User Manual

C887T0011, valid for C-887.53, .531, .532, .533
BRo, 3/14/2024

C-887.53x EtherCAT Interface Description

EtherCAT® is registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

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The C-887.53x controller series from PI is equipped with an EtherCAT slave board for use as a multi-axis device according to the CiA402 drive profile.

C-887.53x stands for C-887.53, .531, .532, .533.

Contents

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Other Applicable Documents

In general, see the following documentation for descriptions of commands and functionality supported by C-887.53x controllers.

Description	Document
C-887.5xx controllers	MS244E User Manual
Coordinate Systems for Hexapod Microrobots	C887T0007 User Manual
Motion of the Hexapod: Position and Orientation in Space, Center of Rotation	C887T0021 Technical Note
PIVirtualMove: Simulation program for parallel-kinematic multi-axis systems	SM163E User Manual
Fast Multi-Channel Photonics Alignment	E712T0016 User Manual

Depending on the hexapod microrobot to be operated with the C-887.53x, the user manual for the hexapod is also valid, e. g.:

Model Family	Document
H-810 Hexapod Microrobot	MS252E User Manual
H-811 Hexapod Microrobot	MS235E User Manual
H-820 Hexapod Microrobot	MS207E User Manual
H-824 Hexapod Microrobot	MS200E User Manual
H-825 Hexapod Microrobot	MS250E User Manual
H-840 Hexapod Microrobot	MS201E User Manual
H-850 Hexapod Microrobot	MS202E User Manual
H-860 Magnetic Drive Hexapod	H860T0002 User Manual

For basic information regarding EtherCAT network and CiA402 drive profile, it is recommended to read the following documentation:

Description	Document
Adjustable speed electrical power drive systems - Part 7-201: Generic interface and use of profiles for power drive systems - Profile type 1 specification	IEC 61800-7-201:2015
Adjustable speed electrical power drive systems - Part 7-301: Generic interface and use of profiles for power drive systems - Mapping of profile type 1 to network technologies	IEC 61800-7-301:2015
EtherCAT Implementation Directive for CiA402 Drive Profile: Directive for using IEC 61800-7-201 within EtherCAT-based servo drives	ETG.6010 D (R) V1.1.0

Documentation of an EtherCAT sample provided by PI:

Description	Document
Implementing a C-887 PI Controller in TwinCAT 3.1 for Motion and Activation of new Coordinate Systems	A000T0075 User Manual

EtherCAT Connection and LEDs of the C-887.53x

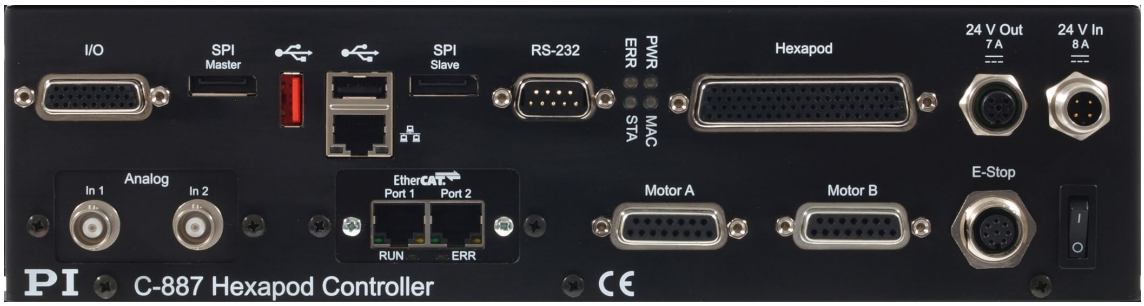
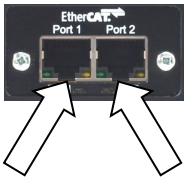
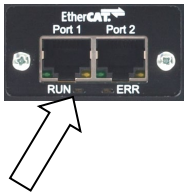
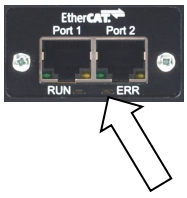


Figure 1: C-887.533 front panel

Labeling	Type	Function
EtherCAT **Port 1** **Port 2**	RJ45 socket with green LED and yellow LED 	Port 1 (left): Connection for EtherCAT master Port 2 (right): Connection for the next EtherCAT slave Green LED: ▪ Lights up continuously: EtherCAT connection was established ▪ Flickers: EtherCAT slave is transmitting/receiving Ethernet frames ▪ Off: No EtherCAT connection Yellow LED: Not used Cable requirements for EtherCAT connection: ▪ CAT 5 (or higher) patch cable (straight-through or cross-over). ▪ Cable length: 0.3 to 100 m
EtherCAT **RUN**	LED, green 	Communication status of the EtherCAT slave: ▪ Off: Slave is in the INIT state. ▪ Flashes (2.5 Hz): Slave is in the PRE-OPERATIONAL state (before operation) ▪ Single flash: Slave is in the SAFE OPERATIONAL state (in safe operation) ▪ Lights up continuously: Slave is in the OPERATIONAL state (in operation)
EtherCAT **ERR**	LED, red 	Communication status of the EtherCAT slave: ▪ Off: No error, slave communicating via EtherCAT ▪ Flashes (2.5 Hz): Invalid configuration. General configuration error. Possible cause: A status change specified by the master is not possible due to register or object settings. ▪ Single flash: Local error. The slave application has independently changed the EtherCAT state. Possible cause 1: A host watchdog timeout has occurred. Possible cause 2: Synchronization error, the slave changes automatically to SAFE-OPERATIONAL. ▪ Double flash: A process data watchdog timeout has occurred. Possible cause: Sync manager watchdog timeout.

For the description of all other front panel elements see the C-887 user manual (MS244).

Commanding via the EtherCAT Interface - Overview

The EtherCAT master specifies the target positions for the axes of the hexapod motion platform in Cartesian coordinates and evaluates the corresponding position feedback of the axes. The C-887.53x (.53x signifies C-887.53, .531, .532, .533) converts the axes' target positions to motion commands for the six hexapod drives. The hexapod system (C-887.53x plus hexapod) acts like an intelligent multi-axis drive pursuant to the CiA402 drive profile.

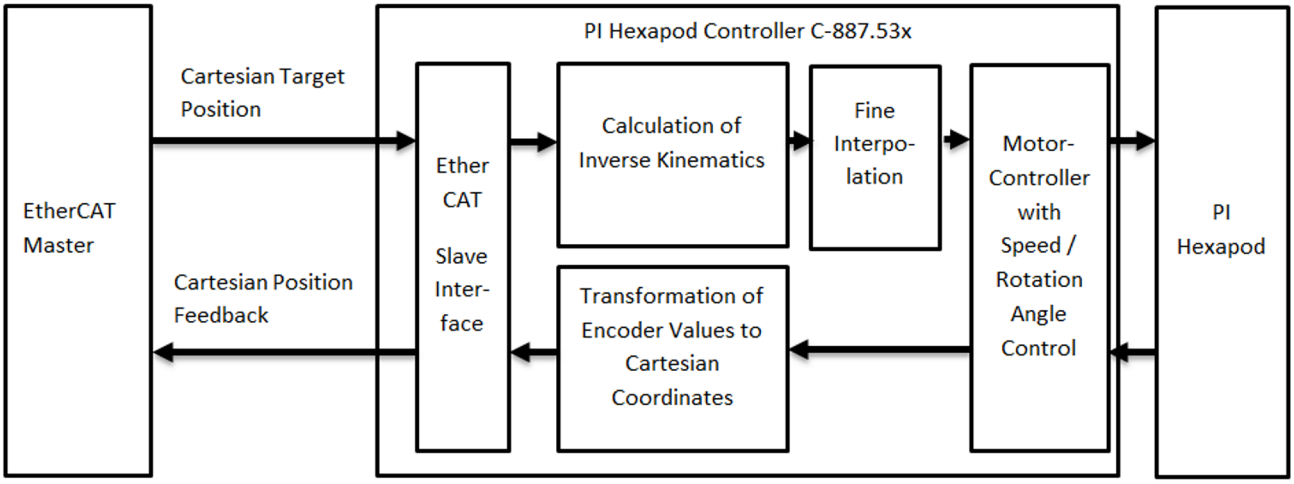


Figure 2: Hexapod system commanded from the EtherCAT master

The following table gives an overview of the most important characteristics for commanding the C-887.53x via an EtherCAT master:

