EZmotion

User Guide

PEC Series Motor Driver Module

Table of Contents

Overview

Applicable Products

Table 1 lists the products for which this user guide is applicable.

Table 1: Applicable Products

Item	Applicable Part Number
1	MMP545400-75-E2-1
2	MMP760400-75-E2-1
3	MMP760200-75-E2-1
4	MMP760100-75-E2-1

Safety Warnings

To prevent personal injury or damage to the motor or other equipment, follow the guidelines listed below:

- Always secure the motor before applying power, since the motor may move unexpectedly, jump, or fall when it starts.
- Keep hair and loose clothing away from the motor.
- Avoid the shaft and any attached mechanical parts when operating the motor.
- Do not open or disassemble the motor.
- Bond the motor enclosure to a protective ground when the motor is installed in a system.
- Ensure that the power source connected to the motor is fused or otherwise current-limited.

Section 1. Product Information

1.1 Introduction

The MMPxxxx00-75-E2-1 driver module family are fully integrated servo motor controllers with a very small size, providing field-oriented control (FOC) for permanent magnet synchronous motors (PMSMs). They integrate an accurate angle sensor, communication interface, advanced motion controller, power inverter, and multi-functional external input/outputs (I/Os) in one package to provide a complete solution (see Figure 1). These motor driver modules simplify the development process for motor control systems.

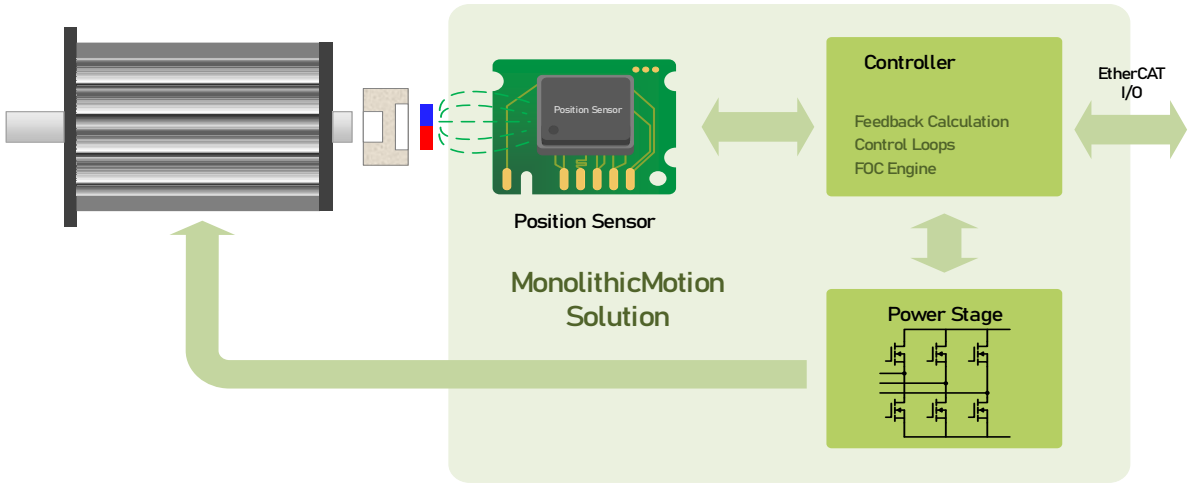


Figure 1: Motor Control Block Diagram

The motor can operate in speed, position, or torque control modes. The motor is controlled though either an EtherCAT interface with a CANopen over EtherCAT (CoE) protocol, or with simple I/O signals. Configurable parameters can be set using a simple PC-based program, which interfaces with the motor through a USB debug interface. Once parameters have been optimized, they can be saved to the module's non-volatile memory (NVM).

To use the module with a servo motor, integrate the module and the motor with a magnet at the motor shaft. Connect a USB debug interface or external pulse inputs to the module, and then use the MotionLAB GUI software to tune and set the control parameters.

For the hardware specifications, refer to the corresponding datasheets on the EZmotion website.

1.2 Features

- Embedded Angular Sensor
- FOC Control
- 100Mbps EtherCAT Communication Interface with Distributed Clock and CoE Protocol
- Supports CiA DSP402 PP, PV, PT, CSP, CSV, CST, and Homing Modes
- Motor and Load Parameter Auto-Identification and Loop Auto-Tuning
- AccuFilter for Low Noise and Vibration
- Advanced Motion Controller Enables Smooth Changes between Different Operation Modes
- INL Calibration Algorithm with Optical Encoder
- Two Separate Notch Filters for Elastic Load Optimization
- External I/O Interface Supports PUL/DIR, PWM/DIR, or A/B Signal Inputs
- General-Purpose I/O for Logic Signal Inputs or Outputs
- DC Link Voltage Sensing and Limit Function
- Temperature-Sensing NTC Input
- Power, Alarm, and Communication Status Indication

1.3 MotionLAB

EZmotion provides a user-friendly, PC-based virtual bench GUI called MotionLAB, which offers a simple way to configure and test the motor and module (see Figure 2).

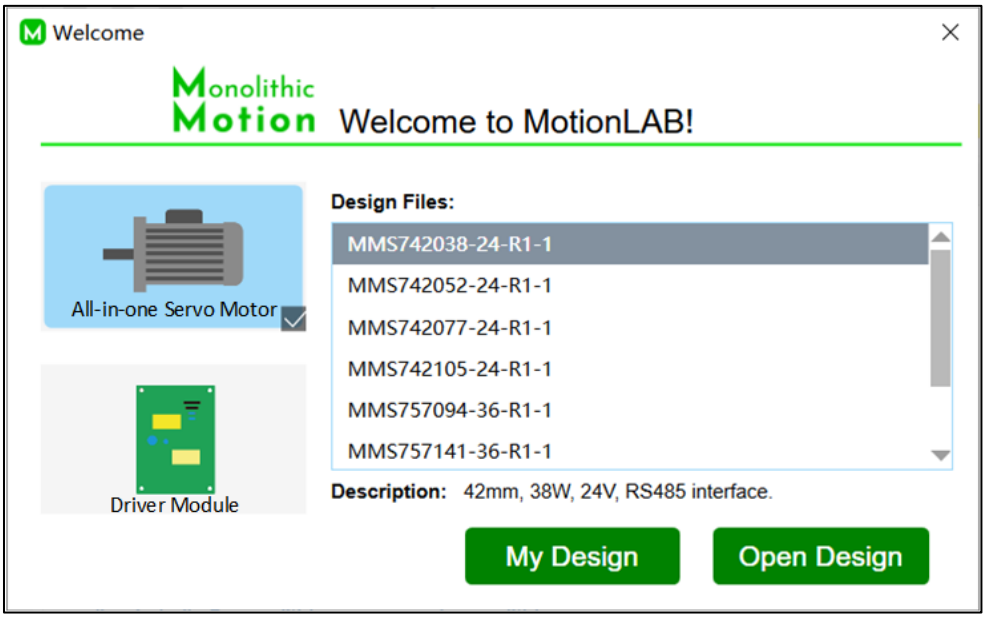


Figure 2: MotionLAB

Download the MotionLAB software and its driver installer from the EZmotion website. The user guide for MotionLAB is also available on the website.

Install MotionLAB and its driver. Read its user guide carefully before using MotionLAB to run the motor.

Section 2. Communication

The driver module uses the EtherCAT CoE protocol to exchange messages between the motion controller and motors.

EtherCAT is a high-performance, simple-to-use industrial Ethernet technology with a flexible topology. Each slave device reads the data addressed to it, and writes its data back to the frame while the frame moves downstream. This leads to improved bandwidth while also eliminating the need for switches or hubs. The unique way that EtherCAT processes frames makes it the fastest industrial Ethernet technology.

The distributed clock technique ensures that all the slave devices are synchronized, and that the jitter is below 1µs. Table 2 lists the main implemented EtherCAT features.

Table 2: EtherCAT Slave Configuration

Item	Description
SyncManager	SM0: Mailbox output SM1: Mailbox input SM2: Process data outputs SM3: Process data inputs
FMMU	FMMU0: Mapped to process data output (RxPDO) area FMMU1: Mapped to process data input (TxPDO) area FMMU2: Mapped to mailbox status
Process data	Fixed PDO mapping
Mailbox(CoE)	SDO request, SDO response, SDO complete access
Synchronization	SM-synchronous, DC-synchronous
LED indicators	NET status (green LED) and NET port activity (yellow LED)

2.1 EtherCAT Introduction

2.1.1 EtherCAT State Machine (ESM)

The EtherCAT State Machine (ESM) coordinates with both the master and slave during start-up and operation. The interactions between the master and slave result in changes of states, which are related to writes that are made to the application layer control word: AL Ctrl (0x0120) (see Figure 3).

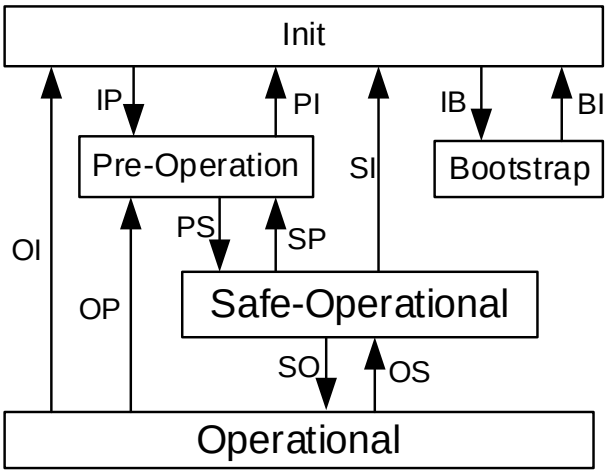


Figure 3: EtherCAT State Machine

Upon the initialization of the data layer and application layer, the ESM enters the initialization (Init) state, which defines the root of the communication relationship between the master and slave in the application layer. In the application layer, there is no direct communication between the master and slave. The master uses the Init state to initialize a configuration register and to set and configure the sync manager.

If the slave supports the optional mailbox and the mailbox settings have been completed, the pre-operational state can be entered. Both the master and slave can use the mailbox and the appropriate protocols to exchange application-specific initializations and parameters. No process data communication is possible in this state.

If the input buffer settings are complete, the safe-operational state can be entered. The slave supports the inputs, while the master requests inputs. The slave applications deliver actual input data without processing the output data. Meanwhile, the slave's real outputs are set to their safe state.

If the output buffer settings are complete and the actual outputs have been delivered to the slave, the operational state can be entered. The slave application delivers the actual input data, and the application of the master provides the output data.

The bootstrap state enables the slave to accept persistent settings that are downloaded with the File over EtherCAT (FoE) protocol. Note that this feature is not supported by this motor driver module.

Operating the connected slaves requires prior initialization from the master via the ESM. Within the ESM, transitions between certain states must follow a given scheme, and are initiated by the master. The slave itself must not execute any transition.

2.1.2 Distributed Clock (DC)

In applications with spatially distributed processes requiring simultaneous actions, such as applications in which multiple servo axes execute coordinated movements, exact synchronization is vital.

In contrast to completely synchronous communication, in which the quality suffers immediately from communication errors, distributed synchronized clocks have a high degree of tolerance for jitter in the communication system.

To ensure synchronicity, the propagation delay must be measured and compensated for each field device. This delay can be measured during network start-up or it can be continuously measured during operation, ensuring that the clocks are simultaneous and operate within 1µs of each other.

This feature is critical in motion control systems that use synchronous cyclic modes. The command is updated every cycle. If the communication period has a large jitter, the motor velocity may not be smooth.

2.1.3 CANopen over EtherCAT (CoE)

CANopen over EtherCAT (CoE) is a commonly used mailbox protocol to read/write to the object dictionary. For more information about CANopen and the object dictionary, refer to the CiA DS301 (Application Layer and Communication Profile) standard.

The SDO request, SDO response, and SDO complete access are supported.

Figure 4 on page 14 shows the application layer structure.

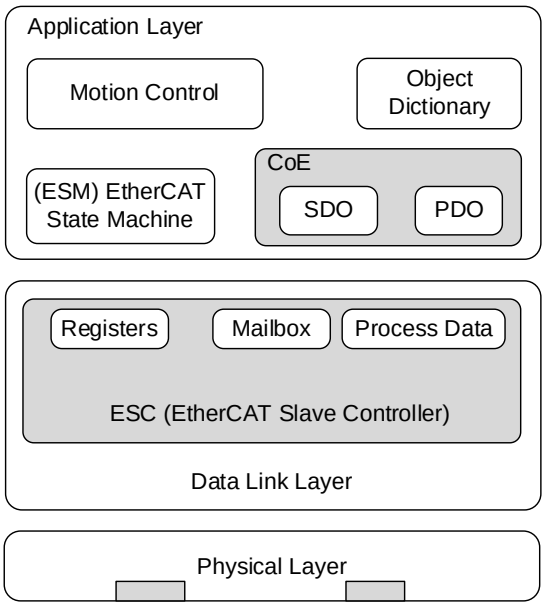


Figure 4: Communication Model

2.1.4 Process Data (PDO)

Process data (PDO) is used for real-time data transitions. Process data uses the producer-consumer communication model. There are two types of process data:

1. Reception PDO (RPDO) is produced by the master to send control commands to slaves.
2. Transmission PDO (TPDO) is produced by the slave to report slave status and other information.

There are four groups of PDO that can be selected according to the operation mode. The RPDO mapped objects are defined by objects 1600h~1603h, and the TPDO mapped objects are defined by objects 1A00h~1A03h. The actual PDO used to exchange data can be configured with object 1C12h and object 1C13h.

Table 3, as well as Table 4 on page 15, list the mapped objects for each PDO.

Table 3: RPDO Mapped Objects

PDO Object Index	Sub-Index	Entry Value	Description
1600h	01h	60400010h	Control word
	02h	60710010h	Target torque
	03h	607A0020h	Target position
	04h	60980010h	Homing method
	05h	60990120h	Homing speed switch
	06h	60990220h	Homing speed zero
	07h	609A0020h	Homing acceleration
	08h	60FE0020h	Physical outputs
	09h	60FF0020h	Target velocity
	0Ah	60600010h	Operation modes
1601h	01h	60400010h	Control word
	02h	607A0020h	Target position
1602h	01h	60400010h	Control word
	02h	60FF0020h	Target velocity

1603h	01h	60400010h	Control word
	02h	60600010h	Operation modes
	03h	607A0020h	Target position
	04h	60FF0020h	Target velocity
	05h	60B20010h	Torque offset
	06h	20800620h	Current limit
	07h	20800120h	K_P
	08h	20800220h	K_I
	09h	20800320h	K_D

Table 4: TPDO Mapped Objects

PDO Object Index	Sub-Index	Entry Value	Description
1A00h	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60640020h	Actual position value
	04h	606C0020h	Actual velocity value
	05h	60610010h	Operation modes display
	06h	60770010h	Actual torque value
	07h	60FD0020h	Digital inputs
1A01h	01h	60410010h	Status word
	02h	60640020h	Actual position value
1A02h	01h	60410010h	Status word
	02h	606C0020h	Actual velocity value
1A03h	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60610010h	Operation mode display
	04h	200E0210h	Actual current value
	05h	60640020h	Actual position value
	06h	606C0020h	Actual velocity value
	07h	200E0510h	Actual torque value
	08h	20400010h	Board temperature
	09h	20810110h	Motor temperature

2.1.5 Network Connection

An EtherCAT network can support up to 65535 devices. The network structure is flexible and supports line, bus, tree, and star topologies. Each motor driver module with an EtherCAT interface has two EtherCAT ports: one for the input and one for the output. This means that different slaves can be connected in a line without additional hubs (see Figure 5). Hubs can be used to achieve tree, star, or other topologies.

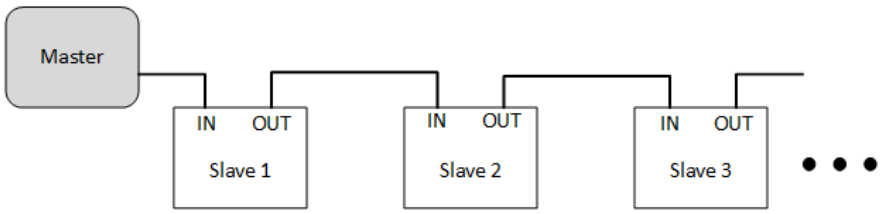


Figure 5: EtherCAT Line Topology

2.1.6 EtherCAT Slave Information (ESI)

For each EtherCAT slave, the slave information is saved in an XML file called the EtherCAT slave information (ESI) file. The ESI file is used by an EtherCAT configuration tool to generate the EtherCAT network information (ENI).

2.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1600h	00h	Number of mapped objects	RO	No	UINT8	-	-	0Bh
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60710010h
	03h	Mapped object 3	RO	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	RO	No	UINT32	-	-	60980010h
	05h	Mapped object 5	RO	No	UINT32	-	-	60990120h
	06h	Mapped object 6	RO	No	UINT32	-	-	60990220h
	07h	Mapped object 7	RO	No	UINT32	-	-	609A0020h
	09h	Mapped object 8	RO	No	UINT32	-	-	60FE0020h
	09h	Mapped object 9	RO	No	UINT32	-	-	60FF0020h
	0Ah	Mapped object 10	RO	No	UINT32	-	-	60600010h
1601h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	607A0020h
1602h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60FF0020h
1603h	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60600010h
	03h	Mapped object 3	RO	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	RO	No	UINT32	-	-	60FF0020h
	05h	Mapped object 5	RO	No	UINT32	-	-	60B20010h
	06h	Mapped object 6	RO	No	UINT32	-	-	20800620h
	07h	Mapped object 7	RO	No	UINT32	-	-	20800120h
	08h	Mapped object 8	RO	No	UINT32	-	-	20800220h
	09h	Mapped object 9	RO	No	UINT32	-	-	20800320h
1A00h	00h	Number of mapped objects	RO	No	UINT8	-	-	0Ah
	01h	Mapped object 1	RO	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60410010h
	03h	Mapped object 3	RO	No	UINT32	-	-	60640020h
	04h	Mapped object 4	RO	No	UINT32	-	-	606C0020h
	05h	Mapped object 5	RO	No	UINT32	-	-	60610010h
	06h	Mapped object 6	RO	No	UINT32	-	-	60770010h
	07h	Mapped object 7	RO	No	UINT32	-	-	60FD0020h
1A01h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60410010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60640020h
1A02h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60410010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60640020h
1A03h	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	Mapped object 1	RO	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60410010h
	03h	Mapped object 3	RO	No	UINT32	-	-	60610010h
	04h	Mapped object 4	RO	No	UINT32	-	-	200E0210h
	05h	Mapped object 5	RO	No	UINT32	-	-	60640020h
	06h	Mapped object 6	RO	No	UINT32	-	-	606C0020h
	07h	Mapped object 7	RO	No	UINT32	-	-	200E0510h
	08h	Mapped object 8	RO	No	UINT32	-	-	20400010h
	09h	Mapped object 9	RO	No	UINT32	-	-	20810110h
1C12h	00h	SyncManager 2 assigned object	RW	No	UINT16	-	-	1600h

1C13h	00h	SyncManager 3 assigned object	RW	No	UINT16	-	-	1A00h

Section 3. Operational Mode

3.1 State Machine

3.1.1 Function Description

The driver module uses a finite state machine to manage the motor controller's state transitions. The state changes according to the current state, control word or local signals, and fault signals. Figure 6 shows the finite state automation diagram.

