preventive measures that can be taken.



CAUTION!

This refers to a hazard that can lead to a less serious or minor injury plus material damage, and also provides information on preventive measures that can be taken.



NOTICE

This describes a situation in which the product or devices could be damaged and also provides information on preventive measures that can be taken. It also highlights areas within the text that are of particular importance.



INFORMATION

This gives advice on applications and provides information on special features.

1.4 Abbreviations used

Abbreviation	Meaning
AL	Application Layer: The protocol used directly by the process instances.
Cat	Category - Classification also for the cables used for Ethernet communication. EtherCAT cables must be classified at least in category 5.
DC	Distributed Clocks Mechanism (Distributed Clock procedure) to synchronise EtherCAT-Slaves and Masters.
DL	Data Link, also Layer 2. EtherCAT used in accordance with IEEE 802.3 standardised Ethernet communication.
EtherCAT (ECAT)	RT standard for industrial Ethernet Control Automation Technology
FPGA	Field Programmable Gate Array (logic block that can be modified on-site)
FTP	File Transfer Protocol
HW	Hardware
ICMP	Internet Control Message Protocol: Protocol to display IP errors.
IEC	International Electrotechnical Commission: International standardisation committee
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IOS/OSI Model	ISO Open Systems Interconnection Basic Reference Model (ISO 7498) (ISO-OSI layer model): Describes the dividing of the communication in seven layers.
LLDP	Lower Layer Discovery Protocol
MAC	Media Access Control
MII	Media Independent Interface: Standard interface between Ethernet Controller and the routers.
MDI	Media-independent interface: Signal transmission using pins.
MDI-X	Media-dependent interface (crossover): Crossed wiring
OSI	Open System Interconnect
OUI	Organizationally Unique Identifier - the first 3 Bits of an Ethernet address. They are assigned to companies or organisation and the can also be used for Protocol Identifiers (e.g.LLDP).

Abbreviation	Meaning
PDI	Physical Device Interface: A set of physical elements that enable access from the process side.
PDO	Process Data Object
PDU	Protocol Data Unit: Includes protocol information from a protocol instance via transparent data to a subordinate layer.
Ping	Program for checking the accessibility of the partner device.
PHY	Physical interface, data conversion in electrical or optical signals.
PLL	Phase Locked Loop
PTP	Precision Time Protocol in accordance with IEEE 1588
RSTP	Rapid Spanning Tree Protocol
RT	Real-time, possible in Ethernet Controller without additional support.
RT Frames	EtherCAT transmission with EtherType 0x88A4.
RX	Receive
RXPDO	Receive PDO
SNMP	Simple Network Management Protocol
SPI	Serial Peripheral Interface
Src Addr.	Source Address: Source address of a transmission.
STP	Shielded Twisted Pair
TCP	Transmission Control Protocol
TX	Transmit
TXPDO	Transmit PDO
UDP	User Datagram Protocol: Unsafe Multicast-Broadcast protocol
UTP	Unshielded Twisted Pair
XML	Extensible Markup Language
XML Parser	Program for checking XML structures
ZA ECAT	Access type EtherCAT
ZA Drive	Access type amplifier

2 Safety



WARNING!

Risk of death or serious injury and material damage during operation

The operator must ensure that the safety guidelines in this manual are taken into account. The operator must ensure that every person entrusted with work at the servo amplifier have read and understood this operating manual.

We offer training and induction courses on request.

2.1 Intended use

Please note the chapters "Intended use" and "Improper use" in the operating manual of the servo amplifier.

The sole purpose of the EtherCAT interface is to connect the servo amplifier to a Master with EtherCAT connection.

The servo amplifiers are installed as components in electrical apparatus or machinery and can only be commissioned as integrated plant components.



INFORMATION

We guarantee compliance of the servo amplifier with the following standards in the industrial sector only when using the components named by us and when complying with the installation manual:

EU EMC Directive 2004/42/EG

EU Low Voltage Directive 2006/95/EG

2.2 Notes on the online edition (PDF format)

Bookmarks:

Table of contents and index are active bookmarks.

Table of contents and index in the text:

The lines are active cross-references. Click the required line to display the corresponding page.

Page number in the text:

Page numbers/chapter numbers with cross references are active. Click on the page number/chapter number to go to the specified target.

3 Installation/commissioning

3.1 Assembly/installation

**WARNING!****Risk of electrocution!**

Install and wire the devices always in a voltage-free state. Ensure that there is a safe enabling of the control cabinet (lock, warning signs etc.). The individual voltages are switched on only when commissioning. Residual charges in the capacitors may still show hazardous values several minutes after the mains voltage is switched off. Measure the voltage in the intermediate circuit and wait until the voltage has dropped below 40 VDC. Control and power connections may still carry voltage, even when the motor is not rotating.