Field bus protocol:	EtherCAT (CoE = CANopen over EtherCAT)
Drive profile:	CiA402 Drive Profile (IEC 61800-7-201)
Type of commanded device, number of axes:	Multi-axis device with 6 individual Cartesian axes
Cycle time for the specification of the target positions, signal processing, and synchronization:	≥1 ms
Operating modes supported according to CiA402:	<table><tr><th>Mode</th><th>Object 0x6060</th><th>Note</th></tr><tr><td>No mode changes / no mode selected</td><td>0</td><td>Safe basic state, target positions will be ignored, required for activating coordinate systems</td></tr><tr><td>Homing mode</td><td>6</td><td>Do a reference move, p. 14</td></tr><tr><td>Cyclic Synchronous Position Mode (CSP)</td><td>8</td><td>Cyclic specification of target positions by the EtherCAT master, p. 15</td></tr></table>
Supported synchronization mode:	Distributed clocks, synchronous with SYNC0 event, see objects 0x1C32 and 0x1C33
Fieldbus connector:	RJ45 socket

INFORMATION

In this user manual it is assumed that you have a fundamental understanding of EtherCAT networks as well as the CiA402 drive profile. For detailed information, it is recommended to read the following documents:

- IEC 61800–7–201 and IEC 61800–7–301 which specify the CiA402 drive profile and its mapping to EtherCAT
- EtherCAT Implementation Directive for CiA402 Drive Profile: Directive for using IEC 61800-7-201 within EtherCAT-based servo drives

Configuring the C-887 for Commanding by the EtherCAT Master

Activating the EtherCAT Interface

The EtherCAT interface is activated on the C-887.53x via the ***Configure Command Mode*** parameter (ID 0x19002000). Possible values of the ***Configure Command Mode*** parameter:

- 0 = EtherCAT interface deactivated (“GCS”)
- 1 = EtherCAT interface activated (“External: EtherCAT”; default)

The value of the ***Configure Command Mode*** parameter can be changed with GCS commands via the TCP/IP or RS-232 communication interfaces of the C-887.53x.

1. Depending on the activation state desired, send
   SPA 1 0x19002000 1
   or
   SPA 1 0x19002000 0
2. The changed parameter value must be activated as follows:
   a. Save the settings to nonvolatile memory of the C-887.53x by sending:
   WPA 101 1 0x19002000
   b. Reboot the C-887.53x by sending the RBT command or switching the C-887.53x off and on again.

EtherCAT Interface and GCS Commands

If the EtherCAT interface is activated via the ***Configure Command Mode*** parameter, GCS commands can still be sent via the TCP/IP or RS-232 communication interfaces of the C-887.53x. However, the execution of the following GCS commands is blocked when the hexapod axes are in the **Operation enabled** state of the CiA402 drive state machine:

- Commands which trigger motion (e.g., MOV)
- Commands which stop motion (e.g., HLT and STP)
- The WPA command

The **Operation enabled** state cannot be left with GCS commands.

If the EtherCAT interface is activated, the coordinate systems used are defined and activated by PI-specific objects (SDO; p. 18). The settings for coordinate systems cannot be changed by GCS commands when the EtherCAT interface is activated.

When the EtherCAT interface is used, parallel GCS communication (e.g., sending GCS commands or using PC software, such as PIMikroMove) should be avoided because GCS communication can reduce the EtherCAT performance of the C-887.53x. Use GCS communication only for initial operation, support cases, and debugging.

An inactive EtherCAT interface does not allow commanding via the EtherCAT master, but only via GCS commands.

Configuring the EtherCAT Master

The steps of configuration, start-up, and operation of the EtherCAT master depend on the device used. See the documentation of your EtherCAT master for details.

For the integration of the C-887.53x in the EtherCAT network, the Physik_Instrumente_Hexapod.xml XML file provided by PI must be saved on the EtherCAT master. The XML file can be found in the EDS directory on the data carrier included in the scope of delivery of the C-887.53x.

In addition, the following settings of the EtherCAT master must be changed to adapt it to the C-887.53x.

The following must be set for each Cartesian axis of the hexapod system:

- Scaling factor numerator: 1
  Scaling factor denominator: 100,000
  See “Factor Group” (p. 14) for more information.
- Reference system: Absolute (the C-887.53x provides absolute positions to the EtherCAT master)
- Dead time compensation: Depends on the cycle time. Calculation and examples:
  dead time = 4 * cycle time + 5 * interpolation buffer time (2 ms)
  1 ms cycle time: 14 ms dead time
  2 ms cycle time: 18 ms dead time
  Empirical optimization recommended.
- Acceleration, velocity, and jerk should be adapted to the hexapod to prevent motion errors (for technical data, see the documentation of the hexapod)

The following must be set for the entire hexapod system:

- Synchronization mode: Distributed clock, synchronous with SYNC0

During commanding by the EtherCAT master, the minimum cycle time of the hexapod system (1 ms) must be maintained. If the actual cycle time is shorter than the minimum cycle time of the hexapod system, the hexapod does not move.

The actual cycle time of the C-887.53x can be read out via the value of the ***Cycletime For Interpolation In External Mode*** parameter (ID 0x19002010). To read out the parameter value, send the GCS command SPA? via the TCP/IP or RS-232 communication interfaces of the C-887.53x (see MS244E user manual).

EtherCAT Communication State Machine

The states of the connection to the EtherCAT network are described by a communication state machine. The states of the communication state machine are displayed by LEDs on the C-887.53x front panel (p. 2).

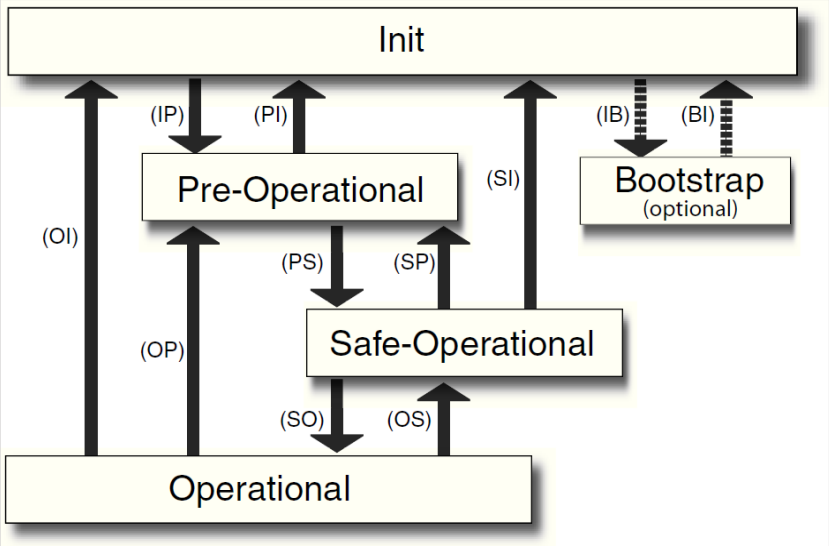


Figure 3: EtherCAT state machine

State	Description
Init	Initialization, the device is starting
Pre-Operational	The device is ready for parametrization. Mailbox communication is possible.
Safe-Operational	PDO input data (TxPDO device) is read. PDO output data (RxPDO device) is ignored.
Operational	Cyclic I/O communication PDO output data (RxPDO device) is processed.