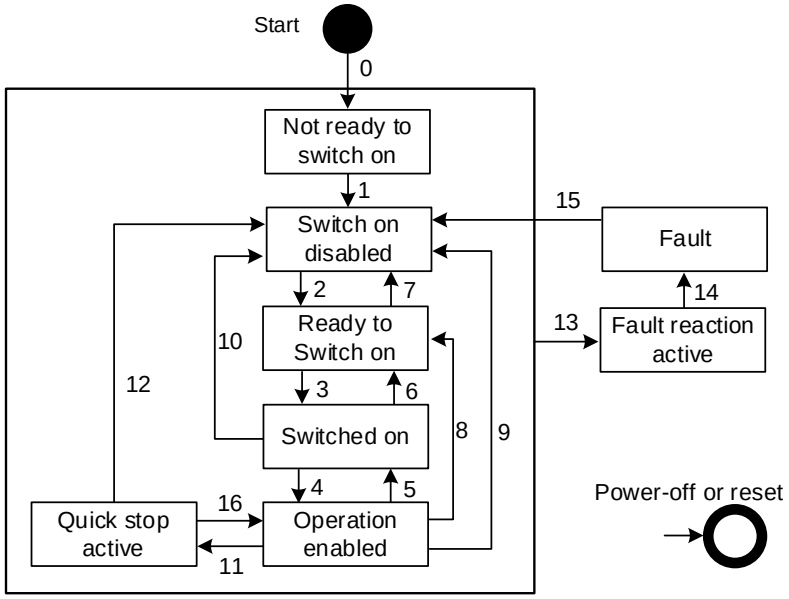


Figure 6: Finite State Automation

Table 5 lists the transition event and actions.

Table 5: Transition Events and Actions

Transition	Event(s)	Action(s)
0	Automatic transition after start-up or reset	Perform self-initialization and self-test
1	Automatic transition	Communication is activated
2	Shutdown command	None
3	Switch on command	Power stage switch on
4	Enable operation command	Drive function is enabled
5	Disable operation command	Drive function is disabled
6	Shutdown command	Motor is free to rotate
7	Quick stop command	None
8	Shutdown command	Motor is free to rotate
9	Disable voltage command	Motor is free to rotate
10	Disable voltage command or quick stop command	Motor is free to rotate
11	Quick stop command	The quick stop function is started
12	Disable voltage command or quick stop finished	Power stage switch off
13	Fault signal	Fault reaction function is executed
14	Automation transition	Drive function is disabled
15	Fault reset command	Leave fault status if no fault exists
16	Enable operation command	Drive function is enabled

Table 6 on page 19 lists the relationship between events and "Control word".

Table 6: Command Coding

Command	Bits of "Control Word"					Transitions
	Bit[7]	Bit[3]	Bit[2]	Bit[1]	Bit[0]	
Shutdown	0	X	1	1	0	2, 6, 8
Switch on	0	0	1	1	1	3
Switch on + enable operation	0	1	1	1	1	3 + 4 (1)
Disable voltage	0	X	X	0	X	7, 9, 10, 12
Quick stop	0	X	0	1	X	7, 10, 11
Disable operation	0	0	1	1	1	5
Enable operation	0	1	1	1	1	4, 16
Fault reset	↑	X	X	X	X	15

Note:

1) The automatic transition to the enable operation state is made after executing the "switch on" state.

After start-up, the state transition function to switch on is disabled. Writing 0x0006 to "Control word" (the shutdown command) causes the state to advance to the "ready to switch on" state. Then writing 0x000F to "Control word" (the switch on + enable operation) causes the state to advance to the "enable operation" state, and the motor operates according to the set operation mode.

If the motor is in a fault state and there are no additional errors, then a rising edge on "Control word", bit[7] returns the system to the "switch on disabled" state.

3.1.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	RW	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-

3.2 Profile Position Mode

3.2.1 Function Description

Profile position mode accepts the user's target position command and profile parameters. The trajectory generator automatically generates a position curve according to the profile parameters. The profile velocity, profile acceleration, and profile deceleration can be changed before a new set point is updated. Figure 7 shows the overall structure for this mode.

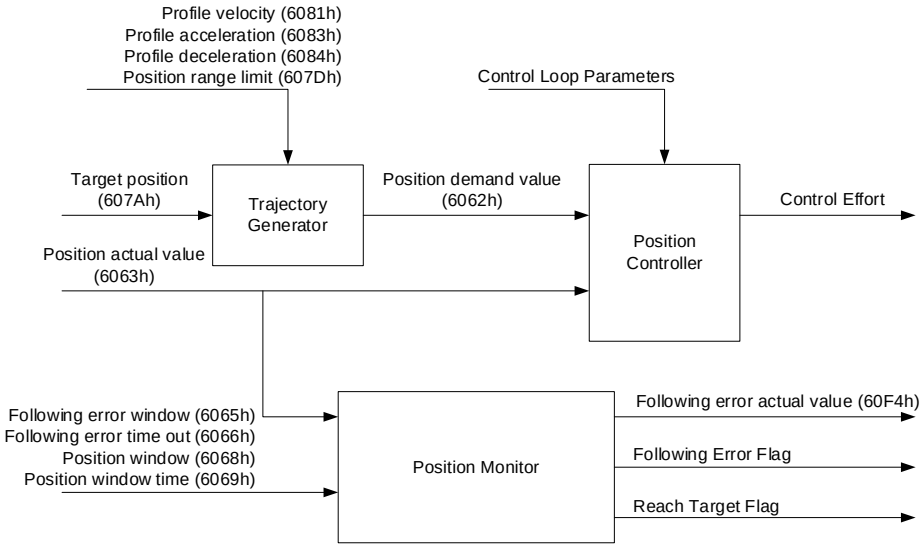


Figure 7: Profile Position Mode Block Diagram

The driver module uses a trapezoidal profile, with the acceleration and deceleration constant between two set points (see Figure 8).

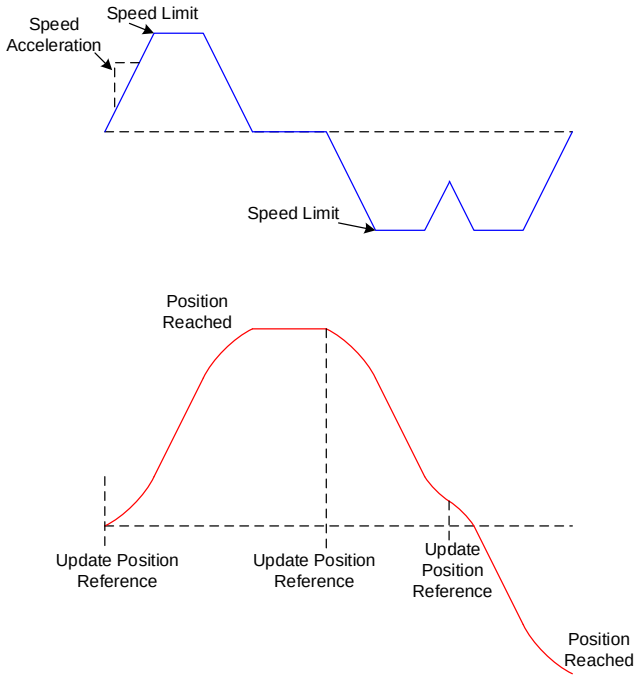


Figure 8: Profile Position Trajectory Generator

If the profile velocity (6081h) has not been reached and there is enough distance left for the motor to decrease the velocity and stop, the motor increases the velocity using the profile acceleration object (6083h). When the velocity reaches the profile velocity, the motor limits the velocity at that value. When the trajectory generator block detects that the remaining distance is not sufficient for the motor to decrease the velocity using the profile deceleration object (6084h), then the motor velocity decreases so that the velocity is zero once the position is reached.

If a new position command is given while the motor speed is decreasing, the trajectory generator increases the motor speed again to make the motor reach the target position as soon as possible.

3.2.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6062h	00h	Position demand value	RO	TPDO	INT32	INC	INT32	-
6063h	00h	Actual internal position value	RO	TPDO	INT32	INC	INT32	-
6064h	00h	Actual position value	RO	TPDO	INT32	INC	INT32	-
6065h	00h	Following error window	R/W	No	UINT32	INC	UINT32	182
6066h	00h	Following error timeout	R/W	No	UINT32	ms	UINT32	10
6067h	00h	Position window	R/W	No	UINT32	INC	UINT32	182
6068h	00h	Position window time	R/W	No	UINT16	ms	UINT32	10
607Ah	00h	Target position	R/W	Yes	INT32	INC	INT32	0
607Dh	01h	Min position range limit	R/W	No	INT32	INC	INT32	-2^{31}
	02h	Max position range limit	R/W	No	INT32	INC	INT32	$2^{31} - 1$
6081h	00h	Profile velocity	R/W	No	UINT32	INC/s	UINT32	655360
6083h	00h	Profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800

6084h	00h	Profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
6086h	00h	Motion profile type	R/W	No	INT16	-	0	0
60F4h	00h	Follow error actual value	RO	TPDO	INT32	INC	INT32	-

3.2.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6		Absolute/relative mode	0: Absolute position mode 1: Relative position mode					
5		Reserved	Unused					
4		New set point	The rising edge of this bit updates the new target position and profile parameters.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; DC power is always enabled.					
0		Switch on	Enable power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:14		Reserved	Unused.					
13		Set point acknowledge	1: A new set point is allowed 0: The previous set point still in process					
12		Following error	1: The position following error is too large 0: The position following error is within the set range					
11		Internal limit active	If position limit is reached, this is set.					
10		Target reached	0: Target not reached (if Halt equals 0); axis deceleration (if Halt equals 1) 1: Target reached (if Halt equals 0); velocity axis is 0 (if Halt equals 1)					
9		Remote	If set, the parameters may be modified by communication. This bit is always 1.					
8		Reserved	Reserved.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	Sets the switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always set to 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

3.2.4 Simple Example

Move the motor to position 10 revolutions and 0 degrees, then move the motor to 20 revolutions and 0 degrees at the profile position mode.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x01	Set mode to profile position mode.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on + enable operation command.
4	607Ah-00h	0x000A0000	Set target position to 10 rounds and 0 degrees.
5	6040h-00h	0x001F	New set point active.
6	6041h-00h	bit 10	Check target reach flag.
7	607Ah-00h	0x00140000	Set target position to 20 rounds and 0 degrees.
8	6040h-00h	0x000F	Clear new set point active bit.
9	6040h-00h	0x001F	New set point active.

3.3 Homing Mode

3.3.1 Function Description

Homing mode is used to find the home position (also called the datum, reference point, or zero point). There are various methods to achieve this using a limit switch at the end of travel, or a home switch (zero-point switch) in the middle of travel. Most of the methods also use the index (zero) pulse from an angle sensor (see Figure 9).

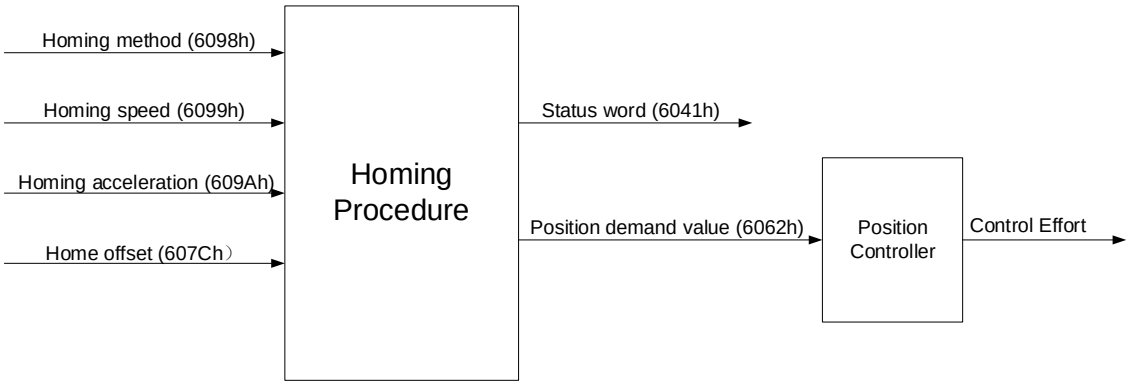


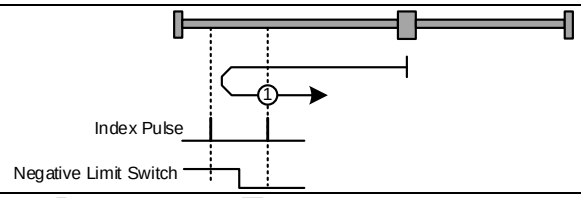
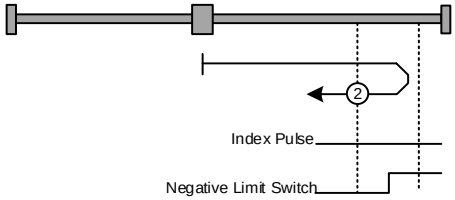
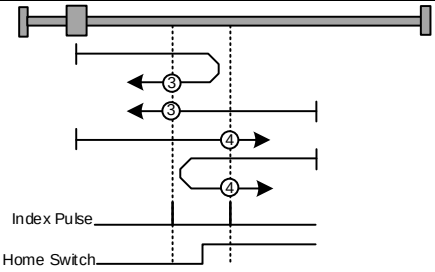
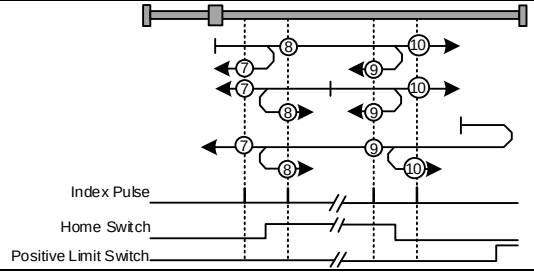
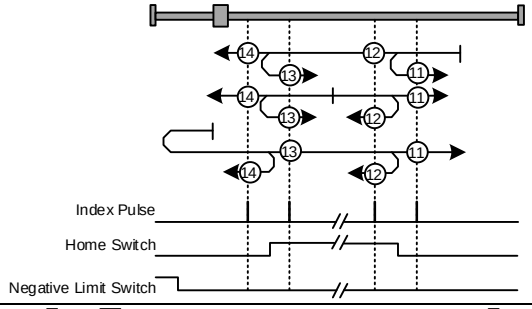
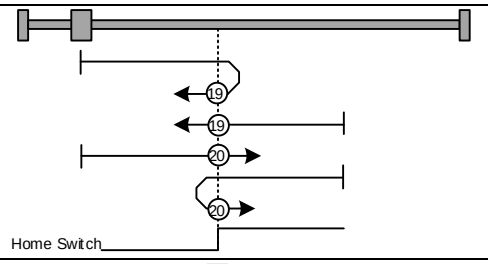
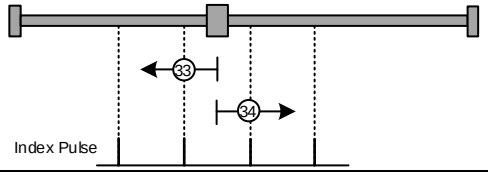
Figure 9: Homing Mode Block Diagram

The user should specify the speed, acceleration, and homing method. There are two homing speeds; typically, the faster speed is used to find the home switch (homing speed switch), and the slower speed is used to find the index pulse (homing speed zero).

The controller supports methods 1–14, methods 17–30, method 33, and method 34, as defined in the CiA DSP 402 standard. In addition, the controller also supports homing with torque limit methods. Table 7 lists the description and diagram for each method.

Table 7: Homing Methods

Method	Description	Diagram
-3	Homing clockwise with limited torque.	These two methods allow for homing without a limit switch or home switch. The motor goes in one direction until it reaches the mechanical range limit. The motor output torque is limited with the homing torque settings (object 2070h).
-2	Homing counterclockwise with limited torque.	

1	Homing on the negative limit switch and index pulse.	
2	Homing on the positive limit switch and index pulse.	
3, 4	Homing on the positive home switch and index pulse.	
7–10	Homing on the home switch and index pulse (positive initial motion).	
11–14	Homing on the home switch and index pulse (negative initial motion).	
17–30	These methods are similar to methods 1–14 except that the home position is not dependent on the index pulse. It is only dependent on the relevant home or limit switch transitions. For example, methods 19 and 20 are similar to methods 3 and 4.	
33, 34	Homing on the index pulse.	

3.3.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
2071h	02h	Homing time	R/W	No	UINT16	ms	UINT16	500
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
607Ch	00h	Home offset	R/W	No	INT32	INC	INT32	0
6098h	00h	Homing method	R/W	No	INT8	-	-3 to +35	1
6099h	01h	Homing speed switch	R/W	No	UINT32	INC/s	UINT32	655360
	02h	Homing speed zero	R/W	No	UINT32	INC/s	UINT32	65536
609Ah	00h	Homing acceleration	R/W	No	UINT32	INC/s^2	UINT32	0

3.3.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:5		Reserved	Unused.					
4		Homing operation	1: Homing operation enabled 0: Homing operation disabled					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:14		Reserved	Unused.					
13		Homing error	1: A homing error has occurred 0: No homing error has occurred					
12		Homing attained	1: Homing is complete 0: Homing has not started (or in progress)					
11		Internal limit active	1: Internal limit is reached 0: Internal limit not reached					
10		Target reached	If the set point is reached, this bit is set.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, the driver is at the switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

3.3.4 Simple Example

For this example, homing the motor is accomplished using the homing method 1.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x06	Set to homing mode.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on + enable operation command.
4	8098h-00h	0x01	Set homing method to 1.
4	6099h-01h	0x00020000	Set homing speed switch to 120rpm.
5	6099h-02h	0x00010000	Set homing speed switch to 60rpm.
6	609Ah-00h	0x00320000	Set homing acceleration to 3000rpm/s.
7	6040h-00h	0x001F	Enable homing operation.