**WARNING!****Possible loss of the safety**

Electronic devices are not fail-safe as a matter of principle. The user is responsible that the drive is led to a safe condition for machinery or personnel when the servo amplifier fails, e.g. by using a mechanical brake. Drives with servo amplifiers in EtherCAT networks are remotely operated machines. They can set in motion at any time without prior notice. Warn the operator and maintenance personnel by corresponding instructions. Use a relevant protective measure to ensure that an unintended startup of the machine does not lead to a hazardous situation for man and machine. Software end switches do not replace the hardware end switches of the machine.

**NOTICE**

Wire the servo amplifier as described in the operating manual. The wiring of the analogue set value input and the position interface after the connection image of the operating manual may be omitted.

**INFORMATION**

Due to the internal representation of the position control parameters, the position controller can only be operated if the final speed of the drive does not exceed the following values:

rotary:

Sinusoidal²-shaped acceleration: max. 7500 U/min

Trapezoidal acceleration: max. 12000 U/min

linear:

Sinusoidal²-shaped acceleration: max. 4 m/s

Trapezoidal acceleration: max. 6.25 m/s

**INFORMATION**

All the data regarding resolution, incremental value, positioning accuracy etc. refers to the arithmetic values. Non-linearities in the mechanics (backlash, elasticity etc.) are not considered.

If the motor's end speed needs to be changed, all the position control and motion block parameters that were entered previously will need to be adapted.

3.1.1 Connection technology

Connection to the EtherCAT network via RJ45 connector (IN and OUT interfaces).

3.1.2 Commissioning

3.1.2.1 Guide to commissioning

**INFORMATION**

The servo amplifier may only be commissioned by qualified personnel with sound knowledge of control and drive technology.

**CAUTION!****Possible loss of the safety**

Ensure that no hazard can result for personnel or machinery, even if the drive should move unintentionally.

Procedure:

Step	Description
Check assembly/installation	Check that all the safety guidelines in this manual and in the operating manual for the servo amplifier are respected and implemented.
Connect PC, start commissioning software	Use the commissioning software to set the parameters for the servo amplifier.
Commissioning the basic functions	Commission the basic functions of the servo amplifier and optimise the current, speed and position controller. This part of the commissioning process is described in more detail in the commissioning software's online help.
Save parameters	Once the parameters have been optimised they should be saved in the servo amplifier.

3.1.2.2 EtherCAT commissioning

To commission with the TwinCAT tool please use the documents in the download area of the Pilz homepage.

To commission with the motion controller PMCprimo please use the documents in the download area of the Pilz homepage.

4 EtherCAT

4.1 Slave Register

The following table displays the addresses of individual registers in the FPGA memory. The data exist in little endian format, the "least significant byte" is on the lower address. A detailed description of all registers and FPGA locations can be seen from the "EtherCAT Slave Controller" description of the EtherCAT user organisation (www.ethercat.org).

Address	Length (Byte)	Description	ZA ECAT	ZA Drive
0x0120	2	AL Control	r/w	r/-
0x0130	2	AL Status	r/-	r/w
0x0134	2	AL Status Code	r/-	r/w
0x0204	2	Interrupt enable register	r/-	r/w
0x0220	2	AL Event (IRQ Event)	r/w	r/-
0x0800	8	AL Manager 0 (Mail Out control register)	r/w	r/-
0x0808	8	AL Manager 1 (Mail Out control register)	r/w	r/-
0x0810	8	AL Manager 2 (Process data Output Control Register)	r/w	r/-
0x0818	8	AL Manager 3 (Process data Input Control Register)	r/w	r/-
0x0820	8	AL Manager 4	r/w	r/-
0x0828	8	AL Manager 5	r/w	r/-
0x0830	8	AL Manager 6	r/w	r/-
0x0838	8	AL Manager 7	r/w	r/-
0x0840	8	AL Manager 8	r/w	r/-
0x1100	64	ProOut Buffer (process data output, set values ECAT)	r/w	r/-
0x1140	72	ProIn (process data input, actual values of ECAT)	r/-	r/w
0x1800	512	Mail Out Buffer (Object channel buffer of ECAT)	r/w	r/-
0x1C00	512	Mail In Buffer (Object channel buffer of serve amplifier)	r/-	r/w
*:ZA ECAT = Access type EtherCAT				
ZA Drive = Access type amplifier				

4.2 AL event (interrupt event) and interrupt enable

The communication between the drive and EtherCAT FPGA is completely interrupt-controlled. The Interrupt enable register and the AI event register are responsible for the interrupt functionality of the EtherCAT interface. With a 1 in the corresponding Bit of the Interrupt enable register the servo amplifier activates the individual events of the EtherCAT interface, with a 0 the events are deactivated.