Transition	Description
IP	Start mailbox communication
PI	Stop mailbox communication
PS	Start input update
SP	Stop input update

Transition	Description
SO	Start output update
OS	Stop output update
OP	Stop output update / stop input update
SI	Stop input update / stop mailbox communication
OI	Stop output update / stop input update / stop mailbox communication

CiA402 Object Structure

For details, see the object dictionary in the appendix, p. 21.

CiA402 Drive State Machine

For each Cartesian single axis of the hexapod system, a separate drive state machine is used.

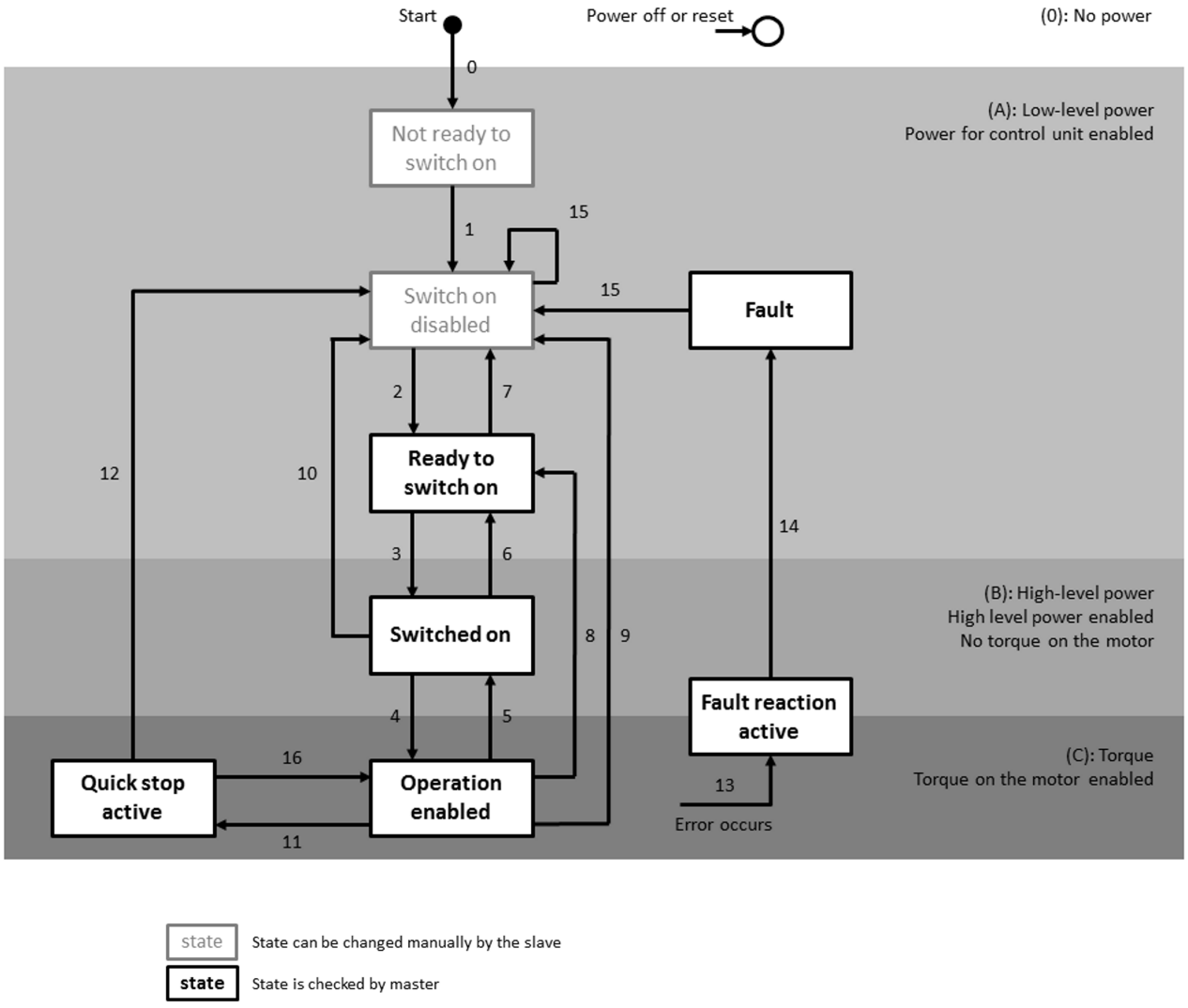


Figure 4: Drive state machine details

Transition 1 is made automatically by the C-887.53x so that the hexapod axes are in the **Switch on disabled** state when switched on or rebooted.

The C-887.53x does not support transition 16 because of the complex system behavior.

State/Function	Not ready to switch on	Switch on dis-abled	Ready to switch on	Switched on	Operation enabled	Quick stop active	Fault reaction active	Fault
Brake applied, if present	Yes	Yes	Yes	Yes	Depending if required for drive function enabled			Yes
Low-level power applied	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
High-level power applied	No	No	No	Yes	Yes	Yes	Yes	No
Drive function enabled (mode of operation)	No	No	No	No	Yes	Yes	Yes	No
Configuration allowed	Yes	Yes	Yes	Yes	No	No	No	Yes

The axes of the hexapod motion platform are coupled together. Therefore, the state of the hexapod system results from commanding *all* axes, and thus from the states of *all* axes. The state of the hexapod system is displayed by object 0x5013, subindex 1 as follows:

State	Value
Not ready to switch on	1
Switch on disabled	2
Ready to switch on	3
Switched on	4
Operation enabled	5
Quick stop active	6
Fault reaction active	7
Fault	8

Some transitions have to be performed by *all* axes while other transitions have to be performed by *at least one* axis to affect the whole hexapod system.

Transition	All axes have to perform this transition	At least one axis has to perform this transition	Power level is switched to
0	x		0
1	x		0
2	x		A
3	x		B
4	x		C
5		x	B
6		x	A
7		x	0
8		x	A
9		x	0
10		x	0
11		x	C
12		x	0
13		x	C
14	x		0
15	x		0

CiA402 Modes of Operation

The mode of operation can be selected via the Modes of Operation object of the first axis (0x6060) and will be valid for all axes. The selection is possible in the **Operation enabled** state. The current mode of operation is displayed via the Modes of Operation Display objects of all axes (0x6061 for the first axis, 0x6861 for the second axis, …).

The C-887.53x supports the following modes of operation according to CiA402:

Code	Mode
0	No mode change / no mode assigned: Safe basic state; target values are ignored; required for activation of coordinate systems
6	Homing mode (perform reference move, p. 14)
8	Cyclic Synchronous Position mode (CSP; cyclic specification of target positions by the EtherCAT master, p. 15)

When a mode change is requested, first the current action is finished (e.g., homing). Afterwards the mode change is displayed in the Modes of Operation Display objects.

If an error occurs during the mode change, the C-887.53x performs the fault reaction (transition 13). Afterwards the Modes of Operation Display objects will display the value 0.

The table below lists possible mode changes and the corresponding reactions of the C-887.53x:

Mode change requested	Finished successfully if …	Fault reaction (transition 13), if ...	Remark
0 → 8	… the C-887.53x is ready for operation.	… an internal error occurs.	
0 → 6	… the C-887.53x is ready for operation and the mode is supported.	… the mode is not supported.	
8 → x	… new target position values are ignored immediately and the current velocity is 0.	… new target position values are ignored immediately and the current velocity is not 0.	The current velocity results from the interpolated commanded target positions of the last 10 cycles.
6 → x	… homing has finished successfully.	… homing has not finished successfully.	

CiA402 Control Word

The control word (object 0x6040) contains bits which trigger transitions between the states of the drive state machine, and bits whose function depends on the selected mode of operation. The bits are only set and accepted for the control word of the first axis, but affect all axes because the axes of the hexapod motion platform are coupled together.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Func-tion	reserved	reserved	Halt	Fault reset	Operation mode specific	Enable operation	Quick stop	Enable voltage	Switch on

Figure 5: All bits of the CiA402 control word

The transitions between the drive states are triggered by combinations of bits 0, 1, 2, 3 and 7 of the control word. If the **Quick stop active** state is not supported by the EtherCAT master, bit 2 of the control word must always be set.