3.4 Profile Velocity Mode

3.4.1 Function Description

In profile velocity mode, the user can set the profile velocity, profile acceleration, and profile deceleration. The controller automatically generates a smooth velocity curve. The velocity demand value generated by the trajectory generator goes to the velocity controller, and the controller performs closed-loop speed control.

The velocity monitor block monitors when the speed reaches the target and the motor speed zero status. This block sets the corresponding bits in the status word.

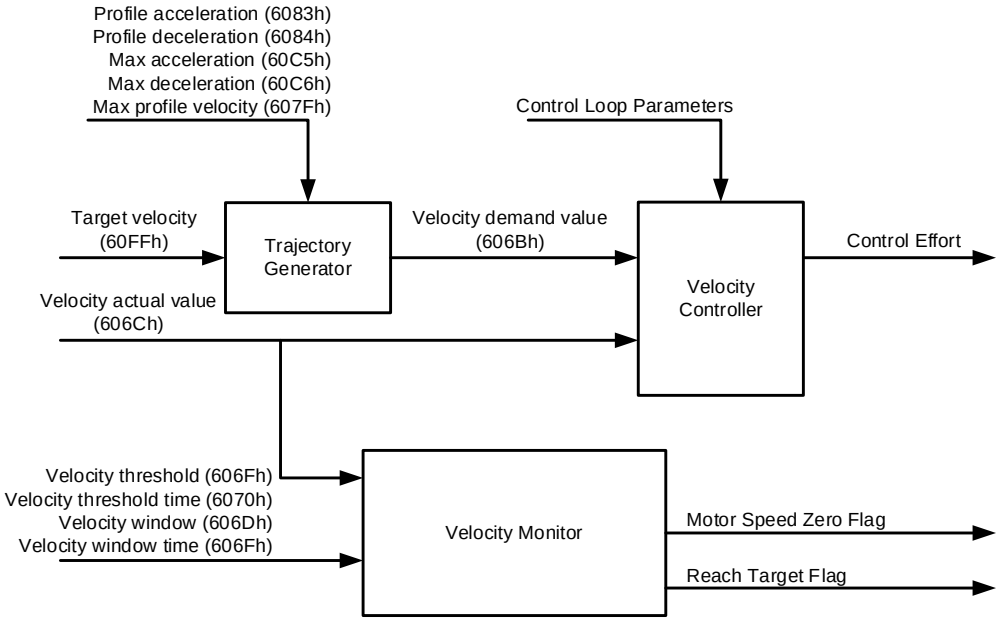


Figure 10: Profile Velocity Mode

A trapezoidal profile is supported (see Figure 11 on page 26). If the actual velocity value is below the target velocity after a new speed command is sent to the controller, the motor speed decreases. Otherwise, the motor speed increases.

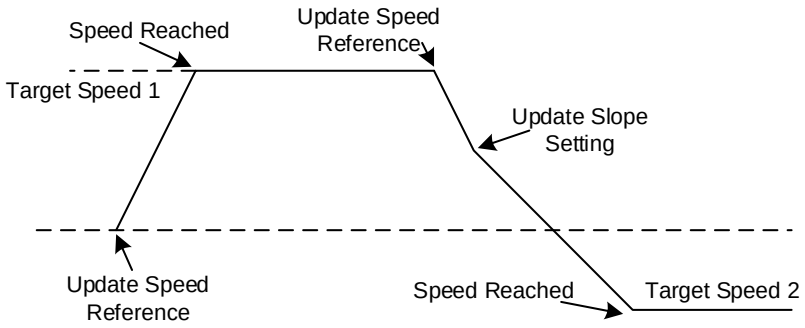


Figure 11: Trapezoidal Speed Profile

3.4.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
606Bh	00h	Velocity demand value	RO	TPDO	INT32	INC/s	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
606Dh	00h	Velocity window	R/W	No	UINT16	INC/s	UINT16	65536
606Eh	00h	Velocity window time	R/W	No	UINT16	ms	UINT16	10
606Fh	00h	Velocity threshold	R/W	No	UINT16	INC/s	UINT16	65536
6070h	00h	Velocity threshold time	R/W	No	UINT16	ms	UINT16	10
6083h	00h	Profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
6084h	00h	Profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
60C5h	00h	Max acceleration	R/W	No	UINT32	INC/s^2	UINT32	$2^{32} - 1$
60C6h	00h	Max deceleration	R/W	No	UINT32	INC/s^2	UINT32	$2^{32} - 1$
60FFh	00h	Target velocity	R/W	Yes	IN32	INC/s	INT32	0

3.4.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:13		Reserved	Unused.					
12		Zero speed	1: Speed is equal to zero 0: Speed is not equal to zero					
11		Internal limit active	If the internal limit is reached, this bit is set.					
10		Target reached	0: Target not reached (if Halt equals 0); axis deceleration (if Halt equals 1) 1: Target reached (if Halt equals 0); velocity axis is 0 (if Halt equals 1)					
9		Remote	If set, parameters may be modified by communication.					

8	Reserved	Unused.
7	Warning	0: No warning 1: Warning
6	Switch on disabled	If set, the driver is in switch on disabled state.
5	Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)
4	Voltage enabled	Always 1. A high voltage is applied to the drive.
3	Fault	If a fault occurs, this bit is set.
2	Operation enabled	Operation enabled mode is entered.
1	Switch on	The driver switch is on.
0	Ready to switch on	The driver is ready to switch.

3.4.4 Simple Example

Set the motor velocity to 1000rpm in profile velocity mode.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x03	Set the mode to profile velocity mode.
2	6040h-00h	0x0006	Shutdown command.
3	60FFh-00h	0x0010AAAB	Set the target speed to 1000rpm.
4	6083h-00h	0x00320000	Set the profile acceleration to 3000rpm/s.
5	6084h-00h	0x00320000	Set the profile deceleration to 3000rpm/s.
6	6040h-00h	0x000F	Switch on + enable operation command.

3.5 Profile Torque Mode

3.5.1 Function Description

The profile torque mode allows the control device to command the target torque value, which is processed by the trajectory generator. The torque slope and maximum torque are required for the torque trajectory generator.

Figure 12 shows the profile torque mode block diagram. The trajectory generator calculates the torque demand value according to the profile parameter, then sends the value to the torque controller block. The torque controller performs closed-loop torque control according to the torque's demand value and torque's actual value.

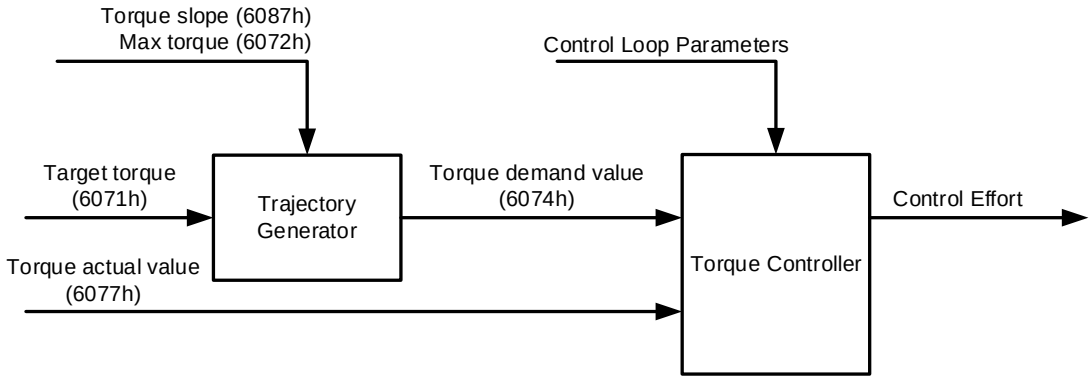


Figure 12: Profile Torque Mode Functional Block

3.5.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	RW	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	100
6072h	00h	Max torque	R/W	NO	UINT16	‰	0 to 3000	3000
6073h	00h	Max current	R/W	NO	UINT16	‰	0 to 3000	3000
6074h	00h	Torque demand value	RO	TPDO	INT16	‰	-3000 to +3000	-
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
6078h	00h	Current actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
6087h	00h	Torque slope	R/W	NO	UINT32	‰/s	UINT32	3000
6088h	00h	Torque profile type	R/W	NO	INT16	-	0	0

3.5.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:12		Reserved	Unused.					
11		Internal limit active	If the internal limit is reached, this bit is set.					
10		Target reached	0: Target not reached (if Halt equals 0); axis deceleration (if Halt equals 1) 1: Target reached (if Halt equals 0); velocity Axis is 0 (if Halt equals 1)					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, the driver is in switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

3.5.4 Simple Example

Run the motor at profile torque mode with 100‰ target torque.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x04	Set the mode to profile torque mode.
2	6072h-00h	0x0BB8	Set the max torque to 3000‰.
3	6087h-00h	0x000003E8	Set the torque slope to 1000‰/s.
4	6071h-00h	0x0064	Set the target torque to 100‰.
5	6040h-00h	0x0006	Shutdown command.
6	6040h-00h	0x000F	Switch on + enable operation command.

3.6 Cyclic Synchronous Position Mode

3.6.1 Function Description

In cyclic synchronous position mode, the trajectory generator is located in the control device. The controller provides a target position to the drive device. The additional velocity and torque values can be provided by the control system to allow for velocity and torque feed-forward. Figure 13 shows the controller block diagram.

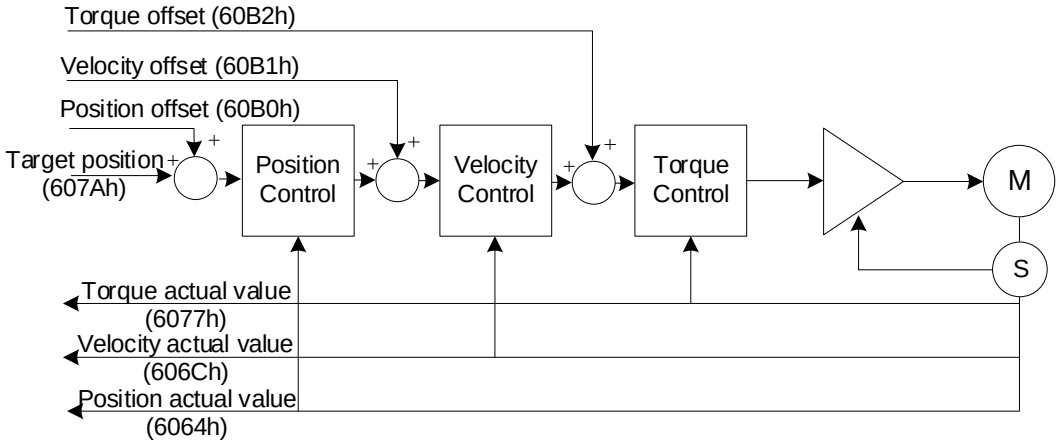


Figure 13: Cyclic Synchronous Position Mode Block Diagram

In this mode, the target position is interpreted as an absolute value.

If the following error exceeds the following error window (6065h) for longer than the following error time out (6066h), an error is triggered and “Status word” (6041h), bit[13] is set.

3.6.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6063h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
6065h	00h	Following error window	R/W	No	UINT32	INC	UINT32	182
6066h	00h	Following error time out	R/W	No	UINT32	ms	UINT32	10
607Ah	00h	Target position	R/W	Yes	INT32	INC	INT32	0
607Dh	01h	Min position limit	R/W	No	INT32	INC	INT32	-2^{31}
	02h	Max position limit	R/W	No	INT32	INC	INT32	$2^{31} - 1$
60B0h	00h	Position offset	R/W	RPDO	INT32	INC	INT32	0
60B1h	00h	Velocity offset	R/W	RPDO	INT32	INC/s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0

60B2h	01h	Interpolation time period value	R/W	No	UINT8	-	1 to 255	1
	02h	Interpolation time index	R/W	No	INT8	-	-4 to -3	-3
60F4h	00h	Follow error actual value	RO	TPDO	INT32	INC	INT32	-

3.6.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:14		Reserved	Unused.					
13		Following error	1: No following error 0: Following error					
12		Target accepted	1: Target position is used as the input to position control loop 0: Target position ignored					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Target reached	Reserved in cyclic synchronous mode.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, in a switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. A high voltage is applied to the drive.					
3		Fault	If fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

3.7 Cyclic Synchronous Velocity Mode

3.7.1 Function Description

Similar to cyclic synchronous positon mode, the motion controller sends velocity commands (and other commands) periodically. In cyclic synchronous velocity mode, the controller provides a target velocity to the motor driver module, which performs velocity control and torque control. Optionally, additive velocity and torque values can be provided by the controller to enable a second source for velocity and torque feed-forward.

Figure 14 shows the controller block diagram.

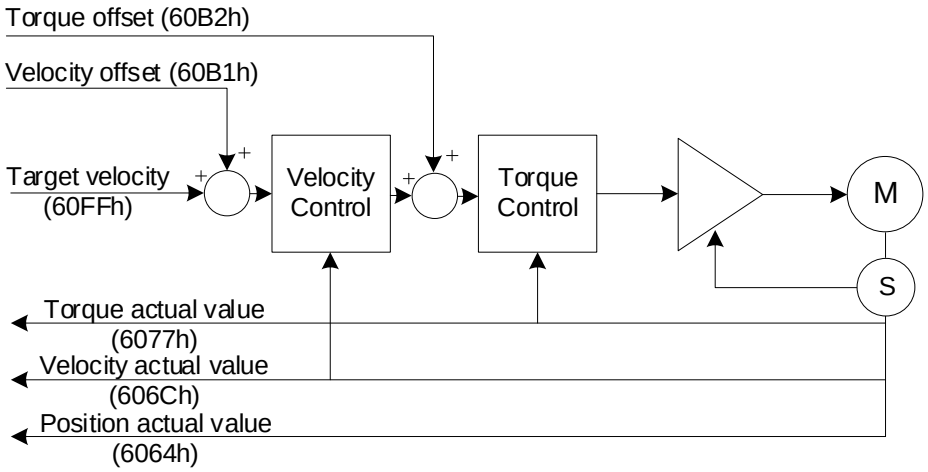


Figure 14: Cyclic Synchronous Velocity Mode Block Diagram

The interpolation time period object (60C2h) defines the time period between two updates of the target velocity, and is used for intercycle interpolation.

3.7.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6063h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
60B1h	00h	Velocity offset	R/W	RPDO	INT32	INC/s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
60FFh	00h	Target velocity	R/W	Yes	IN32	INC/s	INT32	0

3.7.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:13		Reserved	Unused.					
12		Target accepted	1: Target position is used as input to position control loop 0: Target position ignored					

11	Internal limit active	If the position limit is reached, this bit is set.
10	Reserved	Unused.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Unused.
7	Warning	0: No warning 1: Warning
6	Switch on disabled	If set, then in a switch on disabled state.
5	Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)
4	Voltage enabled	Always 1. A high voltage is applied to the drive.
3	Fault	If a fault occurs, this bit is set.
2	Operation enabled	Operation enabled mode is entered.
1	Switch on	The driver switch is on.
0	Ready to switch on	The driver is ready to switch.

3.8 Cyclic Synchronous Torque Mode

3.8.1 Function Description

In cyclic synchronous torque mode, the motion controller provides a target torque to the motor driver module that performs torque control. Optionally, an additive torque value can be provided by the motion controller in order to allow a second source of torque. Figure 15 shows the block diagram.

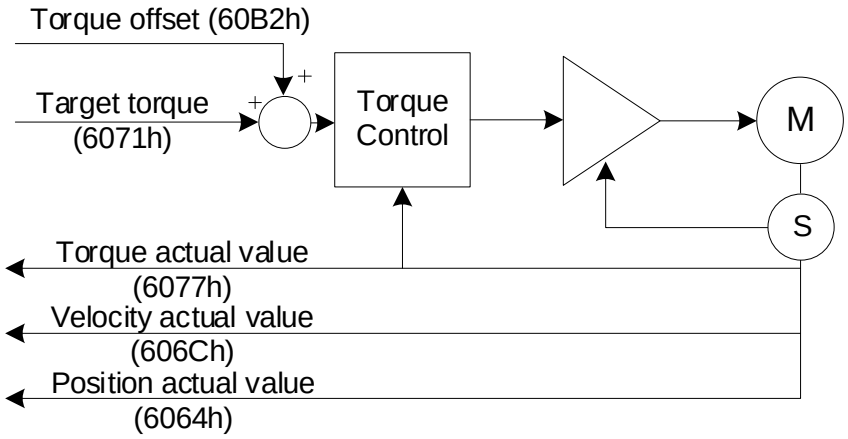


Figure 15: Cyclic Synchronous Torque Mode Block Diagram

The interpolation time period object (60C2h) defines the time period between two updates of the target velocity and is used for intercycle interpolation.

To ensure safe operation in this mode, the motor speed is limited by Torque loop speed limit (object 2005h, sub-index 08h).

3.8.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6063h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0

6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	0

3.8.3 Use of "Control Word" and "Status Word"

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:13		Reserved	Unused.					
12		Target accepted	1: Target position is used as input for position control loop 0: Target position ignored					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Reserved	Unused.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, in a switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

3.9 Impedance Control Mode

3.9.1 Function Description

In robot applications, both the motion of the robot and its contact force must be controlled. Traditional three-loop structures can achieve precise torque, velocity, or position control. However, these structures cannot control the contact force simultaneously.

To achieve impedance control, the driver module implements an impedance controller (see Figure 16 on page 34). The control loop parameters (K_P, K_I, and K_D) are mapped to RPDO, so they can be updated in real time. Changing different loop parameters can obtain different mechanical impedances that allow the robot complete different tasks. This provides more flexibility for the robot's joint control.

Torque offset is the torque feed-forward value that can be added directly to the controller output, which is also the current loop input. This compensates for the motor output torque in certain situations. For example, the robot's weight may need to compensated. The torque offset value can be calculated according to the robot's status, and then inputted to the controller.