4.2.1 Interrupt enable register (address 0x0204:0205)

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
AL Control Event	0x204	0	r/w	r	Activating the AL Control Events for phase runup
--	0x204	1	r/w	r	Reserved
DC Distributed Clock	0x204	2	r/w	r	Activating the Distributed Clock (DC) Interrupts for the complete communication
--	0x204	3 ... 7	r/w	r	Reserved
Mail Out Event	0x205	0	r/w	r	Activating the Mailbox Output Event (SDO, Sync Manager 0) for the object channel
Mail In Event	0x205	1	r/w	r	Activating the Mailbox Input Event (SDO, Sync Manager 1) for the object channel
Pro Out Event	0x205	2	r/w	r	Activating the process data Output Event (PDO, cyclical set values of the card)
Pro In Event	0x205	3	r/w	r	Activating the process data Input Event (PDO, cyclical actual values of the servo amplifier)
--	0x205	4 ... 7	r/w	r	Reserved

With a 1 in the relevant Bit of the AL Event register the EtherCAT interfaces signals to the servo amplifier in the Interrupt routine which event is to be processed by the servo amplifier.

4.2.2 AL Event (address 0x220:0221)

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
AL Control Event	0x220	0	r	r/w	Editing the AL Control Events for phase runup
Sync Manager Watchdog Event	0x220	1	r	r/w	Editing a Sync Manager Watchdog Event
Distributed Clock (DC) Event	0x220	2	r	r/w	Editing a Distributed Clock (DC) Event
--	0x220	3 ... 7	r	r/w	Reserved

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
Sync Manager 0 Event	0x221	0	r	r/w	Activating the Mailbox Output Event (SDO, Sync Manager 0) for the object channel
Sync Manager 1 Event	0x221	1	r	r/w	Activating the Mailbox Input Event (SDO, Sync Manager 1) for the object channel
Sync Manager 2 Event	0x201	2	r	r/w	Activating the process data Output Event (PDO, cyclical set values of the card)
Sync Manager 3	0x201	3	r	r/w	Activating the process data Input Event (PDO, cyclical actual values of the servo amplifier)
Sync Manager 4 – Sync Manager 7 Event	0x221	4 ... 7	r	r/w	Reserved
Sync Manager 8 – Sync Manager 15 Event	0x222	0 ... 7	r	r/w	Reserved

4.3 Phase runup

The registers AL Control, AL Status and AL Status Code are responsible for the communication phase runup (also called EtherCAT change of state) and the display of the current status and any error messages are the registers AL Control, AL Status und AL Status Code. Each Transition request of the EtherCAT interface by the AL Control Register and each AL Control Event (Interrupt) is followed by the servo amplifier with the AL Status Register. Any error messages are displayed in the AL Status Code Register.

4.3.1 AL Control (address 0x0120:0x0121)

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
Status	0x120	3 ... 0	R	w	0x01: Init Request 0x02: PreOperational Request 0x03: Bootstrap Mode Request 0x04: Safe Operational Request 0x08: Operational Request
Acknowledgement	0x120	4	R	w	0x00: No error reset 0x01: Error reset with positive pulse edge
Reserved	0x120	7 ... 5	R	w	--
Appl. specific	0x120	15 ... 8	R	w	--

4.3.2 AL Status (address 0x0130:0x0131)

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
Status	0x130	3 ... 0	w	r	0x01: Init 0x02: PreOperational 0x03: Bootstrap Mode 0x04: Safe Operational 0x08: Operational
Change of state	0x130	4	w	r	0x00: Confirmation during change of state 0x01: Error during change of state, e.g. with not permitted transition
Reserved	0x130	7 ... 5	w	r	--
Appl. specific	0x130	15 ... 8	w	r	--

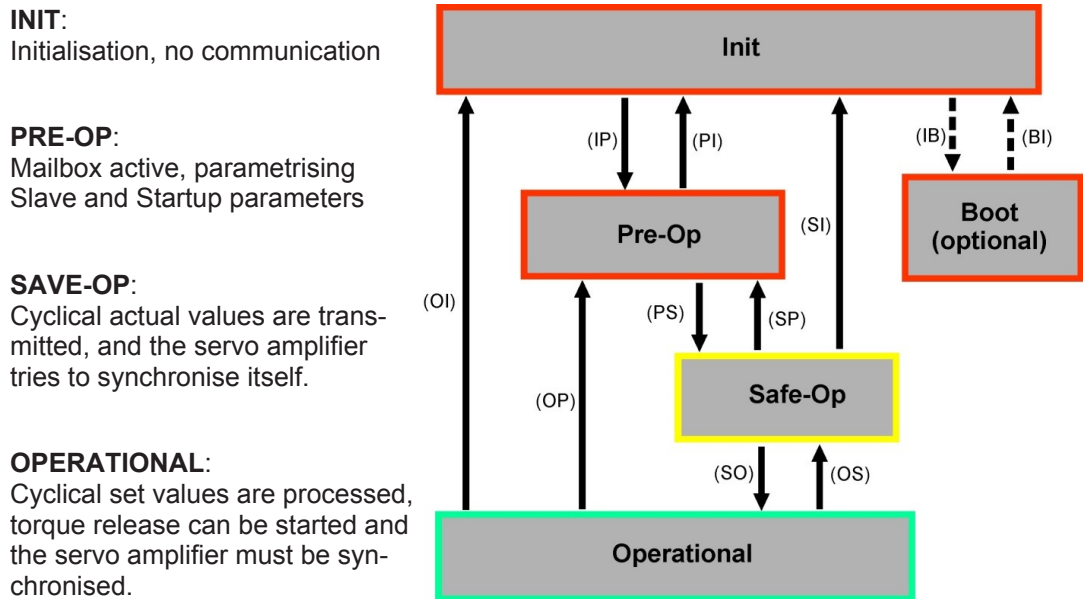
4.3.3 AL Status Code (address 0x0134:0x0135)