Commanding the drive state transitions with combinations of bits 0, 1, 2, 3 and 7:

Command	Bit 7 Fault reset	Bit 3 Enable operation	Bit 2 Quick stop	Bit 1 Enable voltage	Bit 0 Switch on	Transition
Shutdown	0	x	1	1	0	2, 6, 8
Switch on	0	0	1	1	1	3
Disable voltage	0	x	x	0	x	7, 9, 10, 12
Quick stop	0	x	0	1	x	11
Disable operation	0	0	1	1	1	5
Enable operation	0	1	1	1	1	4, 16
Fault reset	0 -> 1	x	x	x	x	15

Figure 6: Bits 0 to 3 and 7 of the CiA402 control word

Incorrectly set bits which lead to undefined transitions will be treated as an error by the axis. All axes will then perform transition 13 and 14 and stay in the **Fault** state until acknowledgment by the master.

Transitions not permitted in the current state will also be treated as error.

„Fault reset“ (bit 7 changes from 0 to 1): In every state transition 15 is performed, except for the states **Switch on disabled** and **Fault reaction active**, In the states **Switch on disabled** and **Fault reaction active**, the “Fault reset” command is ignored. Only the rising edge of bit 7 is considered.

The function of bits 4 to 6 and bit 8 of the control word depends on the selected mode of operation. For the modes of operation supported by the C-887.53x, these bits are used as follows:

Bit / Operation mode	8	6	5	4
Homing mode	Halt	reserved	reserved	Homing operation start
Cyclic Synchronous Position mode (CSP)	reserved	reserved	reserved	reserved

Figure 7: Bits 4 to 6 and 8 of the CiA402 control word

CiA402 Status Word

The status word (object 0x6041 for the first axis, object 0x6841 for the second axis, …) contains bits for information as listed below. Because the axes of the hexapod motion platform are coupled together, the bits of the status word are mirrored for all axes.

Bit	15	14	13	12	11	10	9	8
Function	reserved		Operation mode specific		Internal limit active	Target reached	reserved	reserved

Bit	7	6	5	4	3	2	1	0
Function	Warning	Switch on disabled	Quick stop	Voltage enabled	Fault	Operation enabled	Switched on	Ready to switch on

Figure 8: All bits of the CiA402 status word

Bits 0 to 6 show the state of the drive state machine:

State	Bit 6 Switch on disabled	Bit 5 Quick stop	Bit 4 Voltage enabled	Bit 3 Fault	Bit 2 Operation enabled	Bit 1 Switched on	Bit 0 Ready to switch on
Not ready to switch on	0	0	0	0	0	0	0
Switch on disabled	1	0	0	0	0	0	0
Ready to switch on	0	1	0	0	0	0	1
Switched on	0	1	1	0	0	1	1
Operation enabled	0	1	1	0	1	1	1
Fault	0	0	0	1	0	0	0
Fault reaction active	0	x	x	1	1	1	1
Quick stop active	0	0	1	0	1	1	1

Figure 9: Bits 0 to 6 of the CiA402 status word

If bit 5 (Quick stop) of the status word is 0, this shall indicate that the C-887.53x is reacting on a quick stop request.

If bit 7 (Warning) of the status word is 1, this shall indicate the presence of a warning condition. Warning is not an error or fault (examples: temperature limit exceeded, job refused), i.e., the status of the drive state machine will not be changed. The cause of the warning may be given in the Error code object (0x603F).

Bit 10 shows the on-target state. The bit is set automatically when a target value (setpoint) is reached. The target value depends on the mode of operation. When the target value is changed by the EtherCAT master, bit 10 is changed too.

If bit 11 (Internal limit active) of the status word is 1, this shall indicate that an internal limit is active (example: position range limit). The internal limits depend on the hexapod and the configuration of the hexapod system.

The meaning of bits 12 and 13 depends on the selected mode of operation. For the modes of operation supported by the C-887.53x, these bits show the following:

Bit / Operation mode	13	12
Homing mode	Homing error	Homing attained
Cyclic synchronous mode (csp)	Following error	Target position ignored

Figure 10: Bits 12 and 13 of the CiA402 status word

Factor Group

The EtherCAT master uses the following units for axis positions: mm, deg.

A scaling is required because in PDO communication the position and velocity values (target position, actual position, profile velocity) are transferred between the EtherCAT master and C-887.53x as integer values. The internal position values transferred between the EtherCAT master and C-887.53x by PDO communication are scaled to the actual position values as follows:

Position actual value = (Position internal value × Numerator) / Denominator

The following objects contain scaling information:

- 0x6093:00 Position factor
- 0x6093:01 Numerator (default: 1)
- 0x6093:02 Denominator (default: 100,000)

See “Configuration of the EtherCAT Master” (p. 6) for the required numerator and denominator settings in the EtherCAT master.

Note: In contrast to the PDO communication, the PI-specific SDOs 0x5000 to 0x5014 specify all position values in µm, or deg * 1000. This applies accordingly to the velocity and acceleration values included in these objects.

Homing Mode

The Homing mode (Modes of Operation = 6) is used to perform a reference move of the hexapod.

NOTICE

Damage from collisions during the reference move!

During a reference move, the hexapod moves unpredictably. **No** collision check or prevention takes place, even when a configuration for collision prevention has been stored on the C-887 with the PIVeriMove Software for the Collision Check.

As a result, collisions are possible between the hexapod, the load to be moved and the environment. Collisions can damage the hexapod, the load to be moved and the environment.

- ➢ Make sure that no collisions between the hexapod, the load to be moved and the environment are possible during the reference move of the hexapod.
- ➢ Do not place any objects in areas where they can get caught by moving parts during the reference move.
- ➢ After a successful reference move, supply a command for the corresponding target position in order to return to the reference position (default: zero position) from any given position. Do **not** start a new reference move.

All axes have to be in the **Operation enabled** state. Otherwise the hexapod will not move.

Supported objects (per axis):

Index*	Name
0x6040	Controlword
0x6041	Statusword
0x6064	Position actual value
0x603F	Error code

0x6060	Modes of operation
0x6061	Modes of operation display

* Index for the first axis. Note that the object index is shifted by 0x800 per axis, e.g. the index of the status word for the second axis is 0x6841.

The Homing mode is selected via the Modes of Operation object of the first axis (0x6060). The Homing mode is active for all axes as long as this mode is selected for the first axis.

Homing-mode-specific bits of the control word:

Bit	Name	Value	Description
4	Start Homing	0 → 1	Start homing
8	Halt	0 1	Homing mode active Stop axis with profile deceleration

Homing-mode-specific bits of the status word:

Bit	Name	Value	Description
10	Target reached	0 1	Halt = 0: Home position not reached Halt = 1: Axis decelerates Halt = 0: Home position reached Halt = 1: Axis has velocity 0
12	Homing attained	0 1	Homing mode not yet completed Homing mode carried out successfully
13	Homing error	0 1	No homing error Homing error occurred, Homing mode carried out not successfully. The error cause can be found by reading the Error code object (0x603F).

INFORMATION

The hexapod moves unpredictably during the reference move. Therefore, the Position Lag Monitoring done by the EtherCAT master should be deactivated in Homing mode.

Cyclic Synchronous Position Mode (CSP)

In CSP (Modes of Operation = 8), the EtherCAT master cyclically provides Cartesian target positions for the axes of the hexapod system and performs position control.

NOTICE

Cyclic transfer of target positions!

Acceleration/deceleration, velocity, and steadiness of the motion depend on the following factors during the cyclic transfer of target positions:

- Target position values
- Observance of the cycle time

The execution of an unsuitable dynamics profile can tilt the hexapod. Tilting can damage the hexapod and/or the load affixed to it.

➢ For this reason, observe the following during the cyclic transfer of target positions:
  – The path that is specified by the target positions must be continuously differentiable at least twice.
  – During the execution of the dynamics profile, the maximum permissible velocity and acceleration of the hexapod must **not** be exceeded.
  – To generate the target positions and continuously transfer them to the C-887 during the motion, it is recommended to use a suitable program.