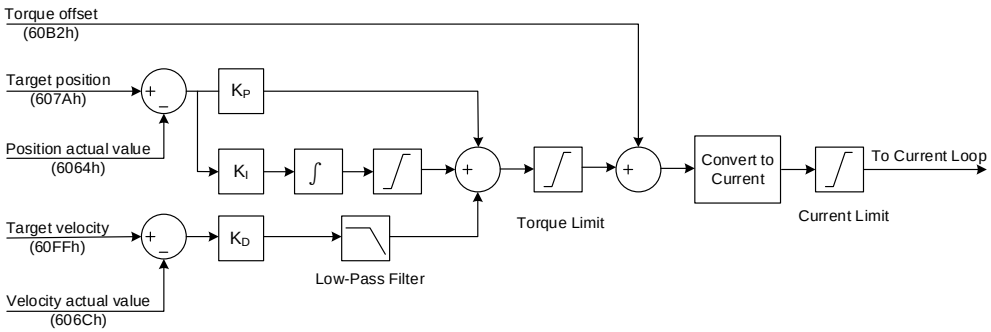


Figure 16: Impedance Controller Block Diagram

3.9.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	01h	K_P	R/W	RPDO	REAL32	-	-	0
	02h	K_I	R/W	RPDO	REAL32	-	-	0
	03h	K_D	R/W	RPDO	REAL32	-	-	0
	04h	Filter cutoff frequency	R/W	No	REAL32	Hz	-	1000
	05h	Joint torque limit	R/W	No	REAL32	Nm	-	0
	06h	Motor current limit	R/W	RPDO	REAL32	A	-	0
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6063h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0

3.9.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:13		Reserved	Unused.					
12		Target accepted	1: Target position shall be used as input to position control loop 0: Target position ignored					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Reserved	Unused.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					

6	Switch on disabled	In switch on disabled state if set.
5	Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)
4	Voltage enabled	Always 1. High voltage is applied to the drive.
3	Fault	If fault happened, this bit is set.
2	Operation enabled	Operation enabled mode is entered.
1	Switch on	The driver switch is on.
0	Ready to switch on	The driver is ready to switch.

Section 4. Advanced Functions

4.1 Parameter Identification

4.1.1 Function Description

To make the motor controller simple and easy to use, this solution implements parameter identification and loop auto-tuning. Users only need to few basic motor and driver parameters (i.e. rated voltage, rated current, rated speed, pole pairs, and current-sense gain). The driver module identifies other parameters (e.g. motor phase resistance, phase inductance, friction ratio, and load inertia). Based on the identified parameters, the controller calculates the appropriate loop parameters that optimize the dynamic response and system noise.

A range-limited parameter identification function is provided to ensure that the solution is suitable for range-limited systems. The total allowed revolutions for the motor and the revolutions used for acceleration and deceleration should be provided. If using unlimited range parameter identification, these parameters are not required.

After several seconds, the motor and system load parameters are identified. Loop control parameters are also updated according to the identified results. Figure 17 shows the block diagram.

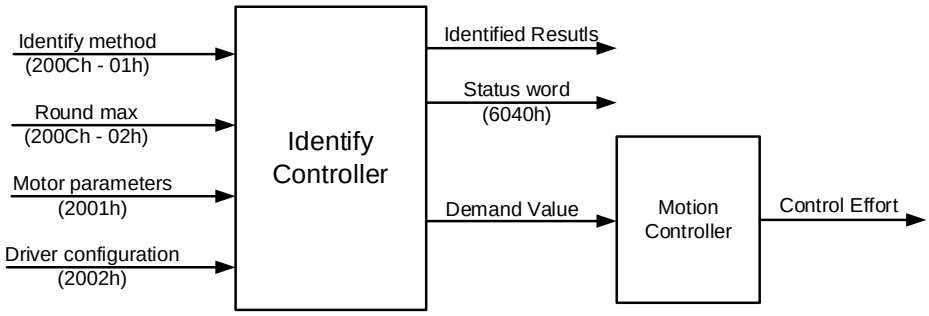


Figure 17: Parameter Identification Block Diagram

4.1.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
2001h	04h	Pole pairs	R/W	No	UINT8	-	UINT8	4
	07h	Rated voltage	R/W	No	UINT32	mV	UINT32	36000
	08h	Rated current	R/W	No	UINT32	mA	UINT32	5000
	09h	Rated speed	R/W	No	UINT32	rpm	UINT32	3000
2002h	02h	Amplifier gain	R/W	No	UINT8	V/V	1 to 100	10
	03h	Current-sense resistor	R/W	No	UINT8	mΩ	1 to 100	10
200Ch	01h	Identify method	R/W	No	UINT8	-	0 to 1	0
	02h	Round max	R/W	No	UINT16	round	3 to 65535	50
	03h	Round acceleration	R/W	No	UINT16	round	1 to 65535	10
	04h	Round J	R/W	No	UINT16	round	1 to 65535	10
	05h	Identification status	RO	No	UINT8	-	-	0
	06h	Identified R_S	RO	No	UINT32	mΩ	-	0
	07h	Identified L_D	RO	No	UINT32	µH	-	0
	08h	Identified L_Q	RO	No	UINT32	µH	-	0
	09h	Identified K_T	RO	No	UINT32	mNm/A	-	0
	0Ah	Identified J	RO	No	UINT32	g x cm^2	-	0
	0Bh	Identified B	RO	No	UINT32	mNm/rad	-	0
	0Ch	Identified T_F	RO	No	UINT32	mNm	-	0

4.1.3 Use of "Control Word" and "Status Word"

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0

Bits	Name	Description
15:12	Reserved	Unused.
11	Enable auto tuning	1: Enabled 0: Disabled
10:9	Reserved	Unused.
8	Halt	Enable halt.
7	Fault reset	Change from 0 to 1 reset the internal fault status.
6:4	Reserved	Unused.
3	Enable operation	Enter operation mode.
2	Quick stop	Enter quick stop mode.
1	Enable voltage	No effect; the DC power is always enabled.
0	Switch on	Enable the power stage switch.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-

Bits	Name	Description
15	Reserved	Unused.
14	Auto tuning status	1: Finished 0: On-going or not started
13:12	Reserved	Unused.
11	Internal limit active	If position limit is reached, this bit is set.
10	Target reached	If the set point is reached, this bit is set.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Unused.
7	Warning	0: No warning 1: Warning
6	Switch on disabled	If set, the driver is in a switch on disabled state.
5	Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)
4	Voltage enabled	Always 1. A high voltage is applied to the drive.
3	Fault	If a fault occurs, this bit is set.
2	Operation enabled	Operation enabled mode is entered.
1	Switch on	The driver switch is on.
0	Ready to switch on	The driver is ready to switch.

4.1.4 Simple Example

Identify the motor and mechanical system parameters with range-limited method. The motor-rated current is 9A, the rated voltage is 36V, the rated speed is 3000rpm, and the pole pairs is 4. For the motor driver, the current-sense resistor is 10mΩ, and the amplifier gain is 10. The maximum allowed motor revolutions is 50, the set acceleration and deceleration revolutions are 10, and the identify inertia revolution is 10.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0xFC	Set the mode to profile torque mode.
2	2001h-04h	0x04	Set the motor pole pairs to 4.
3	2001h-07h	0x00008CA0	Set the rated voltage to 36000mV.
4	2001h-08h	0x00002328	Set the rated current to 9000mA.
5	2001h-09h	0x00000BB8	Set the motor rated speed to 3000rpm.
6	2002h-03h	0x0A	Set the current-sense resistor to 10mΩ.
7	2002h-02h	0x0A	Set the amplifier gain to 10V/V.

8	200Ch-01h	0x01	Set the identify method to the range-limited method.
9	200Ch-02h	0x0032	Set the identify max revolution to 50 revolutions.
10	200Ch-03h	0x000A	Set the identify max acceleration revolutions to 10 revolutions.
11	200Ch-04h	0x000A	Set the identify max inertia revolutions to 10 revolutions.
12	6040h-00h	0x0006	Shutdown command.
13	6040h-00h	0x000F	Switch on + enable operation command.
14	200Ch-05h	Read	Check the identify status.
15	6040h-00h	0x0006	Shutdown command after identification is complete.

4.2 INL Calibration

To improve the integral nonlinearity (INL) of the angle sensor, the controller embeds an INL calibration function with 32 data points, which is stored in the NVM for calibration.

4.2.1 Function Description

To obtain the angle error between the sensor angle and the real mechanical angle, determine the reference angle. The reference can be the position information from the optical encoder connected to the PUL and DIR pins. The driver module controls the motor to 32 points in one mechanical revolution, then records the angle error between the magnet sensor and optical encoder.

It is recommended to perform INL calibration using the MotionLAB software.

Use the driver module to implement the calibration sequence by following the steps below:

1. Connect the optical encoder's A and B signals to the driver module's PUL/DIR pins.
2. Set the mode request to INL Calibration mode and run the motor. The controller moves the motor to 32 equal, divided points of one mechanical revolution and records the error between the optical encoder and angle sensor. Then the INL caibration data is calculated according to the error.
3. Send the store parameters command to save the INL calibration data to the controller's NVM.

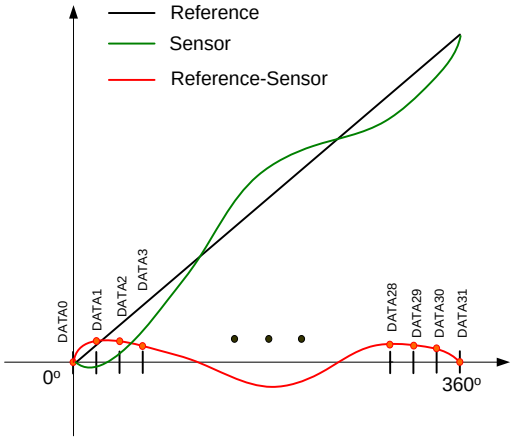


Figure 18: INL Calibration Principle

4.2.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
2003h	05h	INL enable	R/W	No	UINT8	-	0 to 1	0
2010h	01h~20h	INL data 1 to INL data 32	RO	No	INT16	LSB	-	0

4.2.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0

Bits	Name	Description
15:12	Reserved	Unused.
11	Enable	1: Enable INL calibration
10:9	Reserved	Unused.
8	Halt	1: Enable halt 0: Disable halt
7	Fault reset	Change from 0 to 1 to reset the internal fault status.
6:4	Reserved	Unused.
3	Enable operation	Enter operation mode.
2	Quick stop	Enter quick stop mode.
1	Enable voltage	No effect; the DC power is always enabled.
0	Switch on	Enable the power stage switch.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-

Bits	Name	Description
15	Reserved	Unused.
14	INL Status	1: INL calibration complete 0: INL calibration not started or ongoing
13:12	Reserved	Unused.
11	Internal limit active	If the position limit is reached, this bit is set.
10	Target reached	If the set point is reached, this bit is set.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Unused.
7	Warning	0: No warning 1: Warning
6	Switch on disabled	If set, the driver is in switch on disabled state.
5	Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)
4	Voltage enabled	Always 1. High voltage is applied to the drive.
3	Fault	If a fault occurs, this bit is set.
2	Operation enabled	Operation enabled mode is entered.
1	Switch on	The driver switch is on.
0	Ready to switch on	The driver is ready to switch.

4.2.4 Simple Example

For INL calibration, assume that the control parameters are already correctly set.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0xFD	Set the mode to INL calibration mode.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on and enable operation command.
4	6040h-00h	0x080F	Enable INL calibration.
5	6041h-00h	Bit[14]	If INL calibration is complete, check “Status Word”, bit[14].
6	6040h-00h	0x0006	Shutdown command.

4.3 Rotor Alignment

4.3.1 Function Description

To detect the rotor position, attach a magnet at the shaft of the motor (see Figure 19). The magnetic angular sensor embedded in the driver module works as an absolute rotor position sensor. In the FOC algorithm, the electrical angle must be used for the Park and inverse Park transformations. The sensor only detects the magnetic field angle of the magnet attached to the motor shaft, which means that users should first determine the sensor position bias angle compared to the rotor permanent magnet flux.

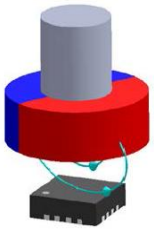


Figure 19: Sensing the Rotor Position

Ensure that the driver module finds the theta bias sequence by following the steps below:

1. Apply a current to the motor windings to generate torque.
2. Drag the rotor to a 300° electrical angle, then read the sensor data 1.
3. Apply a current to the motor windings to generate torque.
4. Drag the rotor to a 60° electrical angle, then read the sensor data 2.
5. Calculate THETA_BIAS and THETA_DIR from sensor data 1 and sensor data 2.
6. Store THETA_BIAS and THETA_DIR to the controller register.

The MotionLAB software provides an automatic theta-bias function. After setting the bias current, send the find theta bias command. The controller should automatically follow the steps below.

4.3.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
2002h	07h	Theta Bias current	R/W	No	UINT16	‰	0 to 3000	500

4.3.3 Use of “Control Word” and “Status Word”

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:12		Reserved	Unused.					
11		Enable rotor alignment	1: Enabled 0: Disabled					
10:9		Reserved	Unused.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Unused.					
3		Enable operation	Enter operation mode.					

2	Quick stop	Enter quick stop mode.
1	Enable voltage	No effect; the DC power is always enabled.
0	Switch on	Enable the power stage switch.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15		Reserved	Unused.					
14		Rotor aligning status	1: Rotor aligning finished 0: Rotor aligning on going or not started					
13:12		Reserved	Unused.					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Target reached	If the set point is reached, this bit is set.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Unused.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, the driver is in switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. High voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

4.3.4 Simple Example

Perform Rotor aligning using 500‰ bias current.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0xFE	Set the mode to rotor aligning mode.
2	2002h-07h	0x01F4	Set the bias current to 500‰ of rated current.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on and enable operation command.
4	6040h-00h	0x080F	Enable INL calibration.
5	6041h-00h	Bit[14]	Check “Status word”, bit[14]; if it is 1, rotor aligning is complete.
6	6040h-00h	0x0006	Shutdown command.

4.4 External I/O Function

In applications that require a simple control interface (i.e. PUL/DIR, PWM/DIR, or A/B input signals), external I/O inputs are provided.

4.4.1 PUL/DIR Control

In PUL/DIR command control mode, the motor works in an incremental position mode similar to a stepper motor. Each rising edge on the PUL input moves the motor by a configurable increment. The number of pulses per revolution is set by Electronic_Gear_Ratio_Numerator and Electronic_Gear_Ratio_Denominator, and is calculated with Equation (1):

Pulses per revolution = 65536 x Electronic_Gear_Ratio_Numerator / Electronic_Gear_Ratio_Denominator (1)

The movement direction is controlled by the DIR input signal. The polarity of the DIR input signal can be selected using “I/O polarity”, bit[4]. If the I/O polarity is non-inverted, a high level on the DIR input moves the motor clockwise.

4.4.2 PWM/DIR Control

In PWM/DIR command control mode, the motor velocity or torque is controlled by the PWM input's duty cycle, while the direction is controlled by the signal on the DIR input.

For profile velocity mode, the real motor speed is the target velocity multiplied by the PWM duty cycle.

For profile torque mode, the real motor torque is the target torque multiplied by the PWM duty cycle.

The PWM signal frequency should be between 100Hz and 10kHz to achieve good adjustment resolution. The DIR input can control the velocity or torque direction. The polarity of the DIR input signal can be selected by "I/O polarity", bit[4]. If I/O polarity is non-inverted, a high level on the DIR pin moves the motor clockwise.

4.4.3 A/B Control

In A/B control mode, quadrature signals can be input to the PUL and DIR inputs. The internal quadrature decoder calculates the target position from the A/B signals.

The number of pulses per revolution is set by Electronic_Gear_Ratio_Numerator and Electronic_Gear_Ratio_Denominator, estimated with Equation (2):

Pulses per revolution = 65536 x Electronic_Gear_Ratio_Numerator / Electronic_Gear_Ratio_Denominator (2)

The moving direction is controlled by the logic of A/B signal (see Figure 20).

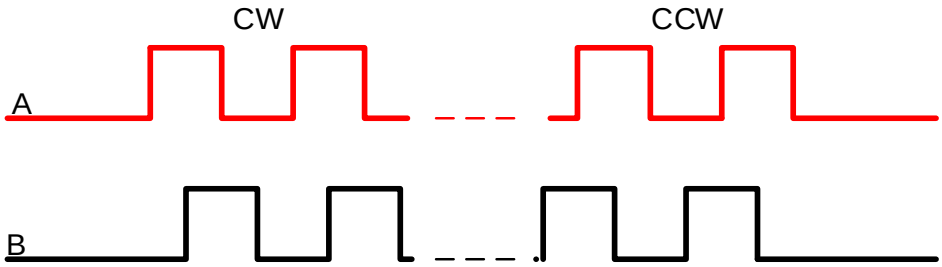


Figure 20: Quadrature Signal Logic

4.4.4 I/O Function

The driver module has two outputs and four inputs to connect external control signals, such as a home switch, a negative switch, a positive switch, and pulse/PWM and direction control signals.

Each I/O has multiple functions that can be selected according to the application requirements. See the Object Details section on page 65 for more information about the I/O function and polarity selection.

If using an optocoupler, the signal may be need to be inverted, as the optocoupler output has an inverted polarity compared to the input.

4.4.5 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	08h	Command type	R/W	No	UINT8	-	0 to 4	0
2030h	01h	I/O 1 function	R/W	No	UINT8	-	0 to 3	0
	02h	I/O 2 function	R/W	No	UINT8	-	0 to 6	0
	03h	I/O 3 function	R/W	No	UINT8	-	0 to 3	0
	04h	I/O 4 function	R/W	No	UINT8	-	0 to 6	0
	05h	I/O 5 function	R/W	No	UINT8	-	0 to 6	0
	06h	I/O 6 function	R/W	No	UINT8	-	0 to 3	0
	07h	I/O 7 function	R/W	No	UINT8		0 to 2	0
	08h	I/O 8 function	R/W	No	UINT8		0 to 3	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Enable source	R/W	No	UINT16	-	0 to 1	0
2060h	01h	Numerator	R/W	No	UINT32	-	UINT32	1

	02h	Denominator	R/W	No	UINT32	-	UINT32	1
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-

4.4.6 Simple Example

Set the pulses per revolution to 4000.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x01	Set mode to profile position mode.
2	2002h-08h	0x02	Command source from PUL/DIR.
3	2060h-01h	0x07D0	Set Electronic_Gear_Ratio_Numerator to 2000.
4	2060h-02h	0x8000	Set Electronic_Gear_Ratio_ Denominator to 32768.
5	2030h-04h	0x00	Set I/O4 to PUL function.
6	2030h-05h	0x00	Set I/O5 to DIR function.
7	2030h-06h	0x00	Set I/O6 to ENA function.
8	2031h-00h	0x0000	Set PUL/DIR/ENA polarity to non-inverted.
9	200Dh-00h	0x65766173	Store the parameters to the NVM.
10	200Dh-00h	0x626F6F74	Reset system command or reset power.

After setting, the position can be controlled by the PUL/DIR signals.

Set the velocity to 3000rpm when the PWM duty is 100%.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x03	Set the mode to profile speed mode.
2	2020h-08h	0x03	Command source from PWM/DIR.
3	60FFh-00h	0x00320000	Set the target velocity to 3000rpm.
4	2030h-04h	0x00	Set I/O4 to the PUL function.
5	2030h-05h	0x00	Set I/O5 to the DIR function.
6	2030h-06h	0x00	Set I/O6 to the ENA function.
7	2031h-00h	0x0000	Set the PUL/DIR/ENA polarity to non-inverted.
8	200Dh-00h	0x65766173	Store the parameters to the NVM.
9	200Dh-00h	0x626F6F74	Reset the system command or reset power.