Parameter	Address	Bit	ZA Drive	ZA ECAT	Description
Status	0x134	7 ... 0	w	r	See table below
Status	0x135	7 ... 0	w	r	See table below

Code	Description	Current status (change of state)	Resulting status
0x0000	No error	All	Current status
0x0011	Faulty change of state request	I -> S, I -> O, P -> O, O -> B, S -> B, P -> B	Current status + E
0x0017	Incorrect synchronisation manager configuration	P -> S, S -> O	Current status + E
0x001A	Synchronisation error	O S -> O	S + E

Other codes are not supported.

4.3.4 EtherCAT communication phases



Description of the individual communication transitions

Trans- ition	AL Control (Bit 3 ... 0)	Description
(IB)	0x03	Hardware reset requirement by the control.
(BI)	--	Hardware reset on the servo amplifier.
(IP)	0x02	Activation of the mailbox (SyncManager 0 and 1) and activation of the amplifier synchronisation routine. As the EC interface does not yet created cyclical interrupts, the warning n17 (no sync.) appears in the amplifier.
(PI)	0x01	Deactivation of all EtherCAT Events except AL control and stopping of mailbox activities.
(PS)	0x04	The amplifier checks the communication configuration specified by the Master in status Pre-Op. Non-fatal errors are deleted automatically (no COLDSTART). Mapping of various set and actual values (PDO mapping). The mapping can be preset by the mailbox. The ECAT interface produces cyclical interrupts and therefore cyclical actual values are available to the EAT interface. The amplifier starts synchronising with the cyclical IRQ of the ECAT interface. The Pro_In and Pro_Out events are activated, which are responsible for the cyclical set (Pro_Out) and actual values (Pro_In) of the amplifier.
(SP)	0x02	The ECAT interface no longer produces cyclical interrupts. Therefore the warning for lost synchronisation in the amplifier (in17) and the actual values are not activated further.

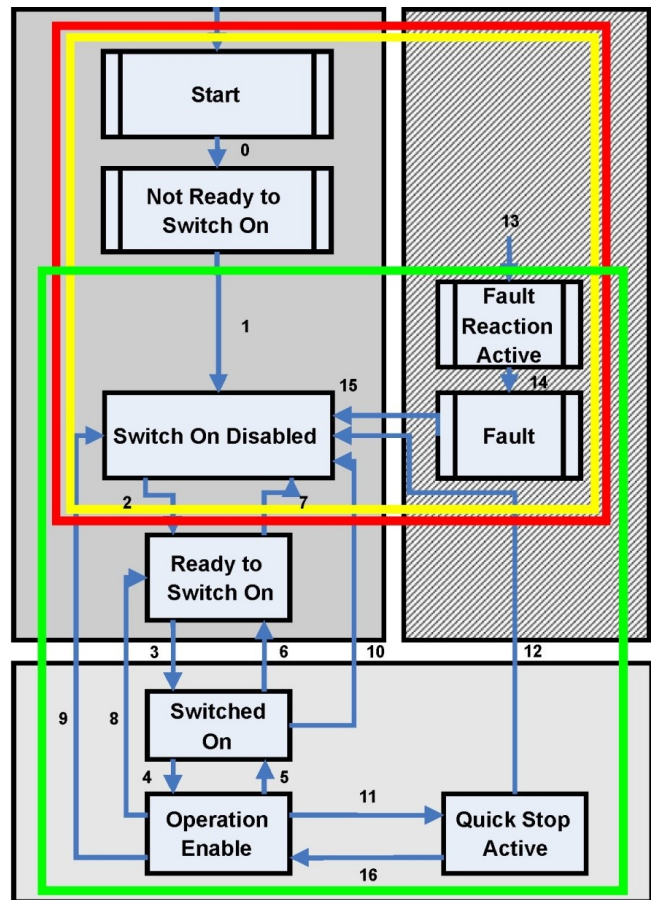
Trans- ition	AL Control (Bit 3 ... 0)	Description
(SI)	0x01	Deactivate all EtherCAT Events except AL Control. In addition, the ECAT interface does not send any more interrupts, and the amplifier loses synchronisation (warning n17) and it no longer updates the actual values. Also, all mailbox activities are stopped.
(SO)	0x08	The amplifier finishes this transition only when synchronisation has been performed, the synchronisation warning (n17) is deleted. Otherwise a synchronisation error (F28) is set after a time-out period. This transition enables the editing of the control word and therefore the acceptance and processing of the cyclical PDO set values.
(OS)	0x04	Locking the set value acceptance
(OP)	0x02	The ECAT interface no longer produces cyclical interrupts. Therefore the warning for lost synchronisation in the amplifier (in17) and the actual values are not activated further.
(OI)	0x01	Deactivate all EtherCAT Events except AL Control. In addition, the ECAT interface does no longer send interrupts, and the amplifier loses synchronisation (warning n17) and it no longer updates the actual values. Stopping of a mailbox activities.