All axes have to be in the **Operation enabled** state. Otherwise the hexapod will not move.

Supported objects (per axis):

Index*	Name
0x6040	Controlword
0x6041	Statusword
0x607A	Target position
0x6064	Position actual value
0x60F4	Following error actual value (calculated by the C-887.53x)
0x603F	Error code
0x6060	Modes of operation
0x6061	Modes of operation display

* Index for the first axis. Note that the object index is shifted by 0x800 per axis, e.g. the index of the status word for the second axis is 0x6841.

The CSP is selected via the Modes of Operation object of the first axis (0x6060). The CSP is active for all axes as long as this mode is selected for the first axis.

The CSP uses no mode-specific bits of the control word.

Mode-specific bits of the status word:

Bit	Name	Value	Description
10	Target reached	0/1	In CSP the new target position is given cyclically by the EtherCAT master. Bit 10 of the status word is therefore used as status-toggle information to indicate if the EtherCAT master provides updated input data. The bit is toggled between 0 and 1 with every update of the input process data.
12	Target position ignored	0 1	Target position ignored Target position shall be used as input to position control loop (axis is in the **Operation enabled state** and follows the target and set-point values of the EtherCAT master)

13	Following error	0 1	No following error Following error

Stop Options

If the hexapod axes are in the **Operation enabled** state, a motion can be stopped by the following actions:

Action	Reaction	PI default	Remarks
Control word → Quick stop (transition 11)	All axes of the hexapod are stopped	Slow down on quick-stop ramp and stay in Quick stop	When the transition has finished, Mode Of Operation Display is set to 0. Error register see p. 18
Control word → Disable operation (transition 5)	All axes of the hexapod are stopped	Slow down on quick-stop ramp	
Control word → Shutdown (transition 8)	All axes of the hexapod are stopped		
Control word → Disable voltage (transition 9, transition 12)	All axes of the hexapod are stopped		
Control word → Halt bit depending on mode of operation (bit 8)	All axes of the hexapod are stopped	Slow down on quick-stop ramp"	
Control word incorrect → Fault (transition 13)		Slow down on quick-stop ramp and disable drive function if necessary If transition 13 is triggered for *one* axis, *all* axes are stopped.	
Internal drive and/or sensor error, safety function	Control word → Fault (transition 13)		
E-Stop socket	Control word → Fault (transition 13)		
EtherCAT master is switched off/cable is removed	In every state → Fault (transition 13)		
GCS commands HLT, STP, #24	Commands are ignored		
Change of mode of operation	See “CiA402 Modes of Operation”, p. 11		

Hexapod-Specific SDOs

The object range 0x5000 to 0x5014 contains PI-specific SDOs for coordinate systems and information on travel range, velocity, and acceleration.

The SDOs 0x5000 to 0x5014 specify all position values in µm, or deg * 1000. This applies accordingly to the velocity and acceleration values included in these objects.

Query Hexapod Travel Range

You can query the maximum absolute position that can be commanded when the platform of the hexapod moves along a certain direction vector. In addition, the maximum values for velocity and acceleration are displayed. Note: In case of superposition of motion, the displayed velocity values are only valid for the current position and can be lower along the queried vector.

- Object 0x5011 specifies the components of the axes on the direction vector. Must be different from zero for at least one queried axis. Can have a negative sign.
- Object 0x5010:03 triggers the query.
- Object 0x5012 displays the maximum commandable absolute position for the axes when

the platform of the hexapod moves along the given direction vector (based on the current position at the time of the query)
- Object 0x5014:01 displays the maximum permissible translational velocity
- Object 0x5014:02 displays the maximum permissible angular velocity
- Object 0x5014:03 displays the maximum permissible translational acceleration
- Object 0x5014:04 displays the maximum permissible angular acceleration

Hexapod Coordinate Systems

The PI-specific object range provides objects for definition and activation of work and tool coordinate systems.

Activation of coordinate systems changes the current position of the hexapod axes. Therefore, the mode of operation must be set to 0 before a coordinate system can be activated.

Objects for coordinate systems (default values are set on delivery):

- Object 0x5000 for definition of the work coordinate system, every axis has its own subindex
- Object 0x5001 for definition of the tool coordinate system, every axis has its own subindex
- Object 0x5010:01 for activation of the work coordinate system
- Object 0x5010:02 for activation of the tool coordinate system

Note that the EtherCAT interface and thus also the coordinate systems defined by the objects listed above are active by default when the C-887.53x is switched on or rebooted. Refer to “Configuration of the C-887 for Commanding by the EtherCAT Master” (p. 5) for further details on activation/deactivation of the EtherCAT interface.

For further details on user-defined coordinate systems, see the C-887 user manual (MS244) and the document “Coordinate Systems for Hexapod Microrobots” (C887T0007).

Error Codes and Error Handling

Error codes are displayed in the Error code object 0x603F and in the Error register object 0x1001. Many of the GCS errors displayed here are indications only, and as such will not trigger the fault reaction (transition 13) and thus not stop the motion.

The Error register object shows the system state. If a bit is set to 1, the specified error has occurred.

Each axis has its own Error code object (0x603F, 0x683F, …).

All bits are reset by Fault reset (transition 15). If no Fault reset has been sent: Objects 0x1001 and 0x603F can also be reset by the Reset Error Code object 0x5010:04.

Error Register 0x1001

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Function	Manufacturer-specific error code	Reserved, always "0"	Device-profile-specific error	Communication	Temperature	Voltage	Current	Generic error

Error Codes

Emergency error codes (IEC 61800-7-201)	**Name**	**Corresponds to GCS error**	**Error register**	**Remark**
0	No error	0	0	

Emergency error codes (IEC 61800-7-201)	Name	Corresponds to GCS error	Error register	Remark
0x2220	Continuous Over Current Detected		0x3	
0x2250	Short Circuit		0x3	
0x3130	Phase Failure		0x81	
0x4300	Temperature Drive Error		0x9	
0x4310	Temperature Drive Excess Limit		0x9	
0x4320	Temperature Drive Too Low		0x9	
0x5110	Supply Low Voltage	66	0x5	
0x6320	Parameter Error	54, 233	0x81	
0x7120	Motor General Failure		0x81	
0x7121	Motor Blocked	657	0x81	Safety Stop because motor has got stuck
0x7122	Motor Error Or Commutation malfunction		0x81	
0x7305	Sensor Incremental Encoder Fault		0x81	
0x7310	Sensor Speed Error	606	0x81	Rate of change of sensor too high
0x7320	Sensor Position Error	505	0x81	
0x7500	Communication Error		0x11	
0x8140	Recovered From Bus Off		0x81	
0x8141	Bus Off Occurred		0x81	
0x8210	PDO not Processed Due To Length Error		0x81	
0x8220	PDO length Exceeded		0x81	
0x8300	Torque Control		0x81	
0x8400	Velocity Controller Error	8	0x81	
0x8500	Position Controller Error	7	0x81	
0x8611	Positioning Following Error	1024	0x81	
0x8612	Positioning Reference Limit	216	0x81	
0xFF00 to 0xFFFF	**Manufacturer-specific Error Codes**			
0xFF04	Phasing Process Out Of Tolerance detected		0x81	
0xFF05	Unallowable move attempted on unreferenced axis, or move attempted with servo off	5	0x81	
0xFF06	Error/Timeout During Homing Process	45	0x81	
0xFF10	Divide By Zero Instruction detected		0x81	
0xFFDC	FIFO Buffer underrun (DSP)	220	0x81	
0xFFDD	FIFO Buffer overflow (DSP)	221	0x81	
0xFF50	Safety stop triggered	500, 501, 657	0x81	**E-Stop** socket

Emergency error codes (IEC 61800-7-201)	Name	Corresponds to GCS error	Error register	Remark
0xFFFF	Hardware Error	333, 555	0x81	General hardware error, communication with DSP fails

GCS Error Codes Related to the EtherCAT Interface

Error code	Error name	Description	Notes
700	COMMAND_NOT_ALLOWED_IN_EXTERNAL_MODE	Command not allowed in external mode	See p. 5 for more information
715	INVALID_MODE_OF_OPERATION	Invalid mode of operation	Only modes 6, 8 and 0 are supported, see p. 11.