After setting, the motor speed can be controlled by the PWM/DIR signals.

4.5 Loop Tuning

4.5.1 Function Description

The driver module uses a three-loop control method. The innermost loop is the current loop, also called the torque loop. The middle loop is the speed loop, and the outer loop is the position loop. Figure 21 shows the block diagram.

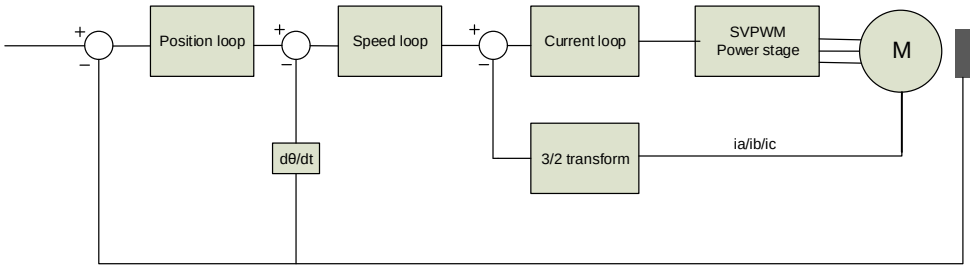


Figure 21: Control Loop Block Diagram

EZmotion provides an easy-to-use GUI to help engineers design and tune the loop parameters. Download the MotionLAB software from the EZmotion website.

To simplify tuning, the loop parameters are simplified to the loop bandwidth with the motor and load parameters. There is a tradeoff to optimize the loop parameters: a higher speed and position loop bandwidth improve dynamic response, but cause more vibrations and noise.

Current Loop

The current loop is the innermost loop. The driver module uses ID = 0 control, which controls the direct-axis current to 0. This makes the output torque proportional to the quadrature axis current (I_Q). It is recommended to set the loop between 1kHz and 2kHz. A good starting value for the current loop is 1kHz.

Speed Loop

In the speed loop, a PI compensator controls the motor speed. The input is the speed command, and the output is the reference of the current loop.

The speed loop limits the maximum peak current of the motor phase current, which limits the maximum output torque.

The recommended bandwidth setting is between 50Hz and 400Hz, with an integral time constant between 2Hz and 20Hz. A good starting value is to set a bandwidth between 200Hz and 2Hz for the integral time constant.

Position Loop

The position loop is the outermost loop, and is used to control the motor position. The input is the position command, and the output is a speed reference for the speed loop. The position loop uses P control to avoid overshoot. Feed-forward functionality can be enabled if a low following error is required.

The position loop limit limits the maximum motor speed in position mode.

The recommended loop setting is 10Hz to 100Hz. A good starting value for the loop setting is 50Hz.

4.5.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	01h	Position loop bandwidth	R/W	No	UINT16	Hz	1 to 200	20
2005h	03h	Speed loop bandwidth	R/W	No	UINT16	Hz	1 to 500	200
2005h	04h	Speed loop integral constant	R/W	No	UINT16	Hz	1 to 500	200
2005h	05h	Torque loop bandwidth	R/W	No	UINT16	Hz	200 to 2000	1000
2005h	06h	Position loop out limit	R/W	No	UINT32	rpm	UINT32	3000
2005h	07h	Speed loop out limit	R/W	No	UINT16	I_Q (A)	UINT16	15
2005h	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000

4.5.3 Simple Example

Set the current loop to 1000Hz, the speed loop to 200Hz, and the position loop to 20Hz. Limit the position loop output below 3000pm, and set the speed loop output below 3000‰ of the rated torque.

Steps	Index and Sub-Index	Data	Description
1	2050h-01h	0x0014	Set the position loop bandwidth to 20Hz.
2	2050h-02h	0x0014	Set the position loop bandwidth to 20Hz.
3	2050h-03h	0x00C8	Set the speed loop bandwidth to 200Hz.
4	2050h-04h	0x03E8	Set the current loop bandwidth to 1000Hz.
5	2050h-06h	0x00320000	Set the position loop limit to 3000rpm.
6	2050h-07h	0x0BB8	Set the speed loop limit to 3000‰ of the rated torque.
7	200Dh-00h	0xAA5555AA	Recalculate the loop parameters according to the settings.

4.6 Halt and Quick Stop Options

A halt or quick stop may be required during operation. The halt function slows the motor velocity according to the halt option, but the device remains in the operation enable state. The quick stop function slows

down the motor velocity and transitions to the switch on disabled state, or the device stays in the quick stop active state, according to the quick stop settings.

4.6.1 Halt Option

If the halt option is set to the disable drive function, the inverter switches are all turned off, and the motor velocity slows down with mechanical friction.

If the halt option is set to the slow down ramp, the motor velocity slows down using the profile deceleration (6084h). When the motor velocity is below the brake speed threshold, the motor maintains its current position.

If the halt option is set to the quick stop ramp, the motor velocity slows down using quick stop deceleration (6085h). When the motor velocity is below the brake speed threshold, the motor maintains its current position.

If the halt option is set to the current limit, the motor velocity slows down by controlling the motor torque current. When the motor velocity is below the brake speed threshold, the motor maintains its current position.

4.6.2 Quick Stop Option

The quick stop command changes the motor status to quick stop active, and the motor velocity slows down according to the configured quick stop option.

If the quick stop option is set from 0 to 3, the status changes to switch on disabled once the motor velocity is below the brake speed threshold.

If quick stop option is set from 5 to 7, the status stays in a quick stop active state once the motor velocity is below the brake speed threshold. Meanwhile, the motor maintains its current position.

4.6.3 Brake Control Logic

If a mechanical brake is required, the brake control logic can be used to control the brake relay. The control signal can be output from the GPI/O and BRAKE pins. The signal polarity is also configurable. See the External I/O Function section on page 41 for more details.

The brake control logic can be changed for several situations. These situations are described below.

Servo On

If the motor enters operation enabled mode, the brake is active after about 4ms. Figure 22 shows the brake's servo on logic.

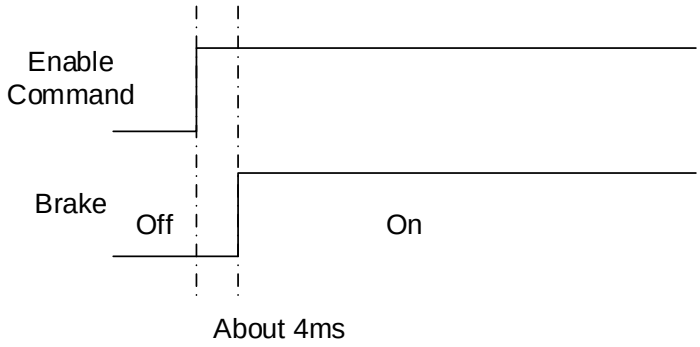


Figure 22: Brake Servo On Logic

Servo Off ("Brake Enable" Set to 1)

The brake has a turn-off time (typically several ms). If the motor turns off immediately when the disable operation command is received, the motor shaft may move a little during the brake turn-off delay time, especially in a system with vertical movement (see Figure 23). Set "Brake enable" to 1 to avoid this behavior.

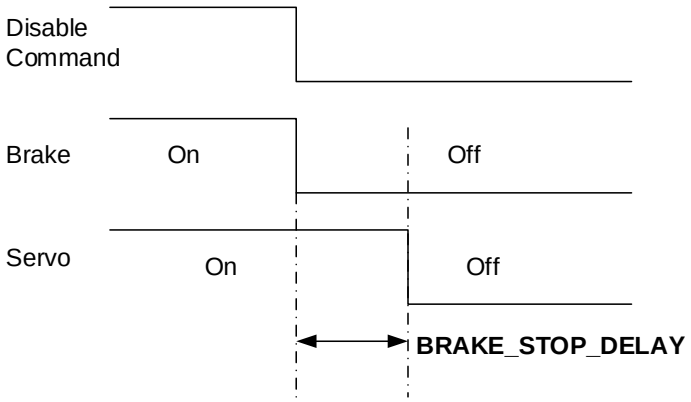


Figure 23: Brake Servo Off Logic (Brake Enable Set to 1)

Servo Off ("Brake Enable" Set to 0)

If users do not want a delay time between the disable operation command and servo off, set "Brake enable" to 0. The servo turns off immediately after the disable operation command is received (see Figure 24).

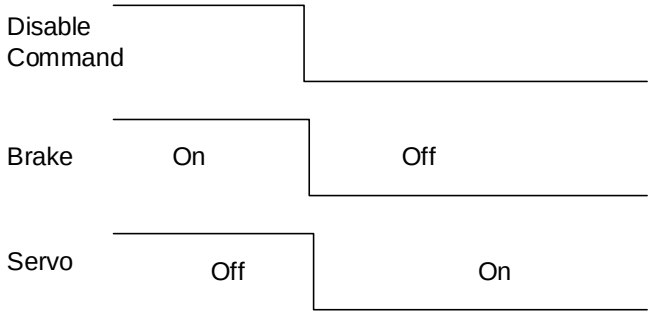


Figure 24: Brake Servo Off Logic (Brake Enable Set to 0)

Disable Operation (or an Error Occurs)

If a disable operation command is received during high-speed operation (or an error occurs), the servo turns off immediately (see Figure 25 on page 46). Two configurations affect the brake logic. If the motor speed is below BRAKE_OFF_SPEED or the delay time is longer than BRAKE_OFF_DELAY, the brake turns off.

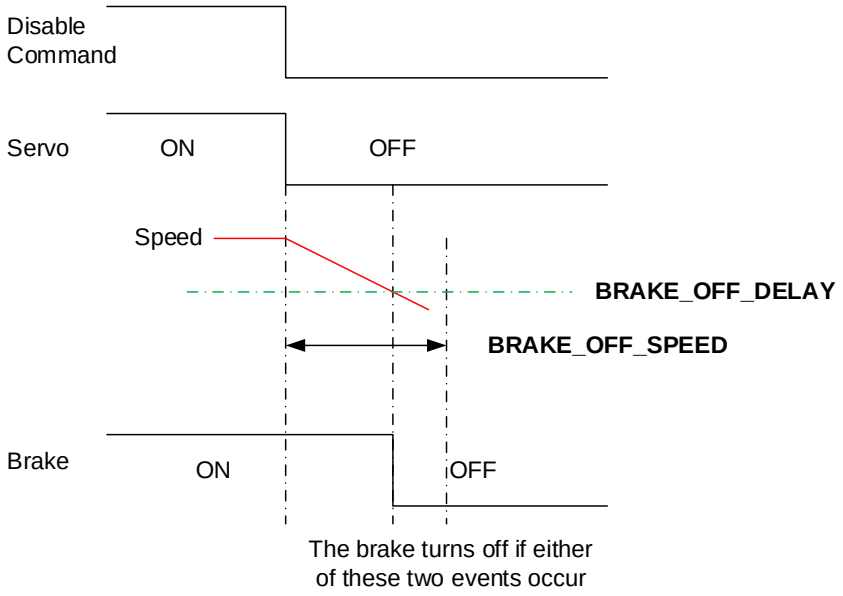


Figure 25: Brake Logic if an Error Occurs

Clear Error

The servo error must be cleared to enable operation again. The brake logic is the same as the servo on logic.

4.6.4 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	05h	Brake current	R/W	No	UINT16	0.1%	0 to 3000	200
2002h	06h	Brake speed threshold	R/W	No	UINT16	rpm	0 to 500	10
2108h	01h	Brake enable	R/W	No	UINT8	-	0 to 1	0
2108h	02h	Brake off speed	R/W	No	UINT16	rpm	0 to 1000	30
2108h	03h	Brake off delay	R/W	No	UINT16	ms	1 to 65535	1000
2108h	04h	Brake stop delay	R/W	No	UINT16	ms	1 to 65535	1
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	R/O	TPDO	UINT16	-	UINT16	-
605Ah	00h	Quick stop option code	R/W	No	INT16	-	INT16	2
605Dh	00h	Halt option code	R/W	No	INT16	-	INT16	1
6085h	00h	Quick stop deceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800

4.6.5 Simple Example

If the motor is working at profile velocity mode, halt the motor with halt option 1.

Steps	Index and Sub-Index	Data	Description
1	6040h-00h	0x010F	Halt command. The motor velocity slows down using profile deceleration. When the velocity is below the brake speed threshold, the motor changes to position mode and maintains its current position.
2	-	-	Delay a few seconds.
3	6040h-00h	0x000F	Disable halt. The motor runs using the configured mode and profile.

4.7 Advanced Settings

Advanced settings, such as feed-forward and filter functions, are provided to improve control performance.

4.7.1 Feed-Forward

Speed Feed-Forward

Speed feed-forward can be used to minimize the position following error. Figure 26 shows the block diagram. The speed reference for the speed loop is the sum of the speed feed-forward and the output of the position control loop. If the position reference is changed, the speed reference changes immediately, without delaying the position control loop. This makes the position response faster and minimizes errors.

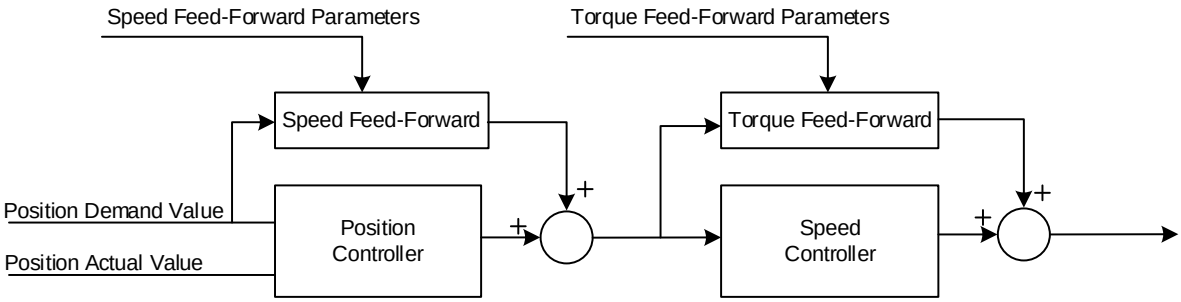


Figure 26: Feed-Forward Block Diagram

The speed feed-forward gain object (2004h-06h) and speed feed-forward time constant object (2004h-07h) can be set to obtain a filtered feed-forward value.

The speed feed-forward function can be disabled by setting “Feed-forward enable”, bit[2] (2004h-01h).

Torque Feed-Forward

Torque feed-forward can make the speed loop control response faster (see Figure 26). The torque reference to the torque loop is the sum of the feed-forward and the output of speed loop controller. If the speed reference changes, the torque reference changes immediately without the speed control loop delay. This makes the speed response faster.

The torque feed-forward gain object (2004h-04h) and torque feed-forward time constant object (2004h-05h) can be set to obtain a filtered feed-forward value.

The torque feed-forward function can be disabled by setting “Feed-forward enable”, bit[1] (2004h-01h).

Decoupling

From the voltage equation of a PMSM motor, the $-\omega L_Q I_Q$ and $-\omega(L_D I_D + \psi_F)$ parameters (from the motor’s back electromotive force (EMF)) should be decoupled to make the equation a linear equation. Note that the decoupling function relies on accurate motor parameters for L_D, L_Q, and the flux (ψ_F). U_D and U_Q can be calculated with Equation (3) and Equation (4), respectively:

$$U_D = RI_D + L_D \frac{dI_D}{dt} - \omega L_Q I_Q \quad (3)$$

$$U_Q = RI_Q + L_Q \frac{dI_Q}{dt} - \omega\left(L_D I_D + \psi_F\right) \quad (4)$$

The decoupling gain object (2004h-02h) and speed decoupling time constant object (2004h-03h) can be set to obtain a filtered decoupling value. The decoupling function can be disabled by setting “Feed-forward enable”, bit[0] (2004h-01h). Figure 27 on page 49 shows the decoupling block diagram.

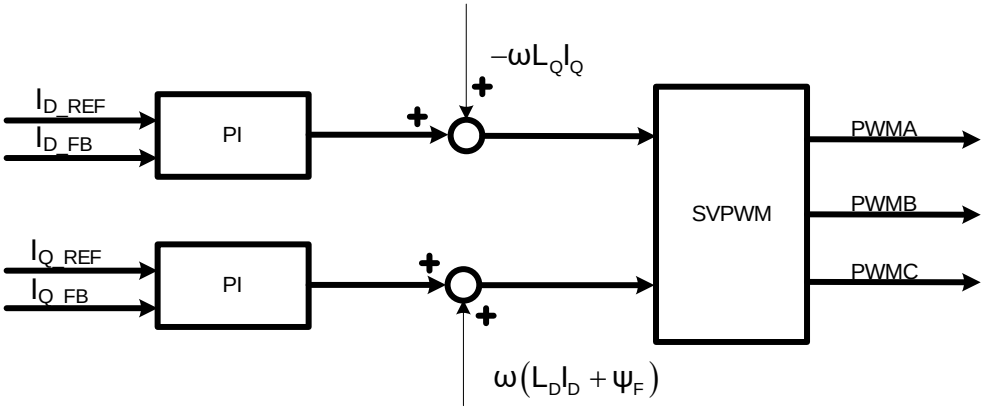


Figure 27: Decoupling Block Diagram

4.7.2 Filters

Position Feedback Filter

Because the position angle sensor has noise that can cause system vibrations and audible noise, it is recommended to use a position feedback filter to minimize the noise. It is typically recommended to set the position filter bandwidth 10 times larger than the position loop bandwidth to minimize the filter phase delay.

Speed Feedback Filter

The speed feedback signal is obtained from the deviation of the position feedback signal, which also has noise that can cause system vibrations. The speed filter 1 bandwidth and speed filter 2 bandwidth should be set below the noise level. It is typically recommended to set the filter bandwidth to be 5 to 10 times the speed loop bandwidth.

Notch Filter

If the system has a resonant frequency, it may cause a large amount of system vibrations or even system instability. A notch filter can be used to filter out the resonant frequency component. The notch filter is a band-stop filter with a narrow stop band and deep filter depth. To configure the notch filter, an appropriate resonant center frequency (in Hz), stop bandwidth (in Hz), and filter depth (in dB) should be selected. Notch filter parameters a1, a2, b1, and b2 can be calculated with Equation (5), Equation (6), Equation (7), and Equation (8), respectively:

$$a1 = \left(\left(2\pi \times f_C \times t_S\right)^2 + 10^{f_D/20} \times 2\pi \times f_B \times t_S - 2\right) \times 10000 + 32768 \quad (5)$$

$$a2 = \left(1 - 10^{f_D/20} \times 2\pi \times f_B \times t_S\right) \times 10000 + 32768 \quad (6)$$

$$b1 = \left(\left(2\pi \times f_C \times t_S\right)^2 + 2\pi \times f_B \times t_S - 2\right) \times 10000 + 32768 \quad (7)$$

$$b2 = \left(1 - 2\pi \times f_B \times t_S\right) \times 10000 + 32768 \quad (8)$$

Where f_C is the resonant center frequency, f_B is the bandwidth, and f_D is the filter depth.