4.4 CANopen over EtherCAT (CoE) state machine

The state machine for control word and status word corresponds to the CANopen state machine according to DA402. Control word and status word can be found in any fixed PDO mapping.

The status word is updated and written only in **Safe-Op** and **Operational** states by the amplifier.

The control word is read in only in **Operational** state.



4.4.1

Description of states

State	Description
Not Ready to Switch On	Servo amplifier is not ready to switch on; the amplifier has not signalled operational readiness (BTB). The servo amplifier is still in the boot phase or in an error state.
Switch On Disable	In the 'Switch On Disable' state the amplifier cannot be enabled by the EtherCAT interface, e.g. because there is no power switched on.
Ready to Switch On	In the 'Ready to Switch On' status the servo amplifier must be brought to the enable state using the control word.
Switched On	In 'Switched On' status the amplifier is enable, however the set values of the EtherCAT interface are not yet accepted. The amplifier is in standstill and a positive edge in Bit 3 of the control word switches on the actual value acceptance (transition to the Operation Enable state).
Operation Enable	In this state the servo amplifier is enabled and set values are accepted from the EtherCAT interface.
Quick Stop Active	The servo amplifier follows a quick stop ramp.
Fault Reaction Active	The servo amplifier reacts to a fault with an E-STOP ramp.
Fault	A fault is present, the drive has been stopped and locked.

4.4.2 Commands in the control word

The servo amplifier evaluated the individual Bits of the control word.

Commands in the control word for a change of state:

Transition	Bit 7 Reset error	Bit 3 General set value enable	Bit 2 Enable for Bit 3 and display Bit 5 in the status word	Bit 1 Cancel switch on disable	Bit 0 Switch on (enable) when Bit 1 = 1
0	X	X	X	X	X
1	X	X	X	0	X
2	X	X	X	1	0
3	X	X	1	1	P
4	X	P	1	1	1
5	X	N	1	1	1
5	X	X	N	1	1
6	X	X	X	1	N
7	X	X	X	N	X
8	X	X	X	1	N
9	X	X	X	N	X
10	X	X	X	N	X
11	X	1	N	1	1
12	X	X	X	N	X
13	X	1	1	1	1
14	X	1	1	1	1
15	P	X	X	X	X

Legend

X	Bits are irrelevant
1/0	Status of the individual bits
P	Signalises a positive edge in the Bit
N	Signalises a negative edge in the Bit

Action with positive edges in the control word Bits:

Bit	Action
0	Enable the servo amplifier when the switch-on disable is cancelled (Bit1 = 1).
1	Cancelling the switch-on disable.
2	Activate the display of Bit 5 in the status word when Bit 0 & Bit 1 = 1 enable for Bit 3 in the control word
3	Set value enable when Bit0, Bit1 and Bit2 = 1.
7	Delete error, transmit command (CLRFAULT). With a set Bit 19 of the ASCII parameter SERCSET and a present fault that involves a hardware reset, the servo amplifier generated an F29.
15	Start of a reference run, when the drive is in the operating mode referencing (OPMODE 8).
12	Transmit a SAVE command.

Action with negative edges in the control word Bits:

Bit	
0	Switch off drive (transmit the ASCII command DS).
1	If Bit 1 has no negative edge, brake and disable with the ramp DECSTOP.
2	When Bit 1 and Bit 2 do not show negative edges, brake with the ramp DECDIS and remain enabled.
3	Switch off set value acceptance from the EtherCAT interface and stop the drive in the operating mode speed control (OPMODE 0).
7	Delete fault (CLRFAULT), delete command channel.
15	Delete reference run command channel.
12	Delete SAVE command channel.