Appendix: Object Dictionary

The object range 0x6000 to 0x67FF is dedicated to the CiA402 drive profile. For multi-axis devices like the hexapod system, the object range 0x6000 to 0x67FF is shifted by 0x800 per axis as described in the IEC 61800-7-201. This way, each axis has its own objects in this object range. Nevertheless, some objects are without function for all but the first axis („X“) because the hexapod axes are coupled to each other. This applies, for example, to the „Modes Of Operation“ objects of axes Y, Z, U, V, and W—the mode of operation can only be set for the first axis, but this setting is valid for all hexapod axes.

The object range 0x5000 to 0x5014 contains PI-specific objects for coordinate systems and information on travel range, velocity, and acceleration. See “Hexapod-Specific SDOs” (p. 17) for more information.

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	1000	Device type	RO		0x00020192	131474	UINT32	
	1001	Error register	RO		0x00	0	UINT8	
	1008	Manufacturer device name	RO		C-887 EtherCAT		STRING	
	1009	Manufacturer hardware version	RO		0		STRING	
	100A	Manufacturer software version	RO		0		STRING	
	1018:00	Idendity object	RO		4		UINT8	
	1018:01	Vendor ID	RO		0x0000076D	1901	UNINT32	
	1018:02	Product code	RO		0x00000003	3	UNINT32	
	1018:03	Revision number	RO		0	0	UNINT32	
	1018:04	Serial number	RO		0x12345678	305419896	UNINT32	
Mappings Rx	1600:00	RxPDO - CSP	RO		3			
	1600:01	Controlword	RO		0x6040:00, 16			
	1600:02	Modes of operation	RO		0x6060:00, 8			
	1600:03	Target position	RO		0x607A:00, 32			
	1601:00	RxPDO - PP	RO		5			
	1601:01	Controlword	RO		0x6040:00, 16			
	1601:02	Modes of operation	RO		0x6060:00, 8			
	1601:03	Target position	RO		0x607A:00, 32			
	1601:04	Profile velocity	RO		0x6081:00, 32			
	1601:05	Profile acceleration	RO		0x6083:00, 32			
	1610:00	RxPDO - CSP	RO		3			
	1610:01	Controlword	RO		0x6840:00, 16			
	1610:02	Modes of operation	RO		0x6860:00, 8			
	1610:03	Target position	RO		0x687A:00, 32			
	1611:00	RxPDO - PP	RO		5			
	1611:01	Controlword	RO		0x6840:00, 16			
	1611:02	Modes of operation	RO		0x6860:00, 8			
	1611:03	Target position	RO		0x687A:00, 32			
	1611:04	Profile velocity	RO		0x6881:00, 32			
	1611:05	Profile acceleration	RO		0x6883:00, 32			
	1620:00	RxPDO - CSP	RO		3			
	1620:01	Controlword	RO		0x7040:00, 16			

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	1620:02	Modes of operation	RO		0x7060:00, 8			
	1620:03	Target position	RO		0x707A:00, 32			
	1621:00	RxPDO - PP	RO		5			
	1621:01	Controlword	RO		0x7040:00, 16			
	1621:02	Modes of operation	RO		0x7060:00, 8			
	1621:03	Target position	RO		0x707A:00, 32			
	1621:04	Profile velocity	RO		0x7081:00, 32			
	1621:05	Profile acceleration	RO		0x7083:00, 32			
	1630:00	RxPDO - CSP	RO		3			
	1630:01	Controlword	RO		0x7840:00, 16			
	1630:02	Modes of operation	RO		0x7860:00, 8			
	1630:03	Target position	RO		0x787A:00, 32			
	1631:00	RxPDO - PP	RO		5			
	1631:01	Controlword	RO		0x7840:00, 16			
	1631:02	Modes of operation	RO		0x7860:00, 8			
	1631:03	Target position	RO		0x787A:00, 32			
	1631:04	Profile velocity	RO		0x7881:00, 32			
	1631:05	Profile acceleration	RO		0x7883:00, 32			
	1640:00	RxPDO - CSP	RO		3			
	1640:01	Controlword	RO		0x8040:00, 16			
	1640:02	Modes of operation	RO		0x8060:00, 8			
	1640:03	Target position	RO		0x807A:00, 32			
	1641:00	RxPDO - PP	RO		5			
	1641:01	Controlword	RO		0x8040:00, 16			
	1641:02	Modes of operation	RO		0x8060:00, 8			
	1641:03	Target position	RO		0x807A:00, 32			
	1641:04	Profile velocity	RO		0x8081:00, 32			
	1641:05	Profile acceleration	RO		0x8083:00, 32			
	1650:00	RxPDO - CSP	RO		3			
	1650:01	Controlword	RO		0x8840:00, 16			
	1650:02	Modes of operation	RO		0x8860:00, 8			
	1650:03	Target position	RO		0x887A:00, 32			
	1651:00	RxPDO - PP	RO		5			
	1651:01	Controlword	RO		0x8840:00, 16			
	1651:02	Modes of operation	RO		0x8860:00, 8			
	1651:03	Target position	RO		0x887A:00, 32			
	1651:04	Profile velocity	RO		0x8881:00, 32			
	1651:05	Profile acceleration	RO		0x8883:00, 32			
Mappings Tx	1A00:00	TxPDO - CSP	RO		4			
	1A00:01	Statusword	RO		0x6041:00, 16			
	1A00:02	Modes of operation display	RO		0x6061:00, 8			
	1A00:03	Position actual value	RO		0x6064:00, 32			

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	1A00:04	Following error actual value	RO		0x60F4:00, 32			
	1A01:00	TxPDO - PP	RO		3			
	1A01:01	Statusword	RO		0x6041:00, 16			
	1A01:02	Modes of operation display	RO		0x6061:00, 8			
	1A01:03	Position actual value	RO		0x6064:00, 32			
	1A10:00	TxPDO - CSP	RO		4			
	1A10:01	Statusword	RO		0x6841:00, 16			
	1A10:02	Modes of operation display	RO		0x6861:00, 8			
	1A10:03	Position actual value	RO		0x6864:00, 32			
	1A10:04	Following error actual value	RO		0x68F4:00, 32			
	1A11:00	TxPDO - PP	RO		3			
	1A11:01	Statusword	RO		0x6841:00, 16			
	1A11:02	Modes of operation display	RO		0x6861:00, 8			
	1A11:03	Position actual value	RO		0x6864:00, 32			
	1A20:00	TxPDO - CSP	RO		4			
	1A20:01	Statusword	RO		0x7041:00, 16			
	1A20:02	Modes of operation display	RO		0x7061:00, 8			
	1A20:03	Position actual value	RO		0x7064:00, 32			
	1A20:04	Following error actual value	RO		0x70F4:00, 32			
	1A21:00	TxPDO - PP	RO		3			
	1A21:01	Statusword	RO		0x7041:00, 16			
	1A21:02	Modes of operation display	RO		0x7061:00, 8			
	1A21:03	Position actual value	RO		0x7064:00, 32			
	1A30:00	TxPDO - CSP	RO		4			
	1A30:01	Statusword	RO		0x7841:00, 16			
	1A30:02	Modes of operation display	RO		0x7861:00, 8			
	1A30:03	Position actual value	RO		0x7864:00, 32			
	1A30:04	Following error actual value	RO		0x78F4:00, 32			
	1A31:00	TxPDO - PP	RO		3			
	1A31:01	Statusword	RO		0x7841:00, 16			
	1A31:02	Modes of operation display	RO		0x7861:00, 8			
	1A31:03	Position actual value	RO		0x7864:00, 32			
	1A40:00	TxPDO - CSP	RO		4			
	1A40:01	Statusword	RO		0x8041:00, 16			
	1A40:02	Modes of operation display	RO		0x8061:00, 8			
	1A40:03	Position actual value	RO		0x8064:00, 32			
	1A40:04	Following error actual value	RO		0x80F4:00, 32			
	1A41:00	TxPDO - PP	RO		3			
	1A41:01	Statusword	RO		0x8041:00, 16			
	1A41:02	Modes of operation display	RO		0x8061:00, 8			
	1A41:03	Position actual value	RO		0x8064:00, 32			
	1A50:00	TxPDO - CSP	RO		4			