The driver module has two notch filters that can be enabled separately.

4.7.3 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	01h	Feed-forward enable	R/W	No	UINT8	-	UINT8	0
	02h	Decouple gain	R/W	No	UINT8	%	0 to 200	100
	03h	Decoupling filter time constant	R/W	No	UINT16	ms	UINT16	0
	04h	Torque feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	05h	Torque feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
	06h	Speed feed-forward gain	RW	No	UINT8	%	0 to 200	100
	07h	Speed feed-forward filter time constant	RW	No	UINT16	ms	UINT16	0
2007h	01h	Position filter bandwidth	RW	No	UINT16	Hz	100 to 2000	200
	02h	Speed filter 1 bandwidth	RW	No	UINT16	Hz	100 to 2000	1000
	05h	Speed filter2 bandwidth	RW	No	UINT16	Hz	100 to 2000	1000
2008h	01h	Notch enable	RW	No	UINT8	-	UINT8	0
	02h	Notch1_a1	RW	No	UINT16	LSB	UINT16	0
	03h	Notch1_a2	RW	No	UINT16	LSB	UINT16	0
	04h	Notch1_b1	RW	No	UINT16	LSB	UINT16	0
	05h	Notch1_b2	RW	No	UINT16	LSB	UINT16	0
	06h	Notch2_a1	RW	No	UINT16	LSB	UINT16	0
	07h	Notch2_a2	RW	No	UINT16	LSB	UINT16	0
	08h	Notch2_b1	RW	No	UINT16	LSB	UINT16	0
	09h	Notch2_b2	RW	No	UINT16	LSB	UINT16	0

4.7.4 Simple Example

Set the position filter bandwidth and speed filter bandwidth to 1000Hz.

Steps	Index and Sub-Index	Data	Description
1	2007h-01h	0x03E8	Set the position filter bandwidth to 1000Hz.
2	2007h-02h	0x03E8	Set the speed filter 1 bandwidth to 1000Hz.
3	2007h-03h	0x03E8	Set the speed filter 2 bandwidth to 1000Hz.
4	200Dh-00h	0xAA5555AA	Recalculate the control parameters to make the change take effect.

4.8 Hardware Settings

4.8.1 Driver Parameters

Object 2000h is used to identify controller versions. The part number object (2000h-01h), sensor version object (2000h-03h), and part version object (2000h-04h) are read-only. These registers are used to identify the driver module version. The motor number object (2000h-02h) and driver number object (2000h-05h) can be set by the user to identify the motor controller vision.

4.8.2 Motor Parameters

Motor parameters are used for control loop design and other operational functions. As described in the Parameter Identification section on page 36, the user can set basic motor parameters and allow for other detailed parameters to be identified automatically. If parameter identification cannot be performed, the user should set the motor parameters object (2001h) before running the motor.

4.8.3 Current-Sense Parameters

Current-sense parameters sense the motor's phase current. Select and appropriate current-sense resistor and amplifier gain obtain the correct current feedback.

The current-sense resistor's (R_{CS}) power rating must be selected carefully. The overall power dispatched on this resistor can be estimated with Equation (9):

$$P = \frac{1}{2} \times I_{RMS}^2 \times R_{CS} \quad (9)$$

A good rule of thumb is to leave a 50% margin for the power rating to guarantee the device can work normally at higher temperatures. Using Figure 28 below, the amplifier gain can be calculated with Equation (10):

$$G = \frac{R_1}{R_2 + R_3} \quad (10)$$

Where R1 is fixed to 20kΩ and R2 is fixed to 1kΩ, so changing R3 changes the amplifier gain (G).

Select G so that is meets the condition estimated with Equation (11):

$$I_{MAX} \times R_{CS} \times G < 1.65V \quad (11)$$

Where I_{MAX} is the maximum allowed motor winding current, and R_{CS} is the current-sense resistor.

It is typically recommended to leave a minimum 20% margin to guarantee a robust design. Ensure that this value is not too small. To improve current-sense accuracy, the calculated value should be at least 60% of 1.65V. Figure 28 shows the current-sense diagram.

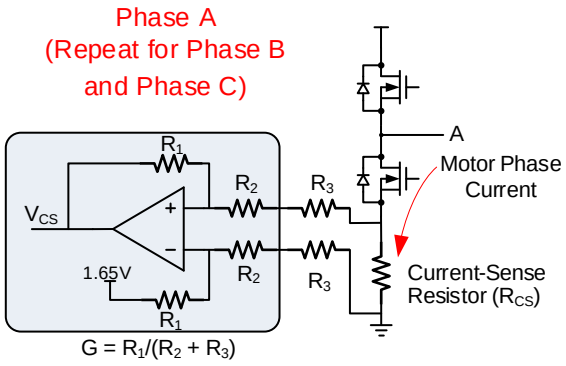


Figure 28: Current-Sense Diagram

The driver module supports three-phase or two-phase current sensing. This value is set by "Current sample mode" (2002h-0Bh). If using two-phase current sensing, only the phase A and phase C currents are used.

4.8.4 Pre-Driver Parameters

The driver module allows for two types of pre-drivers. If the driver type is set to 0, pre-drivers with 6 separate gate signals (GLx + GHx) are supported. If the driver type is set to 1, pre-drivers with (ENx + PWMx) signals are supported.

If using drivers with GLx + GHx signals, set a proper dead time. The dead time should be selected according to the MOSFET's specifications, as well as operational conditions such as voltage and current. For applications with MOSFET, a dead time between 200ns and 500ns is sufficient.

4.8.5 Voltage-Sensing Parameters

A voltage divider scales the DC link voltage to a reasonable voltage range so that the controller can sense the DC link voltage. Figure 29 shows how to set the voltage resistor dividers.

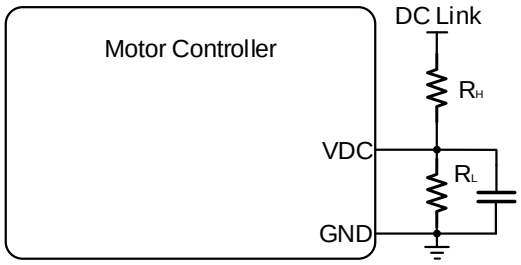


Figure 29: Voltage Divider

4.8.6 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2000h	01h	Controller part number	RO	No	UINT16	-		0x6720
	02h	Motor part number	RO	No	UINT16	-	-	0x0000
	03h	Encoder part number	RO	No	UINT16	-	-	0x0732
	04h	Software version	RO	No	UINT16	-	-	0x0100
	05h	Hardware version	RO	No	UINT16	-	-	0x0100
2001h	01h	Phase resistance	R/W	No	UINT32	mΩ	UINT32	600
	02h	D-axis inductance	R/W	No	UINT32	μH	UINT32	700
	03h	Q-axis inductance	R/W	No	UINT32	μH	UINT32	700
	04h	Pole pairs	R/W	No	UINT8	-	UINT8	4
	05h	Torque constant	R/W	No	UINT32	mNm/A	UINT32	56
	06h	Inertia	R/W	No	UINT32	g x cm2	UINT32	210
	07h	Rated voltage	R/W	No	UINT32	mV	UINT32	36000
	08h	Rated current	R/W	No	UINT32	mA	UINT32	5000
	09h	Rated speed	R/W	No	UINT32	rpm	UINT32	3000
2002h	02h	Amplifier gain	R/W	No	UINT8	V/V	1~100	10
	03h	Current-sense resistor	R/W	No	UINT8	mΩ	1~100	10
	09h	Driver type	R/W	No	UINT8	-	0	0
	0Ah	Dead time	R/W	No	UINT16	ns	0-1000	500
	0Bh	Current sample mode	R/W	No	UINT8	-	0-1	0
2050h	01h	Lower divider	R/W	No	UINT16	kΩ	1-65535	10
	02h	Upper divider	R/W	No	UINT16	kΩ	1-65535	402

4.8.7 Simple Example

Set the pre-driver type to the GLx + GHx type, and set the dead time to 500μs.

Steps	Index and Sub-Index	Data	Description
1	2002h-09h	0x00	Select pre-drivers with GLx + GHx signals.
2	2002h-0Ah	0x01F4	Set the dead time to 500ns.
3	200Dh-00h	0x65766173	Store the parameters to the NVM.
4	200Dh-00h	0x626F6F74	Reset the controller.

4.9 Store Parameters

4.9.1 Function Description

To store the tuned control parameters to driver module's NVM, some function codes can be sent to object 200Dh to trigger specific functions. The functions and function code are listed below.

Function	Function Code	Description
Update control parameters	0xAA5555AA	Update the control parameters according to the register value. This command should be sent after new configurations. Control word, status word, operation mode, and the trajectory profile related parameters do not need to this function code to be activated.
Store parameters	0x65766173	Store all control parameters to the controller's NVM.
Restore default parameters	0x64616F6C	Restore all control parameters to the default values.
System reset	0x626F6F74	Restart the motor controller to simulate a power reset.

4.9.2 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Dh	00h	Special command	RW	UINT32	-	-	See supported command above	0

4.9.3 Simple Example

Store the parameters to the NVM.

Steps	Index and Sub-Index	Data	Description
1	200Dh-00h	0x65766173	Store the parameters to the NVM.

Section 5. Protections and Errors

The driver module provides rich protection functions to avoid unexpected failures and external component damage. The fault type can be determined based on the value of “Error status” (200Bh-0Bh). During a fault, the ALARM signal outputs a high-level voltage, and the fault indication LED is illuminated.

5.1 Function Description

5.1.1 Power Stage Fault Protection

If the power stage fault signal is connected to the controller’s nFT pin, the controller can detect a power stage fault.

If a power stage fault is detected, the controller shuts down the power stage to avoid further damage to the system.

5.1.2 Under-Voltage Lockout (UVLO) Protection

If under-voltage lockout (UVLO) protection is enabled, then the UVLO bit object (200Bh-0Bh) is set when the DC link voltage drops below the UVLO threshold object (200Bh-03h). If UVLO protection is triggered, the controller enters a fault state.

UVLO protection can be disabled by setting UVLO_EN to 0.

5.1.3 DC Link Voltage Limit Protection

The VDC pin senses the DC link voltage. If the DC link voltage exceeds the DC link limit upper threshold (200Bh-09h), VDCCON starts switching. If the DC link voltage falls below the DC link limit lower threshold (200Bh-0Ah), VDCCON stops switching. This limits the voltage when energy is returned from the motor to the DC link.

The voltage on the VDC pin is sensed by a voltage divider. The correct divider voltage should be set via the voltage divider 1 object (2050h-01h) and the voltage divider 2 object (2050h-02h). Note that activating this protection does not cause the controller to enter a fault state.

This function can be disabled by setting VIN_LIMIT_EN to 0.

5.1.4 Rotor-Lock Protection

If the target velocity exceeds the lock speed threshold (set via 200Bh-05h) and the angle that the motor shaft turns in during the lock time (set via 200Bh-06h) is less than lock position threshold (set via 200Bh-04h) in profile velocity mode, then rotor-lock protection is triggered.

If the target position is not reached, and the angle that the motor shaft turns in during the lock time (set via 200Bh-06h) is less than the lock position threshold (200Bh-04h) in profile position mode, then rotor-lock protection is triggered.

If rotor lock protection is triggered, the LOCK bit (200Bh-0Bh) is set, and the controller enters a fault state.

This protection can be disabled by setting LOCK_EN to 0.

5.1.5 Over-Current Protection (OCP)

Over-current protection (OCP) usually occurs when the components on the board are damaged or when a short circuit occurs. The driver module shuts down the power stage to avoid further damage to the system.

If any phase current exceeds the OCP current, OCP is triggered and the error status OCP bit (200Bh-0Bh) is set. Then the controller enters a fault state.

5.1.6 Overload Protection

To avoid damaging the mechanical system and the motor, overload protection is triggered if the output torque exceeds 75% of the speed loop limit (set via 2005h-07h) and lasts for longer than the overload time window. The controller shuts down the power stage so that electrical power is not delivered to the motor or mechanical system.

Overload protection can be disabled by setting OVERLOAD_EN to 0, and the overload time window can also be set.

If overload protection is triggered, the OVERLOAD bit (200Bh-0Bh) is set and the controller enters a fault state.

5.1.7 Over-Temperature Protection (OTP)

If there is an NTC thermistor connected to the controller's NTC pin, over-temperature protection (OTP) can be triggered.

Temperature sensing is optimized when using Murata's NCU15XH103F60RC NTC. If using another NTC, the real temperature should be calibrated separately to obtain an accurate temperature measurement. If the sensed temperature exceeds the set value, OTP is triggered. The controller does not shut down the power stage when OTP is triggered; instead, it sends a fault signal and allows the user to respond.

5.2 Clearing the Error

To clear the error and restart the motor from a fault state without shutting down the motor, send the fault reset command (a rising edge on "Control word", bit[7]) to the controller. If no errors are active, then the controller enters switch on disabled status. Sending the switch on + enable operation command restarts the motor.

5.3 Error Identification

If any protection or warning is triggered, the corresponding error indication bit in "Error status" (200Bh-0Bh) is set. If the motor enters the fault state, the fault indication LED will be illuminated.

See object 200Bh-0Bh on page 73 for more details.

5.4 Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	01h	Protection enable	R/W	No	UINT8			0
	02h	OCP threshold	R/W	No	UINT16	A	UINT16	20
	03h	UVLO voltage threshold	R/W	No	UINT16	V	8 to 30	12
	04h	Lock position threshold	R/W	No	UINT32	LSB	UINT32	182
	05h	Lock speed threshold	R/W	No	UINT32	INC/s	UINT32	109226
	06h	Lock time window	R/W	No	UINT16	ms	UINT16	1000
	07h	Retry enable	R/W	No	UINT8		0 to 1	0
	08h	Retry time	R/W	No	UINT16	ms	UINT16	3000
	09h	DC link limit upper threshold	R/W	No	UINT16	V	UINT16	56
	0Ah	DC link limit lower threshold	R/W	No	UINT16	V	UINT16	52
	0Bh	Error status	RO	TPDO	UINT16	-	-	0
2040h	00h	Temperature	RO	No	INT16	°C	-40 to +125	-
2041h	00h	OTP threshold	R/W	No	INT16	°C	-40 to +125	85
2042h	01h	Overload enable	R/W	No	UINT8	-	-	0
	02h	Overload current threshold	R/W	No	UINT16	‰	0-3000	3000
	03h	Over load time window	R/W	No	UINT16	ms	UINT16	1000
2050h	01h	Lower divider	RW	NO	UINT16	kΩ	1-65535	10
	02h	Upper divider	RW	NO	UINT16	kΩ	1-65535	402

5.5 Simple Example

Set the OCP threshold to 2A and enable OCP.

Steps	Index and Sub-Index	Data	Description
1	200Bh-02h	0x0002	Set the OCP threshold to 2A.
2	200Bh-01h	0x01	Enable OCP.
3	200Dh-00h	0xAA5555AA	Recalculate the control parameters to make the change take effect.

Section 6. Object Dictionary

6.1 1000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1600h	00h	Number of mapped objects	RO	No	UINT8	-	-	0Ah
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60710010h
	03h	Mapped object 3	RO	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	RO	No	UINT32	-	-	60980010h
	05h	Mapped object 5	RO	No	UINT32	-	-	60990120h
	06h	Mapped object 6	RO	No	UINT32	-	-	60990220h
	07h	Mapped object 7	RO	No	UINT32	-	-	609A0020h
	08h	Mapped object 8	RO	No	UINT32	-	-	60FE0020h
	09h	Mapped object 9	RO	No	UINT32	-	-	60FF0020h
	0Ah	Mapped object 10	RO	No	UINT32	-	-	60600010h
1601h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	607A0020h
1602h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60FF0020h
1603h	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	Mapped object 1	RO	No	UINT32	-	-	60400010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60600010h
	03h	Mapped object 3	RO	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	RO	No	UINT32	-	-	60FF0020h
	05h	Mapped object 5	RO	No	UINT32	-	-	60B20010h
	06h	Mapped object 6	RO	No	UINT32	-	-	20800620h
	07h	Mapped object 7	RO	No	UINT32	-	-	20800120h
	08h	Mapped object 8	RO	No	UINT32	-	-	20800220h
	09h	Mapped object 9	RO	No	UINT32	-	-	20800320h
1A00h	00h	Number of mapped objects	RO	No	UINT8	-	-	07h
	01h	Mapped object 1	RO	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60410010h
	03h	Mapped object 3	RO	No	UINT32	-	-	60640020h
	04h	Mapped object 4	RO	No	UINT32	-	-	606C0020h
	05h	Mapped object 5	RO	No	UINT32	-	-	60610010h
	06h	Mapped object 6	RO	No	UINT32	-	-	60770010h
	07h	Mapped object 7	RO	No	UINT32	-	-	60FD0020h
1A01h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60410010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60640020h
1A02h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	RO	No	UINT32	-	-	60410010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60640020h

1A03h	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	Mapped object 1	RO	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	RO	No	UINT32	-	-	60410010h
	03h	Mapped object 3	RO	No	UINT32	-	-	60610010h
	04h	Mapped object 4	RO	No	UINT32	-	-	200E0210h
	05h	Mapped object 5	RO	No	UINT32	-	-	60640020h
	06h	Mapped object 6	RO	No	UINT32	-	-	606C0020h
	07h	Mapped object 7	RO	No	UINT32	-	-	200E0510h
	08h	Mapped object 8	RO	No	UINT32	-	-	20400010h
	09h	Mapped object 9	RO	No	UINT32	-	-	20810110h
1C12h	00h	Syncmanager 2 assigned object	R/W	No	UINT16	-	-	1600h
1C13h	00h	Syncmanager 3 assigned object	R/W	No	UINT16	-	-	1A00h