4.4.3

Bits of the status machine (status word)

Status	Bit 6 = Switch-on disable active	Bit 5 = No E- STOP active	Bit 3 = Error	Bit 2 = Operation enabled	Bit 1 = Switched on	Bit 0 = Ready to switch on
Not Ready to Switch On	1	X	0	0	0	0
Switch On Disabled	1	X	0	0	0	0
Ready to Switch On	0	X	0	0	0	1

Status	Bit 6 = Switch-on disable active	Bit 5 = No E- STOP active	Bit 3 = Error	Bit 2 = Operation enabled	Bit 1 = Switched on	Bit 0 = Ready to switch on
Switch On	0	1	0	0	1	1
Operation Enable	0	1	0	1	1	1
Fault	0	1	1	0	0	0
Fault reaction active	0	0	1	1	1	1
Quick Stop Active	0	0	0	0	1	1

Legend

- X Bits are irrelevant
1/0 Status of the individual bits

Additional Information

- Bit 4 1 = Intermediate circuit voltage is present
 Bit 7 1 = A warning is present at the device
 Bit 8 1 = Position error present (in all position modes (OPMODE = 4, 5, 6, 8))
 Bit 10 1 = Target reached (in position)
 Bit 11 1 = Restrictions active (e.g. hardware or software end switch has triggered)
 Bit 12 1 = Reference run active
 Bit 13 1 = Reference run error
 Bit 15 1 = Motion task active (in profile position mode)

4.5 Implemented operating modes

The following operating modes are implemented via the object 0x6060:

- ▶ cyclic synchronous position mode 0x08 and 0xFA
- ▶ cyclic synchronous velocity mode 0x09 and 0xFE
- ▶ cyclic synchronous torque mode 0x0A and 0xFD
- ▶ homing mode 0x06 and 0xF9

The negative values correspond to the manufacturer-specific settings such as the OP-MODE command.

4.6 Setting the EtherCAT cycle time

The cycle time used in the servo amplifier for the cyclical set and actual values can be present either configured in the amplifier in the parameter PTBASE or it can be configured in the start phase.

This is performed via a mailbox SDO access (see [Mailbox Handling](#) [25]) to the CAN-open objects 0x60C2 Subindex 1 und 2.

The subindex 2, called interpolation time index, defines the power of ten of the time value (e.g. -3 corresponds to 10^{-3} , that is millisecond) while the subindex 1 called time units", specifies the number of units (e.g. 4 for 4 units).

If you want to run a cycle time of 2 ms this can be specified via various combinations, e.g. via:

Index = -3, Units = 2

or

Index = -4, Units = 20 etc.

The parameter PTBASE is counted in increments of 250 microseconds inside the device. 2 ms correspond to a PTBASE of 8, for example.

4.7 Recommended cycle time based on the operating modes

With the servo amplifier, the minimum cycle time depends very much of the drive configuration (second actual position value encoder, latching). The analogue evaluation of the drives should be deactivated, if possible (ANOUT1=0, ANOUT2=0, ANCNFG= -1).

Interface	Cycle time PMCprotego D
Position	$\geq 0.25 \text{ ms}$ ($\geq 250 \text{ }\mu\text{s}$)
Speed	$\geq 0.25 \text{ ms}$ ($\geq 250 \text{ }\mu\text{s}$)
Torque	$\geq 0.25 \text{ ms}$ ($\geq 250 \text{ }\mu\text{s}$)

4.8 Synchronisation based on the cycle time

With all the Pilz servo amplifiers the internal PLL can compensate a mean deviation from the cycle time specified by the Master of up to 1000 ppm. This means, for example that with a set cycle time of 1 ms the drive can still synchronise itself with a mean deviation in the cycle time specified by the master of up to $\pm 1 \mu\text{s}$ with its internal PLL. The mean deviation of the cycle time is understood to be the mean length of all cycles.

The servo amplifier enables to report the following jitter in the master cycle time without a synchronisation error, depending on the set cycle time:

Cycle time $\geq 1 \text{ ms}$ $\rightarrow$ permitted jitter = $320 \text{ }\mu\text{s}$

Cycle time $\leq 750 \text{ }\mu\text{s}$ $\rightarrow$ permitted jitter = $70 \text{ }\mu\text{s}$

In the second consecutive master interrupts, outside the permitted jitter, the drive signals a synchronisation error F28 and/or warning F17. The synchronisation monitoring can be switched off with the ASCII command SERCSET Bit 17 and 18.