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	1A50:01	Statusword	RO		0x8841:00, 16			
	1A50:02	Modes of operation display	RO		0x8861:00, 8			
	1A50:03	Position actual value	RO		0x8864:00, 32			
	1A50:04	Following error actual value	RO		0x88F4:00, 32			
	1A51:00	TxPDO - PP	RO		3			
	1A51:01	Statusword	RO		0x8841:00, 16			
	1A51:02	Modes of operation display	RO		0x8861:00, 8			
	1A51:03	Position actual value	RO		0x8864:00, 32			
PDO Assign-ments	1C00:00	Sync Manager communication types	RO		4			
	1C00:01	SubIndex 001	RO		0x01	1		
	1C00:02	SubIndex 002	RO		0x02	1		
	1C00:03	SubIndex 003	RO		0x03	1		
	1C00:04	SubIndex 004	RO		0x04	1		
	1C10:00	Sync Manager 0 PDO assignment	RO		0			
	1C11:00	Sync Manager 1 PDO assignment	RO		0			
	1C12:00	Sync Manage r2 PDO assignment	RW	P->S	6			
	1C12:01	SubIndex 001	RW	P->S	0x1600	5632		
	1C12:02	SubIndex 002	RW	P->S	0x1610	5648		
	1C12:03	SubIndex 003	RW	P->S	0x1620	5664		
	1C12:04	SubIndex 004	RW	P->S	0x1630	5680		
	1C12:05	SubIndex 005	RW	P->S	0x1640	5696		
	1C12:06	SubIndex 006	RW	P->S	0x1650	5712		
	1C12:07	SubIndex 007	RW	P->S	0	0		For future use
	1C13:00	Sync Manager3 PDO assignment	RW	P->S	6			
	1C13:01	SubIndex 001	RW	P->S	0x1A00	6656		
	1C13:02	SubIndex 002	RW	P->S	0x1A10	6672		
	1C13:03	SubIndex 003	RW	P->S	0x1A20	6688		
	1C13:04	SubIndex 004	RW	P->S	0x1A30	6704		
	1C13:05	SubIndex 005	RW	P->S	0x1A40	6720		
	1C13:06	SubIndex 006	RW	P->S	0x1A50	6736		
Synchroni-zation	1C32:01:32	Configuration DC modus						
	1C33:01:32	Configuration DC modus						
PI-specific	5000:00	Work coordinate system	RO		6		UINT8	For further details, see „Hexapod Coordinate Systems“, p. 18
	5000:01	Axis X	RW		0	0	INT32	
	5000:02	Axis Y	RW		0	0	INT32	
	5000:03	Axis Z	RW		0	0	INT32	
	5000:04	Axis U	RW		0	0	INT32	
	5000:05	Axis V	RW		0	0	INT32	
	5000:06	Axis W	RW		0	0	INT32	
	5001:00	Tool coordinate system	RO		6		UINT8	

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	5001:01	Axis X	RW		0	0	INT32	
	5001:02	Axis Y	RW		0	0	INT32	
	5001:03	Axis Z	RW		0	0	INT32	
	5001:04	Axis U	RW		0	0	INT32	
	5001:05	Axis V	RW		0	0	INT32	
	5001:06	Axis W	RW		0	0	INT32	
	5008:00	Motor homing method	RO		6		UINT8	
	5008:01	Axis 1	RW		0	0	INT32	
	5008:02	Axis 2	RW		0	0	INT32	
	5008:03	Axis 3	RW		0	0	INT32	
	5008:04	Axis 4	RW		0	0	INT32	
	5008:05	Axis 5	RW		0	0	INT32	
	5008:06	Axis 6	RW		0	0	INT32	
	5009:00	Software version	RO		4		UINT8	
	5009:01	GCSFW	RO		0		INT32	
	5009:02	DSPFW	RO		0		INT32	
	5009:03	FPGAFW	RO		0		INT32	
	5009:04	IMAGEVER	RO		0		INT32	
	5010:00	Buffered parameters	RO		2		INT32	
	5010:01	Work coordinates	RW		0		INT32	Set to 1 to activate Work coordinate system
	5010:02	Tool coordinates	RW		0		INT32	Set to 1 to activate Tool coordinate system
	5010:03	Direction for Travelrange Calculation	RW		0		INT32	Set to 1 to start travel range calculation
	5010:04	Reset ErrorCode	RW		0		INT32	Set to 1 to reset error codes in objects 0x1001 and 0x603F
	5011:0	Direction for Travelrange	RO		6		UINT8	
	5011:01	Axis X	RW		0		INT32	
	5011:02	Axis Y	RW		0		INT32	
	5011:03	Axis Z	RW		0		INT32	
	5011:04	Axis U	RW		0		INT32	
	5011:05	Axis V	RW		0		INT32	
	5011:06	Axis W	RW		0		INT32	
	5012:0	Available Travelrange	RO		6		UINT8	
	5012:01	Axis X	RO		0		INT32	
	5012:02	Axis Y	RO		0		INT32	
	5012:03	Axis Z	RO		0		INT32	

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	5012:04	Axis U	RO		0		INT32	
	5012:05	Axis V	RO		0		INT32	
	5012:06	Axis W	RO		0		INT32	
	5013:0	Debug Information	RO		2		UINT8	
	5013:01	Hexapod State	RO		0		INT32	Possible values see p. 9
	5013:02	Reserved	RO		0		INT32	
	5014:0	Maximum Velocity and Acceleration	RO		4		UINT8	
	5014:01	Translational Velocity	RO		0		INT32	
	5014:02	Rotational Velocity	RO		0		INT32	
	5014:03	Translational Acceleration	RO		0		INT32	
	5014:04	Rotational Acceleration	RO		0		INT32	
Axis X	603F	Error code	RO		0x0000	0	UINT16	
	6040	Controlword	RW		0x0000	0	UINT16	
	6041	Statusword	RO		0x0000	0	UINT16	
	6060	Modes of operation	RW		0	0	INT8	
	6061	Modes of operation display	RO		0	0	INT8	
	6064	Position actual value	RO		0	0	INT32	
	607A	Target position	RW		0	0	INT32	
	607D:00	Software position limit	RO		2		UINT8	
	607D:01	Min position limit	RW		0	0	INT32	
	607D:02	Max position limit	RW		0	0	INT32	
	6093:00	Position factor	RO		2		UINT8	
	6093:01	Numerator	RW		1	1	INT32	
	6093:02	Denominator	RW		0x186A0	100000	INT32	
	6098	Homing method	RW		0	0	INT8	
	60B0	Position offset	RW		0	0	INT32	
	60C2:00	Interpolation time period	RO		2		UINT8	
	60C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	
	60C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	
	60F4	Following error actual value	RO		0	0	INT32	
	60FD	Digital Inputs	RO		0	0	INT32	
	60FF	Target velocity	RW		0	0	INT32	
	6502	Supported drive modes	RO		0x00000000	0	UINT32	
	67FF	Device profile number	RO		0x00000000	0	UINT32	
Axis Y	683F	Error code	RO		0x0000	0	UINT16	Without function, for CiA402 compatibility only
	6840	Controlword	RW		0x0000	0	UINT16	
	6841	Statusword	RO		0x0000	0	UINT16	
	6860	Modes of operation	RW		0	0	INT8	Without function, for