6.2 2000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2000h	**Device Information**							
	00h	Max sub-index	RO	No	UINT8	-	5	5
	01h	Controller part number	RO	No	UINT16	-	0x6720	0x6720
	02h	Motor part number	RO	No	UINT16	-	-	0x0000
	03h	Encoder part number	RO	No	UINT16	-	-	0x0732
	04h	Software version	RO	No	UINT16	-	-	0x0100
	05h	Hardware version	RO	No	UINT16	-	-	0x0100
2001h	**Motor Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	9	0x09
	01h	Phase resistance	R/W	No	UINT32	mΩ	UINT32	600
	02h	D-axis inductance	R/W	No	UINT32	µH	UINT32	700
	03h	Q-axis inductance	R/W	No	UINT32	µH	UINT32	700
	04h	Pole pairs	R/W	No	UINT8	-	1 to 255	4
	05h	Torque constant	R/W	No	UINT32	mNm/A	UINT32	56
	06h	Inertia	R/W	No	UINT32	g x cm^2	UINT32	210
	07h	Rated voltage	R/W	No	UINT32	mV	UINT32	36000
	08h	Rated current	R/W	No	UINT32	mA	UINT32	5000
	09h	Rated speed	R/W	No	UINT32	rpm	UINT32	3000
2002h	**Driver Configuration**							
	00h	Max sub-index	RO	No	UINT8	-	11	11
	01h	Reserved	-	-	-	-	-	-
	02h	Amplifier gain	R/W	No	UINT8	V/V	1 to 100	10
	03h	Current sensing resistor	R/W	No	UINT8	mΩ	1 to 100	10
	04h	Reserved	-	-	-	-	-	-
	05h	Brake current	R/W	No	UINT16	‰	0 to 3000	200
	06h	Brake speed threshold	R/W	No	UINT16	rpm	0 to 500	10
	07h	Theta bias current	R/W	No	UINT16	‰	0 to 3000	500
	08h	Command type	R/W	No	UINT8	-	0 to 4	0
	09h	Driver type	R/W	No	UINT8	-	0 to 1	0
	0Ah	Dead time	R/W	No	UINT16	ns	0 to 1000	500
	0Bh	Current sample mode	R/W	No	UINT8	-	0 to 1	0

2003h	**Position Sensor Configuration**							
	00h	Max sub-index	RO	No	UINT8	-	6	6
	01h	Sensor bias	R/W	No	UINT32	INC	0 to 65535	0
	02h	Sensor direction	R/W	No	UINT8	-	0 to 1	0
	03h	Reserved	-	-	-	-	-	-
	04h	Reserved	-	-	-	-	-	-
	05h	INL enable	R/W	No	UINT8	-	0 to 1	0
	06h	Speed feedback source	R/W	No	UINT8	-	0 to 2	2
2004h	**Feed-Forward Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	7	7
	01h	Feed-forward enable	R/W	No	UINT8	-	UINT8	0
	02h	Decouple gain	R/W	No	UINT8	%	0 to 200	100
	03h	Decoupling filter time constant	R/W	No	UINT16	ms	UINT16	0
	04h	Torque feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	05h	Torque feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
	06h	Speed feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	07h	Speed feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
2005h	**Loop Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	8	8
	01h	Position loop bandwidth	R/W	No	UINT16	Hz	1 to 200	20
	02h	Reserved	-	-	-	-	-	-
	03h	Speed loop bandwidth	R/W	No	UINT16	Hz	1 to 500	200
	04h	Speed loop integral constant	R/W	No	UINT16	Hz	1 to 50	10
	05h	Torque loop bandwidth	R/W	No	UINT16	Hz	200 - 2000	1000
	06h	Position loop out limit	R/W	No	UINT32	INC/s	UINT32	3276800
	07h	Speed loop out limit	R/W	No	UINT16	‰	UINT16	3000
	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000
2007h	**Filter Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	5
	01h	Position filter bandwidth	R/W	No	UINT16	Hz	100 to 2000	200
	02h	Speed filter1 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
	03h	Reserved	-	-	-	-	-	-
	04h	Reserved	-	-	-	-	-	-
	05h	Speed filter2 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
2008h	**Notch Filter Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	9	9
	01h	Notch enable	R/W	No	UINT8	-	UINT8	0
	02h	Notch1_a1	R/W	No	UINT16	LSB	UINT16	0
	03h	Notch1_a2	R/W	No	UINT16	LSB	UINT16	0
	04h	Notch1_b1	R/W	No	UINT16	LSB	UINT16	0
	05h	Notch1_b2	R/W	No	UINT16	LSB	UINT16	0
	06h	Notch2_a1	R/W	No	UINT16	LSB	UINT16	0
	07h	Notch2_a2	R/W	No	UINT16	LSB	UINT16	0
	08h	Notch2_b1	R/W	No	UINT16	LSB	UINT16	0
	09h	Notch2_b2	R/W	No	UINT16	LSB	UINT16	0

200Bh	**Protection Parameter**							
	00h	Max sub-index	RO	No	UINT8	-	11	11
	01h	Protection enable	R/W	No	UINT8	-	-	0
	02h	OCP threshold	R/W	No	UINT16	A	UINT16	20
	03h	UVLO threshold	R/W	No	UINT16	V	8 to 30	12
	04h	Lock position threshold	R/W	No	UINT32	INC	UINT32	182
	05h	Lock speed threshold	R/W	No	UINT32	INC/s	UINT32	109226
	06h	Lock time window	R/W	No	UINT16	ms	UINT16	1000
	07h	Retry enable	R/W	No	UINT8	-	0 to 1	0
	08h	Retry time	R/W	No	UINT16	ms	UINT16	3000
	09h	DC link limit upper threshold	R/W	No	UINT16	V	UINT16	56
	0Ah	DC link limit lower threshold	R/W	No	UINT16	V	UINT16	52
	0Bh	Error status	RO	TPDO	UINT16	-	-	0
200Ch	**Parameter Identification**							
	00h	Max sub-index	RO	No	UINT8	-	12	12
	01h	Identify method	RW	No	UINT8	-	0 to 1	0
	02h	Round max	R/W	No	UINT16	round	3 to 65535	50
	03h	Round acceleration	R/W	No	UINT16	round	1 to 65535	10
	04h	Round J	R/W	No	UINT16	round	1 to 65535	10
	05h	Identification status	RO	No	UINT8	-	0 to 16	0
	06h	Identified R_S	RO	No	UINT32	mΩ	-	0
	07h	Identified L_D	RO	No	UINT32	uH	-	0
	08h	Identified L_Q	RO	No	UINT32	uH	-	0
	09h	Identified K_T	RO	No	UINT32	mNm/A	-	0
	0Ah	Identified J	RO	No	UINT32	g x cm^2	-	0
	0Bh	Identified B	RO	No	UINT32	mNm x s	-	0
	0Ch	Identified T_F	RO	No	UINT32	mNm	-	0
200Dh	00h	Special command	RW	No	UINT32	-	-	0
200Eh	**Servo Internal Information**							
	00h	Max sub-index	RO	No	UINT8	-	10	10
	01h	I_D	RO	TPDO	INT16	mA	INT16	0
	02h	I_Q	RO	TPDO	INT16	mA	INT16	0
	03h	U_D	RO	TPDO	INT16	mV	INT16	0
	04h	U_Q	RO	TPDO	INT16	mV	INT16	0
	05h	Torque	RO	TPDO	INT16	mNm	INT16	0
	06h	Sensor position	RO	TPDO	UINT16	INC	UINT16	0
	07h	Filtered position	RO	TPDO	UINT16	INC	UINT16	0
	08h	Reserved	-	-	-	-	-	-
	09h	Filtered speed	RO	TPDO	INT32	INC/s	INT32	0
	0Ah	Reserved	-	-	-	-	-	-
200Fh	00h	Encoder PPR	R/W	No	UINT32	INC/r	UINT32	16384
2010h	**INL Data**							
	00h	Max sub-index	RO	No	UINT8	-	32	32
	01h~20h	INL data1 – INL data 32	RO	No	INT16	LSB	INT16	0

2030h	**I/O Functions**							
	00h	Max sub-index	RO	No	UINT8		8	8
	01h	I/O 1 function	R/W	No	UINT8	-	0 – 3	0
	02h	I/O 2 function	R/W	No	UINT8	-	0 – 6	0
	03h	I/O 3 function	R/W	No	UINT8	-	0 – 3	0
	04h	I/O 4 function	R/W	No	UINT8	-	0 – 6	0
	05h	I/O 5 function	R/W	No	UINT8	-	0 – 6	0
	06h	I/O 6 function	R/W	No	UINT8	-	0 – 3	0
	07h	I/O 7 function	R/W	No	UINT8	-	0 – 2	0
	08h	I/O 8 function	R/W	No	UINT8	-	0 – 3	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Enable source	R/W	No	UINT16	-	0-1	0
2040h	00h	Temperature	RO	No	INT16	°C	-40 - 125	-
2041h	00h	OTP threshold	R/W	No	INT16	°C	-40 - 125	85
2042h	**Overload Settings**							
	00h	Max sub-index	RO	No	UINT8	-	3	3
	01h	Overload enable	R/W	No	UINT8	-	0 to 1	0
	02h	Overload current threshold	R/W	No	UINT16	‰	0 to 3000	3000
	03h	Overload time window	R/W	No	UINT16	ms	UINT16	1000
2050h	**Voltage Divider**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Lower divider	R/W	No	UINT16	kΩ	1 to 65535	10
	02h	Upper divider	R/W	No	UINT16	kΩ	1 to 65535	402
2060h	**Electrical Gear Ratio**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Numerator	R/W	No	UINT32	-	1 to 65536	1
	02h	Denominator	R/W	No	UINT32	-	1 to 65536	1
2070h	**Homing Torque Settings**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
	02h	Homing time	R/W	No	UINT16	ms	UINT16	500
2101h	00h	CAN node ID	R//W	No	UINT8			0x02
2102h	00h	CAN bit rate	RW	No	UINT16	kbps		1000
2103h	00h	SYNC counter	R/W	No	UINT16	-	-	0
2108h	00h	Max sub-index	RO	No	UINT8	-	4	4
	01h	Brake enable	R/W	No	UINT8	-	0 to 1	0
	02h	Brake off speed	R/W	No	UINT16	rpm	0 to 1000	30
	03h	Brake off delay	R/W	No	UINT16	ms	1 to 65535	1000
	04h	Brake stop delay	R/W	No	UINT16	ms	1 to 65535	1

3000h	**Customer Data Storage**							
	00h	Max sub-index	RO	No	UINT8	-	8	8
	01h	Info 1	R/W	No	UINT16	-	UINT16	0
	02h	Info 2	R/W	No	UINT16	-	UINT16	0
	03h	Info 3	R/W	No	UINT16	-	UINT16	0
	04h	Info 4	R/W	No	UINT16	-	UINT16	0
	05h	Info 5	R/W	No	UINT16	-	UINT16	0
	06h	Info 6	R/W	No	UINT16	-	UINT16	0
	07h	Info 7	R/W	No	UINT16	-	UINT16	0
	08h	Info 8	R/W	No	UINT16	-	UINT16	0

6.3 6000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
605Ah	00h	Quick stop option code	R/W	No	INT16	-	0 to 4	2
605Dh	00h	Halt option code	R/W	No	INT16	-	0-8	1
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
6062h	00h	Position demand value	RO	TPDO	INT32	INC	INT32	-
6063h	00h	Position actual internal value	RO	TPDO	INT32	INC	INT32	-
6064h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
6065h	00h	Following error window	R/W	No	UINT32	INC	UINT32	182
6066h	00h	Following error timeout	R/W	No	UINT32	ms	UINT32	10
6067h	00h	Position window	R/W	No	UINT32	INC	UINT32	182
6068h	00h	Position window time	R/W	No	UINT16	ms	UINT16	10
606Bh	00h	Velocity demand value	RO	TPDO	INT32	INC/s	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
606Dh	00h	Velocity window	R/W	No	UINT16	INC/s	UINT16	32768
606Eh	00h	Velocity window time	R/W	No	UINT16	ms	UINT16	10
606Fh	00h	Velocity threshold	R/W	No	UINT16	INC/s	UINT16	32768
6070h	00h	Velocity threshold time	R/W	No	UINT16	ms	UINT16	10
6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	0
6072h	00h	Max torque	R/W	No	UINT16	‰	0 to 3000	3000
6073h	00h	Max current	R/W	No	UINT16	‰	0 to 3000	3000
6074h	00h	Torque demand value	RO	TPDO	INT16	‰	-3000 to +3000	-
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
6078h	00h	Current actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
6079h	00h	DC link voltage	RO	TPDO	UINT32	mV	UINT32	36000
607Ah	00h	Target position	R/W	Yes	INT32	INC	INT32	0
607Ch	00h	Home offset	R/W	No	INT32	INC	INT32	0
607Dh	**Software Position Limit**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Min position limit	R/W	No	INT32	INC	INT32	-2^{31}
	02h	Max position limit	R/W	No	INT32	INC	INT32	$2^{31}-1$
607Eh	00h	Polarity	R/W	No	UINT8	-	0 to 1	0
607Fh	00h	Max profile velocity	R/W	No	UINT32	INC/s	UINT32	3276800
6080h	00h	Max motor speed	R/W	No	UINT32	rpm	UINT32	3000
6081h	00h	Profile velocity	R/W	No	UINT32	INC/s	UINT32	655360
6083h	00h	Profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
6084h	00h	Profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
6085h	00h	Quick stop deceleration	R/W	No	UINT32	INC/s^2	UINT32	3276800
6086h	00h	Motion profile type	R/W	No	INT16	-	0	0
6087h	00h	Torque slope	R/W	No	UINT32	‰/s	UINT32	3000
6088h	00h	Torque profile type	R/W	No	INT16	-	0	0
6098h	00h	Homing method	R/W	No	INT8	-	0 to 35	0

6099h	**Homing Speeds**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Homing speed switch	R/W	No	UINT32	INC/s	UINT32	655360
	02h	Homing speed zero	R/W	No	UINT32	INC/s	UINT32	65536
609Ah	00h	Homing acceleration	R/W	No	UINT32	INC/s^2	UINT32	0
60B0h	00h	Position offset	R/W	RPDO	INT32	INC	INT32	0
60B1h	00h	Velocity offset	R/W	RPDO	INT32	INC/s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
60C2h	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Interpolation time period value	R/W	No	UINT8	-	1 to 255	1
	02h	Interpolation time index	R/W	No	INT8	-	-4 to -3	-3
60C5h	00h	Max acceleration	R/W	No	UINT32	INC/s^2	UINT32	2^{32}-1
60C6h	00h	Max deceleration	R/W	No	UINT32	INC/s^2	UINT32	2^{32}-1
60F4h	00h	Follow error actual value	RO	TPDO	IN32	INC	INT32	-
60FCh	00h	Position demand value	RO	TPDO	IN32	INC	INT32	0
60FFh	00h	Target velocity	R/W	Yes	IN32	INC/s	INT32	0
6502h	00h	Supported drive modes	RO	No	UINT32	-	-	0x000003AD

Section 7. Object Details

This section gives detailed function descriptions for each object. For objects 1000h~1FFFh, refer to the CiA DS301 - CANopen application layer and communication profile.

2001h: Motor Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	01h	Phase resistance	R/W	No	UINT32	mΩ	UINT32	600
Bits		**Name**	**Description**					
31:0		Phase resistance	Sets the motor winding phase resistance (in mΩ) for torque loop parameter calculations. If using the parameter identification function, this value is updated with the identified value once parameter identification is complete.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	02h	D-axis inductance	R/W	No	UINT32	µH	UINT32	700
Bits		**Name**	**Description**					
31:0		D-axis inductance	Sets the motor winding direct axis inductance (in µH) for torque loop parameter calculation. If using the parameter identification function, this value is updated with the identified value after parameter identification is complete.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	03h	Q-axis inductance	R/W	No	UINT32	µH	UINT32	700
Bits		**Name**	**Description**					
31:0		Q-axis inductance	Sets the motor winding quadrature axis inductance (in µH) for torque loop parameter calculation. If using the parameter identification function, this value is updated with the identified value after parameter identification is complete.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	04h	Pole pairs	R/W	No	UINT8	-	UINT8	4
Bits		**Name**	**Description**					
7:0		Pole pairs	Sets the motor pole pairs. This parameter is vital to make the motor spin. Setting the wrong value with make the motor stuck.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	05h	Torque constant	R/W	No	UINT32	mNm/A	UINT32	56
Bits		**Name**	**Description**					
31:0		Torque constant	Sets the motor torque constant, which represents the amount of motor output torque per ampere current. The current unit is Arms (the rooted mean square current in Ampere).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	06h	Inertia	R/W	No	UINT32	g x cm^2	UINT32	210
Bits		**Name**	**Description**					
31:0		Inertia	Sets the inertia of the mechanical parts, including the rotor and load inertia, for speed loop and position loop parameter calculations. Set this parameter to an appropriate value. Use the parameter identification function to obtain this value automatically.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	07h	Rated voltage	R/W	No	UINT32	mV	UINT32	36000
Bits		**Name**	**Description**					
31:0		Rated voltage	The motor-rated voltage is in mV.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	08h	Rated current	R/W	No	UINT32	mA	UINT32	5000
Bits		**Name**	**Description**					
31:0		Rated current	The motor-rated current is in mA.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	09h	Rated speed	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Rated speed	The motor-rated speed is in rpm.					