4.9 Latch- control word and latch status word

Latch control word (2 Byte):

Bit	Value (bin)	Value (hex)	Description
0	00000000 00000001	xx01	Enable external latch 1 (positive rise)
1	00000000 00000010	xx02	Enable external latch 1 (negative rise)
2	00000000 00000100	xx04	Enable external latch 2 (positive rise)
3	00000000 00001000	xx08	Enable external latch 2 (negative rise)
4	00000000 00010000	Xx10	Enable internal latch C (positive rise)
5 - 7			Reserved
8 – 12	00000001 00000000	01xx	Read external latch 1 (positive rise)
	00000010 00000000	02xx	Read external latch 1 (negative rise)
	00000011 00000000	03xx	Read external latch 2 (positive rise)
	00000100 00000000	04xx	Read external latch 2 (negative rise)
	00000101 00000000	05xx	Read external latch C (positive rise)
13 - 15			Reserved

Latch status word (2 Byte):

Bit	Value (bin)	Value (hex)	Description
0	00000000 00000001	xx01	External latch 1 valid (positive rise)
1	00000000 00000010	xx02	External latch 1 valid (negative rise)
2	00000000 00000100	xx04	External latch 2 valid (positive rise)
3	00000000 00001000	xx08	External latch 2 valid (negative rise)
4	00000000 00010000	Xx10	Internal latch C valid (positive rise)
5 - 7			Reserved
8 – 11	00000001 00000000	01xx	Acknowledge value external latch 1 (positive rise)
	00000010 00000000	02xx	Acknowledge value external latch 1 (negative rise)

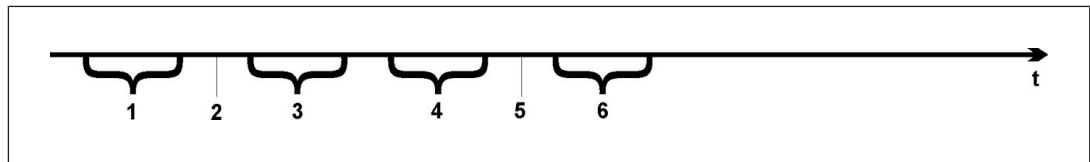
Bit	Value (bin)	Value (hex)	Description
	00000011 00000000	03xx	Acknowledge value external latch 2 (positive rise)
	00000100 00000000	04xx	Acknowledge value external latch 2 (negative rise)
	00000101 00000000	05xx	Acknowledge value internal latch C (positive rise)
12 - 15	00010000 00000000	1xxx	State Digital Input 4
	00100000 00000000	2xxx	State Digital Input 3
	01000000 00000000	4xxx	State Digital Input 2
	10000000 00000000	8xxx	State Digital Input 1

4.10 Mailbox Handling

With EtherCAT the acyclical data traffic (object channel or SDO channel) is called mailbox. The approach of the Master is considered:

Mailbox Output	Data are sent from the Master (EtherCAT control) to the Slave (servo amplifier). It is a requirement (read/write) of the master. The Mailbox Output runs via the Sync Manager 0.
Mailbox Input	Data are sent from the Slave (Servo amplifier) to the Master (EtherCAT control). The Master reads the answer from the slave. The Mailbox Input runs via Sync Manager 1.

The Timing diagram illustrated the processing of a mailbox access:



Legend

- 1 EtherCAT Master writes the mailbox request in the Mail Out Buffer.
- 2 At the next interrupt, the EtherCAT interface triggers a Sync Manager 0 Event (Mailbox Output Event) in the AL Event Register.
- 3 The servo amplifier reads 16 Byte from the Mail Out Buffer and copies it into an internal Mailbox Output Array.
- 4 The servo amplifier detects new files in the internal mailbox output array, and it executes the SDO access to the object requested by the EtherCAT interface. The reply from the servo amplifier is written to an internal Mailbox Input Array.
- 5 The servo amplifier deleted all the data in the internal Mailbox Output Array and paves the way for a new mailbox access.
- 6 The servo amplifier copies the response telegram from the internal Mailbox Input Array into the mail in the buffer of the EtherCAT interface.

4.10.1 Mailbox Output

An interrupt of the EtherCAT interface with a Sync Manager 0 - Event starts a Mailbox Output process. A 1 in the Mail Out Event-Bit of the AL Event Registers signalled to the servo amplifier that the EtherCAT interface wants to transmit a mailbox news and that it has already stored the requested data in the Mail Out Buffer. The servo amplifier reads in the IRQ routine 16 byte from the Mail Out Buffer.

Meaning of the individual bytes:

Address 0x1800								Address 0x180F							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CAN over EtherCAT specific data CoE Header								CAN specific data (standard CAN SDO)							
Byte 0	Length of the following data from Byte 2 (Low Byte)														
Byte 1	Length of the following data from Byte 2 (High Byte)														
Byte 2	Address (Low Byte)														
Byte 3	Address (High Byte)														
Byte 4	Bits 0 ... 5: Channel Bit 6 ... 7: Priority														
Byte 5	Bits 0 ... 3: Type – 1 = Reserved: ADS over EtherCAT – 2 = Reserved: Ethernet over EtherCAT – 3 = CAN over EtherCAT...) Bits 4 ... 7: Reserved														
Byte 6	PDO number (Only in case of PDO transmission, Bit 0 = LSB of the PDO number, see Byte 7 for MSB)														
Byte 7	Bit 0: MSB of the PDO number, see Byte 6) Bit 1 ... 3: Reserved Bit 4 ... 7: CoE specific type – 0: Reserved – 1: Emergency message – 2: SDO requirement – 3: SDO response – 4: TxPDO – 5: RxPDO – 6: Remote transmission request of a TxPDO – 7: Remote transmission request of a RxPDO – 8 ... 15: Reserved for later applications														