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
								CiA402 compatibility only
	6861	Modes of operation display	RO		0	0	INT8	
	6864	Position actual value	RO		0	0	INT32	
	687A	Target position	RW		0	0	INT32	
	687D:00	Software position limit	RO		2		UINT8	
	687D:01	Min position limit	RW		0	0	INT32	
	687D:02	Max position limit	RW		0	0	INT32	
	6893:00	Position factor	RO		2		UINT8	
	6893:01	Numerator	RW		1	1	INT32	
	6893:02	Denominator	RW		0x186A0	100000	INT32	
	6898	Homing method	RW		0	0	INT8	Without function, for CiA402 compatibility only
	68B0	Position offset	RW		0	0	INT32	
	68C2:00	Interpolation time period	RO		2		UINT8	Without function, for CiA402 compatibility only
	68C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	Without function, for CiA402 compatibility only
	68C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	Without function, for CiA402 compatibility only
	68F4	Following error actual value	RO		0	0	INT32	
	68FD	Digital Inputs	RO		0	0	INT32	Without function, for CiA402 compatibility only
	68FF	Target velocity	RW		0	0	INT32	
	6D02	Supported drive modes	RO		0x00000000	0	UINT32	
	6FFF	Device profile number	RO		0x00000000	0	UINT32	
Axis Z	703F	Error code	RO		0x0000	0	UINT16	Without function, for CiA402 compatibility only
	7040	Controlword	RW		0x0000	0	UINT16	
	7041	Statusword	RO		0x0000	0	UINT16	
	7060	Modes of operation	RW		0	0	INT8	Without function, for CiA402

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
								compatibility only
	7061	Modes of operation display	RO		0	0	INT8	
	7064	Position actual value	RO		0	0	INT32	
	707A	Target position	RW		0	0	INT32	
	707D:00	Software position limit	RO		2		UINT8	
	707D:01	Min position limit	RW		0	0	INT32	
	707D:02	Max position limit	RW		0	0	INT32	
	7093:00	Position factor	RO		2		UINT8	
	7093:01	Numerator	RW		1	1	INT32	
	7093:02	Denominator	RW		0x186A0	100000	INT32	
	7098	Homing method	RW		0	0	INT8	Without function, for CiA402 compatibility only
	70B0	Position offset	RW		0	0	INT32	
	70C2:00	Interpolation time period	RO		2		UINT8	Without function, for CiA402 compatibility only
	70C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	Without function, for CiA402 compatibility only
	70C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	Without function, for CiA402 compatibility only
	70F4	Following error actual value	RO		0	0	INT32	
	70FD	Digital Inputs	RO		0	0	INT32	Without function, for CiA402 compatibility only
	70FF	Target velocity	RW		0	0	INT32	
	7502	Supported drive modes	RO		0x00000000	0	UINT32	
	77FF	Device profile number	RO		0x00000000	0	UINT32	
Axis U (ΘX)	783F	Error code	RO		0x0000	0	UINT16	Without function, for CiA402 compatibility only
	7840	Controlword	RW		0x0000	0	UINT16	
	7841	Statusword	RO		0x0000	0	UINT16	
	7860	Modes of operation	RW		0	0	INT8	Without function, for CiA402 compatibility

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
								only
	7861	Modes of operation display	RO		0	0	INT8	
	7864	Position actual value	RO		0	0	INT32	
	787A	Target position	RW		0	0	INT32	
	787D:00	Software position limit	RO		2		UINT8	
	787D:01	Min position limit	RW		0	0	INT32	
	787D:02	Max position limit	RW		0	0	INT32	
	7893:00	Position factor	RO		2		UINT8	
	7893:01	Numerator	RW		1	1	INT32	
	7893:02	Denominator	RW		0x186A0	100000	INT32	
	7898	Homing method	RW		0	0	INT8	Without function, for CiA402 compatibility only
	78B0	Position offset	RW		0	0	INT32	
	78C2:00	Interpolation time period	RO		2		UINT8	Without function, for CiA402 compatibility only
	78C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	Without function, for CiA402 compatibility only
	78C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	Without function, for CiA402 compatibility only
	78F4	Following error actual value	RO		0	0	INT32	
	78FD	Digital Inputs	RO		0	0	INT32	Without function, for CiA402 compatibility only
	78FF	Target velocity	RW		0	0	INT32	
	7D02	Supported drive modes	RO		0x00000000	0	UINT32	
	7FFF	Device profile number	RO		0x00000000	0	UINT32	
Axis V (ΘY)	803F	Error code	RO		0x0000	0	UINT16	Without function, for CiA402 compatibility only
	8040	Controlword	RW		0x0000	0	UINT16	
	8041	Statusword	RO		0x0000	0	UINT16	
	8060	Modes of operation	RW		0	0	INT8	Without function, for CiA402 compatibility only

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	8061	Modes of operation display	RO		0	0	INT8	
	8064	Position actual value	RO		0	0	INT32	
	807A	Target position	RW		0	0	INT32	
	807D:00	Software position limit	RO		2		UINT8	
	807D:01	Min position limit	RW		0	0	INT32	
	807D:02	Max position limit	RW		0	0	INT32	
	8093:00	Position factor	RO		2		UINT8	
	8093:01	Numerator	RW		1	1	INT32	
	8093:02	Denominator	RW		0x186A0	100000	INT32	
	8098	Homing method	RW		0	0	INT8	Without function, for CiA402 compatibility only
	80B0	Position offset	RW		0	0	INT32	
	80C2:00	Interpolation time period	RO		2		UINT8	Without function, for CiA402 compatibility only
	80C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	Without function, for CiA402 compatibility only
	80C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	Without function, for CiA402 compatibility only
	80F4	Following error actual value	RO		0	0	INT32	
	80FD	Digital Inputs	RO		0	0	INT32	Without function, for CiA402 compatibility only
	80FF	Target velocity	RW		0	0	INT32	
	8502	Supported drive modes	RO		0x00000000	0	UINT32	
	87FF	Device profile number	RO		0x00000000	0	UINT32	
Axis W (ΘZ)	883F	Error code	RO		0x0000	0	UINT16	Without function, for CiA402 compatibility only
	8840	Controlword	RW		0x0000	0	UINT16	
	8841	Statusword	RO		0x0000	0	UINT16	
	8860	Modes of operation	RW		0	0	INT8	Without function, for CiA402 compatibility only
	8861	Modes of operation display	RO		0	0	INT8	

Object range	Index:Sub-index	Name	Access	Time of writing	Default Hex value (:Sub-index, Size)	Dec value	Data type	Comment
	8864	Position actual value	RO		0	0	INT32	
	887A	Target position	RW		0	0	INT32	
	887D:00	Software position limit	RO		2		UINT8	
	887D:01	Min position limit	RW		0	0	INT32	
	887D:02	Max position limit	RW		0	0	INT32	
	8893:00	Position factor	RO		2		UINT8	
	8893:01	Numerator	RW		1	1	INT32	
	8893:02	Denominator	RW		0x186A0	100000	INT32	
	8898	Homing method	RW		0	0	INT8	Without function, for CiA402 compatibility only
	88B0	Position offset	RW		0	0	INT32	
	88C2:00	Interpolation time period	RO		2		UINT8	Without function, for CiA402 compatibility only
	88C2:01	Interpolation time period value	RW	P->S	1	1	UINT8	Without function, for CiA402 compatibility only
	88C2:02	Interpolation time index	RW	P->S	-3	-3	INT8	Without function, for CiA402 compatibility only
	88F4	Following error actual value	RO		0	0	INT32	
	88FD	Digital Inputs	RO		0	0	INT32	Without function, for CiA402 compatibility only
	88FF	Target velocity	RW		0	0	INT32	
	8D02	Supported drive modes	RO		0x00000000	0	UINT32	
	8FFF	Device profile number	RO		0x00000000	0	UINT32	

RO = Read only

RW = Read/Write

P → S = Pre-Operational → Safe-Operational (see Figure 3 on p. 7)