Byte 8	Control byte in CAN telegram: – Write access: 0x23=4Byte, 0x27=3Byte, 0x2B=2Byte, 0x2F=1Byte – Read access: 0x40
Byte 9	Low Byte of the CAN object number (index)
Byte 10	High Byte of the CAN object number (index)
Byte 11	Subindex in accordance with the CANopen specification for the Pilz servo amplifier
Byte 12	Data in case of a write access (Low Byte)
Byte 13	Data in case of a write access
Byte 14	Data in case of a write access
Byte 15	Data in case of a write access (High Byte)

The servo amplifier responds to each telegram with a response in the Mailbox Input Buffer.

4.10.2 Mail Input

The servo amplifier responds to each CoE telegram with a 16 Byte response telegram in the Mailbox Input Buffer. The Bits are defined as follows:

Address 0x1C00								Address 0x1C0F							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CAN over EtherCAT specific data CoE Header								CAN specific data (standard CAN SDO)							

Byte 0	Length of the following data (Low Byte)
Byte 1	Length of the following data (High Byte)
Byte 2	Address (Low Byte)
Byte 3	Address (High Byte)
Byte 4	Bits 0 ... 5: Channel Bit 6 ... 7: Priority
Byte 5	Bits 0 ... 3: Type – 1 = Reserved: ADS over EtherCAT – 2 = Reserved: Ethernet over EtherCAT – 3 = CAN over EtherCAT...) Bits 4 ... 7: Reserved
Byte 6	PDO number (Only in case of PDO transmission, Bit 0 = LSB of the PDO number, see Byte 7 for MSB)

Byte 7	Bit 0: MSB of the PDO number, see Byte 6) Bit 1 ... 3: Reserved Bit 4 ... 7: CoE specific type – 0: Reserved – 1: Emergency message – 2: SDO requirement – 3: SDO response – 4: TXPDO – 5: RxPDO – 6: Remote transmission request of a TxPDO – 7: Remote transmission request of a RxPDO – 8 ... 15: Reserved for later applications	
Byte 8	Control byte in CAN telegram: – Write access OK: 0x60 – Write access OK + response length: 0x43 (4 Byte), 0x47 (3 Byte), 0x4B (2Byte), 0x4F (1Byte) – Error during read or write access: 0x80	
Byte 9	Low Byte of the CAN object number (index)	
Byte 10	High Byte of the CAN object number (index)	
Byte 11	Subindex in accordance with the CANopen specification for the Pilz servo amplifier	
Byte 12	Data (Low Byte)	– Error code in accordance with CANopen specification in case of an error – Data value of the object in case of a successful read access
Byte 13	Data	
Byte 14	Data	
Byte 15	Data (High Byte)	

4.10.3 Example of a mailbox access

In the following example, PDOs 0x1704 is mapped.

The master issues the following mailbox output message:

Byte 0	0x0A	The following 10 Bytes include data (from Byte 2 to Byte 11)
Byte 1	0x00	The following 10 Bytes include data (from Byte 2 to Byte 11)
Byte 2	0x00	Address 0
Byte 3	0x00	Address 0
Byte 4	0x00	Channel 0 and priority 0

Byte 5	0x03	CoE object
Byte 6	0x00	PDO number 0
Byte 7	0x20	PDO number 0 and SDO request
Byte 8	0x2B	2 Byte write access
Byte 9	0x12	SDO object 0x1C12
Byte 10	0x1C	SDO object 0x1C12
Byte 11	0x01	Subindex 1
Byte 12	0x04	Data value 0x00001704
Byte 13	0x17	Data value 0x00001704
Byte 14	0x00	Data value 0x00001704
Byte 15	0x00	Data value 0x00001704

The response from the servo amplifier must be:

Byte 0	0x0E	The following 14 Bytes include data (from Byte 2 to Byte 15)
Byte 1	0x00	The following 14 Bytes include data (from Byte 2 to Byte 15)
Byte 2	0x00	Address 0
Byte 3	0x00	Address 0
Byte 4	0x00	Channel 0 and priority 0
Byte 5	0x03	CoE object
Byte 6	0x00	PDO number 0
Byte 7	0x20	PDO number 0 and SDO request
Byte 8	0x60	Successful write access
Byte 9	0x12	SDO object 0x1C12
Byte 10	0x1C	SDO object 0x1C12
Byte 11	0x01	Subindex 1
Byte 12	0x00	Data value 0x00000000
Byte 13	0x00	Data value 0x00000000
Byte 14	0x00	Data value 0x00000000
Byte 15	0x00	Data value 0x00000000