2002h: Driver Configuration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	02h	Amplifier gain	R/W	No	UINT8	-	1 to 100	10
Bits		**Name**	**Description**					
7:0		Amplifier gain	Sets the current-sense circuit's amplifier gain.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	03h	Current sensing resistor	R/W	No	UINT8	mΩ	1 to100	10
Bits		**Name**	**Description**					
7:0		Current sensing resistor	Sets the current-sense resistor (in mΩ). Works with the amplifier gain (2002h-02h) to define the total current-to-voltage ratio for the current-sense circuit.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	05h	Brake current	R/W	No	UINT16	0.1%	0 to 3000	200
Bits		**Name**	**Description**					
15:0		Brake current	Sets the q-axis current during halt operation. It is given as a thousandth of the rated current.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	06h	Brake speed threshold	R/W	No	UINT16	rpm	0 to 500	10
Bits		**Name**	**Description**					
15:0		Brake speed threshold	If the motor speed is below the brake speed threshold during braking, braking is finished.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	07h	Theta bias current	R/W	No	UINT16	0.1%	0 to 3000	500
Bits		**Name**	**Description**					
15:0		Theta bias current	Sets the current injected to the motor winding during theta bias sequence. During rotor alignment, a current is injected into the motor windings to pull the rotor to certain positions. The controller can determine the theta bias between the rotor electrical angle and the sensed angle via the angular sensor. Set this value between 200 and 500 for the sequence.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	08h	Command type	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		Command type	Selects the command source. 0: CAN bus 1: A/B. Used for position mode only 2: PUL/DIR. Used for position mode only 3: FPWM/DIR. Used for speed and torque mode 4: The I/O signals. For I/O-controlled multi-position and multi-speed mode Others: Reserved					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	09h	Driver type	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:1		Reserved	Unused.					
0		Driver type	0: Support drivers with GLx and GHx signals 1: Support drivers with ENx and PWMx signals					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	0Ah	Dead time	R/W	No	UINT16	ns	0 to 1000	500
Bits		**Name**	**Description**					
15:0		Dead time	Sets the GLx and GHx signal dead time (in ns). This does not have to be set when using ENx and PWMx interface pre-drivers.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	0Bh	Current sample mode	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:1		Reserved	Unused.					
0		Current sample mode	0: Three-phase current sensing 1: Two-phase current sensing with phase A and phase C					

2003h: Position Sensor Configuration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	01h	Sensor bias	R/W	No	UINT32	INC	0 to 65535	0
Bits		**Name**	**Description**					
31:0		Sensor bias	Sets the theta bias between the rotor electrical angle and the sensed angle via the angular sensor. The sensor bias and sensor direction are vital parameters to make the motor spin, and the rotor alignment procedure determines these values automatically. Does not have to be set manually. See section 4.3 on page 40 for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	02h	Sensor direction	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:1		Reserved	Unused.					
0		Sensor direction	0: The original angle is used in motor control 1: The complementary angle is used in motor control. See object 2003h-01h above for more details					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	05h	INL enable	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:1		RESERVED	Unused.					
0		INL enable	0: Disable INL calibration function. The angle feedback is the original signal 1: Enable INL calibration. The angle feedback is processed by the INL calibration block and then used for motor control					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	06h	Speed feedback source	R/W	No	UINT8	-	0 to 2	2
Bits		**Name**	**Description**					
7:2		Reserved	Unused.					
1:0		Speed feedback source	0: Use the speed raw data as the feedback source 1: Reserved. Do not use this setting 2: Use the speed after the AccuFilter as the feedback source Others: Reserved					

2004h: Feed-Forward Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	01h	Feed-forward enable	R/W	No	UINT8	-	UINT8	0
Bits		**Name**	**Description**					
7:3		Reserved	Unused.					
2		Speed feed-forward enable	If set, the speed feed-forward function is enabled. Speed feed-forward can reduce the position following error. See section 4.7.1 on page 48 for more details.					
1		Torque feed-forward enable	If set, the torque feed-forward function is enabled.					
0		Decoupling enable	If set, the decoupling function is enabled.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	02h	Decouple gain	R/W	No	UINT8	%	0 to 200	100
Bits		**Name**	**Description**					
7:0		Decoupling gain	Determines the percentage of the decoupling value that should be added to the current loop output.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	03h	Decoupling filter time constant	R/W	No	UINT16	ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Decoupling filter time constant	Determines the rising time constant of the decoupling value to avoid the voltage reference step.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	04h	Torque feed-forward gain	R/W	No	UINT8	%	0 to 200	100
Bits		**Name**	**Description**					
7:0		Torque feed-forward gain	Determines the percent of the torque feed-forward value that should be added to the speed loop output.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	05h	Torque feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Torque feed-forward filter time constant	Determines the rising time constant of the torque feed-forward value to avoid a torque reference step.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	06h	Speed feed-forward gain	R/W	No	UINT8	%	0 to 200	100
Bits		**Name**	**Description**					
7:0		Speed feed-forward gain	Determines the percent of the speed feed-forward value that should be added to the position loop output.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	07h	Speed feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Speed feed-forward time constant	Determines the rising time constant of the torque feed-forward value to avoid speed reference step.					

2005h: Loop Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	01h	Position loop bandwidth	R/W	No	UINT16	Hz	1 to 200	20
Bits		**Name**	**Description**					
15:0		Position loop bandwidth	Sets the position loop bandwidth (in Hz). This is the outermost loop of three-loop control. A reasonable range is between 10Hz and 100Hz; this value should be 5 to 10 times smaller than the speed loop bandwidth (2005h-03h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	03h	Speed loop bandwidth	R/W	No	UINT16	Hz	1 to 500	200
Bits		**Name**	**Description**					
15:0		Speed loop bandwidth	Sets the speed loop bandwidth (in Hz). A reasonable range is 50Hz to 400Hz. This value should be 5 to 10 times larger than the position loop bandwidth (2005h-01h), and 5 to 10 times smaller than the torque loop bandwidth (2005h-05h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	04h	Speed loop integral constant	R/W	No	UINT16	Hz	1 to 500	200
Bits		**Name**	**Description**					
15:0		Speed loop integral constant	Sets the speed loop integral constant. A reasonable range is 2Hz to 20Hz. A larger values results in a faster response, but creates a larger overshoot during speed transitions.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	05h	Torque loop bandwidth	R/W	No	UINT16	Hz	200 - 2000	1000
Bits		**Name**	**Description**					
15:0		Torque loop bandwidth	Sets the torque loop bandwidth. A reasonable range is 1kHz to 2kHz. A larger value improves torque response. This value should be 5 to 10 times larger than the speed loop bandwidth (2005h-03h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	06h	Position loop out limit	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Position loop out limit	This value limits the output of the position controller, which limits the motor speed and prevents damage or controller saturation.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	07h	Speed loop out limit	R/W	No	UINT16	IQ(A)	UINT16	15
Bits		**Name**	**Description**					
15:0		Speed loop out limit	This value limits the speed controller output, which limits the motor torque.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Torque loop speed limit	Sets the speed limit when the motor works in torque mode to prevent the motor from running too fast.					

2007h: Filter Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	01h	Position filter bandwidth	R/W	No	UINT16	Hz	100 - 2000	200
Bits		**Name**	**Description**					
15:0		Position filter bandwidth	To minimize the phase delay caused by the filter, set this value to be 10 times larger than the position loop bandwidth.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	02h	Speed filter1 bandwidth	R/W	No	UINT16	Hz	100 - 2000	1000
Bits		**Name**	**Description**					
15:0		Speed filter1 bandwidth	To minimize the phase delay caused by the filter, set this value to be 5 to 10 times larger than the speed loop bandwidth.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	05h	Speed filter2 bandwidth	R/W	No	UINT16	Hz	100 - 2000	1000
Bits		**Name**	**Description**					
15:0		Speed filter2 bandwidth	To minimize the phase delay caused by the filter, set this value to be 5 to 10x larger than the speed loop bandwidth.					

2008h: Notch Filter Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	01h	Notch enable	R/W	No	UINT8	-	UINT8	0
Bits		**Name**	**Description**					
15:2		RESERVED	Unused.					
1		Notch2 enable	Enables notch filter 2.					
0		Notch1 enable	Enables notch filter 1.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	02h	Notch1_a1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		notch1_a1	Sets notch filter 1's parameter a1. See section 4.7.2 on page 49 for the formula to calculate the notch filter parameter.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	03h	Notch1_a2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch1_a2	Sets notch filter 1's parameter a2.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	04h	Notch1_b1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch1_b1	Sets notch filter 1's parameter b1.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	05h	Notch1_b2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch1_b2	Sets notch filter 1's parameter b2.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	06h	Notch2_a1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch2_a1	Sets notch filter 2's parameter a1.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	07h	Notch2_a2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch2_a2	Sets notch filter 2's parameter a2.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	08h	Notch2_b1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch2_b1	Sets notch filter 2's parameter b1.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	09h	Notch2_b2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch2_b2	Sets notch filter 2's parameter b2.					

200Bh: Protection Parameter

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	01h	Protection enable	R/W	No	UINT8			0
Bits		**Name**	**Description**					
7:4		RESERVED	Unused.					
3		VIN_LIMIT_EN	0: Disable the DC link voltage limit 1: Enable the DC link voltage limit					
2		LOCK_EN	0: Disable rotor lock protection 1: Enable rotor lock protection					
1		UVLO_EN	0: Disable under-voltage lockout (UVLO) 1: Enable UVLO					
0		OCP_EN	0: Disable over-current protection (OCP) 1: Enable OCP					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	02h	OCP threshold	R/W	No	UINT16	A	UINT16	20
Bits		**Name**	**Description**					
15:0		OCP threshold	Sets the over-current threshold (in A). If any phase current exceeds this value, OCP is triggered and the motor stops.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	03h	UVLO voltage threshold	R/W	No	UINT16	V	8 to 30	12
Bits		**Name**	**Description**					
15:0		UVLO voltage threshold	Sets the under-voltage lockout (UVLO) threshold (in V). If the DC link voltage is below this value, UVLO protection is triggered and the motor stops.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	04h	Lock position threshold	R/W	No	UINT32	LSB	UINT32	182
Bits		**Name**	**Description**					
31:0		Lock position threshold	If the position target is not reached and the difference between the position's actual value and the target position exceeds this value for longer than the lock time, then rotor lock protection is triggered.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	05h	Lock speed threshold	R/W	No	UINT32	INC/s	UINT32	109226
Bits		**Name**	**Description**					
31:0		Lock speed threshold	If the target velocity is not reached and the velocity's actual value is below this value for longer than the lock time in speed mode, then rotor lock protection is triggered.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	06h	Lock time window	R/W	No	UINT16	ms	UINT16	1000
Bits		**Name**	**Description**					
15:0		Lock time window	Used for the monitor rotor lock. See the 200Bh-04h and 200Bh-05h sections above for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	07h	Retry enable	R/W	No	UINT8		0 to 1	0
Bits		**Name**	**Description**					
7:1		RESERVED	Unused.					
0		Retry enable	0: Disable the protection retry function 1: Enable the protection retry function					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	08h	Retry time	R/W	No	UINT16	ms	UINT16	3000
Bits		**Name**	**Description**					
15:0		Retry time	If protection retry is enabled and any protection is triggered, then after the protection retry time the motor returns to the operation enable state.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	09h	DC link limit upper threshold	R/W	No	UINT16	V	UINT16	56
Bits		**Name**	**Description**					
15:0		DC link limit upper threshold	If the DC link voltage exceeds this value, the VDCCON pin starts switching.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Ah	DC link limit lower threshold	R/W	No	UINT16	V	UINT16	52
Bits		**Name**	**Description**					
15:0		DC link limit lower threshold	If the DC link voltage is below this value, the VDCCON pin stops switching.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Bh	Error status	RO	TPDO	UINT16	-	-	0
Bits		**Name**	**Description**					
15:7		RESERVED	Unused.					
6		SENSOR_ERR	0: The position sensor is working normally 1: The position sensor is not working normally					
5		POS_LIMIT	0: The position is in the allowed range 1: The position is out of range					
4		OVERLOAD	0: Overload protection has not been triggered 1: Overload protection has been triggered					
3		VIN_LIMIT	0: VIN_LIMIT protection has not been triggered 1: VIN_LIMIT protection has been triggered					
2		LOCK	0: Lock protection has not been triggered 1: LOCK protection has been triggered					
1		UVLO	0: UVLO protection has not been triggered 1: UVLO protection has been triggered					
0		OCP	0: OCP has not been triggered 1: OCP has been triggered					

200Ch: Parameter Identification

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	01h	Identify method	R/W	No	UINT8	-	0-1	0
Bits		**Name**	**Description**					
7:1		RESERVED	Unused.					
0		Identify method	Sets the method for auto-tuning. 0: Range unlimited method 1: Range-limited method					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	02h	Round max	R/W	No	UINT16	round	UINT16	50
Bits		**Name**	**Description**					
15:0		Round max	Sets the maximum allowed revolutions for the motor to spin. It is used in the range-limited method to guarantee that the motor movement does not exceed the mechanical limits.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	03h	Round acceleration	R/W	No	UINT16	round	UINT16	10
Bits		**Name**	**Description**					
15:0		Round acceleration	Sets the allowed maximum revolutions during acceleration. This value should be below half of the identified max revolutions (200Ch-02h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	04h	Round J	R/W	No	UINT16	round	UINT16	10
Bits		**Name**	**Description**					
15:0		Round J	Sets the allowed maximum revolutions during identify inertia. This value should be less than half of the identified max revolutions (200Ch-02h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	05h	Identification status	RO	No	UINT8	-	-	0
Bits		**Name**	**Description**					
7:0		Identification status	Indicates the current identification status. 0: Idle 1: Preparation 2: Identifying phase resistor 3: Ready for identify inductor 4: Identifying d-axis inductor 5:Identifying q-axis inductor 6: Find theta bias 7: Identifying torque constant (range unlimited) 8: Identifying inertia (range unlimited) 9: Identifying inertia the second time (range unlimited) 10: Identify torque constant (range limited) 11: Identifying inertia (range unlimited) 12: Identify complete 13: Homing 14: Identify acceleration design 15: Identify error handling 16: identify error					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	06h	Identified Rs	RO	No	UINT32	mΩ	-	0
Bits		**Name**	**Description**					
31:0		Identified Rs	Indicates the identified phase resistance (in mΩ).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	07h	Identified Ld	RO	No	UINT32	uH	-	0
Bits		**Name**	**Description**					
31:0		Identified Ld	Indicates the identified motor d-axis inductance.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	08h	Identified Lq	RO	No	UINT32	µH	-	0
Bits		**Name**	**Description**					
31:0		Identified Lq	Indicates the identified motor q-axis inductance.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	09h	Identified Kt	RO	No	UINT32	mNm/A	-	0
Bits		**Name**	**Description**					
31:0		Identified Kt	Indicates the identified motor torque constant (in mNm/A).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	0Ah	Identified J	RO	No	UINT32	g x cm^2	-	0
Bits		**Name**	**Description**					
31:0		Identified J	Indicates the identified system inertia (in g x cm^2).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	0Bh	Identified B	RO	No	UINT32	mNm x s	-	0
Bits		**Name**	**Description**					
31:0		Identified B	Indicates the identified system friction constant in (mNm x s).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	0Ch	Identified Tf	RO	No	UINT32	mNm	-	0
Bits		**Name**	**Description**					
31:0		Identified Tf	Indicates the identified static friction torque of the system (in mNm).					

200Eh: Servo Internal Information

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	01h	Id	RO	TPDO	INT16	mA	INT16	0
Bits		**Name**	**Description**					
15:0		Id	Indicates the direct axis current of the motor. Should be close to 0 since the controller is using the $I_D = 0$ control method.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	02h	Iq	RO	TPDO	INT16	mA	INT16	0
Bits		**Name**	**Description**					
15:0		Iq	Sets the quadrature axis current of the motor, which is proportional to the motor output torque.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	03h	Ud	RO	TPDO	INT16	mV	INT16	0
Bits		**Name**	**Description**					
15:0		Ud	Sets the motor's direct axis voltage.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	04h	Uq	RO	TPDO	INT16	mV	INT16	0
Bits		**Name**	**Description**					
15:0		Uq	Sets the motor's quadrature axis voltage.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	05h	Torque	RO	TPDO	INT16	mNm	INT16	0
Bits		**Name**	**Description**					
15:0		Torque	Sets the motor's output torque, which is estimated by the torque observer.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	06h	Sensor position	RO	TPDO	UINT16	INC	UINT16	0
Bits		**Name**	**Description**					
15:0		Sensor position	Sets the angular sensor's raw data. The relationship between object value and real angle is ANGLE = Value / 65536 x 360.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	07h	Filtered position	RO	TPDO	UINT16	INC	UINT16	0
Bits		**Name**	**Description**					
15:0		Filtered position	Sets the angular sensor data after filter, which is also used as the position feedback of the position control loop.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	09h	Filtered speed	RO	TPDO	INT32	INC/s	INT32	0
Bits		**Name**	**Description**					
31:0		Filtered speed	Sets the motor speed after the internal filter, which is also used as the speed feedback for the speed control loop.					

2010h: INL Data

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2010h	01h~20h	INL data1 to INL data 32	RO	No	INT16	LSB	-	0
Bits		**Name**	**Description**					
15:0		INL calibration data	Indicates the INL calibration data, which is used to compensate for the position sensor's nonlinearity. This value is obtained by the INL calibration sequence.					

2030h: I/O Functions

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	01h	I/O1 function	RW	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		I/O 1 function	Selects the I/O 1 function. 0: Pend 1: Alarm 2: Brake 3: Point 2 Pend					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	02h	I/O 2 function	RW	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		I/O 2 function	Selects the I/O 2 function. 0: Homing enabled 1: Negative switch 2: Positive switch 3: Home switch 4: Multi-points 1 5: Multi-point 2 6: Multi-point 3					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	03h	I/O 3 function	RW	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		I/O 3 function	Selects the I/O 3 function. 0: Pend 1: Alarm 2: Brake 3: Point 1 Pend					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	04h	I/O 4 function	RW	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		I/O 4 function	Selects the I/O 4 function. 0: PUL/PWM 1: Negative switch 2: Positive switch 3: Home switch 4: Multi-point 1 5: Multi-point 2 6: Multi-point 3					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	05h	I/O 5 function	R/W	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		I/O 5 function	Selects the I/O 5 function. 0: DIR 1: Negative switch 2: Positive switch 3: Home switch 4: Multi-point 1 5: Multi-point 2 6: Multi-point 3					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	06h	I/O 6 function	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		I/O 6 function	Selects the I/O 6 function. 0: EN 1: Negative switch 2: Positive switch 3: Home switch					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	07h	I/O 7 function	R/W	No	UINT8	-	0 to 2	0
Bits		**Name**	**Description**					
7:0		I/O 7 function	Selects the I/O 7 function. 0: Pend 1: Alarm 2: Brake					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	08h	I/O 8 function	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		I/O 8 function	Selects the I/O 8 function. 0: EN 1: Negative switch 2: Positive switch 3: Home switch					

2031h: I/O Polarity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
Bits		**Name**	**Description**					
15:9		RESERVED	Unused.					
8		BRAKE pin polarity	0: Non-inverted 1: Inverted					
7		I/O 8 polarity	0: Non-inverted 1: Inverted					
6		I/O 7 polarity	0: Non-inverted 1: Inverted					
5		I/O 6 polarity	0: Non-inverted 1: Inverted					
4		I/O 5 polarity	0: Non-inverted 1: Inverted					
3		I/O 4 polarity	0: Non-inverted 1: Inverted					
2		I/O 3 polarity	0: Non-inverted 1: Inverted					
1		I/O 2 polarity	0: Non-inverted 1: Inverted					
0		I/O 1 polarity	0: Non-inverted 1: Inverted					

2032h: Enable Source

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2032h	00h	Enable source	R/W	No	UINT16	-	0 to 1	0
Bits		**Name**	**Description**					
0		Enable source	Select motor enable command source. 0: Data bus 1: ENA I/O signal					

2040h: Temperature

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2040h	00h	Temperature	RO	No	INT16	°C	-40 to +125	-
Bits		**Name**	**Description**					
15:0		Temperature	Indicates the PCB's temperature.					

2041h: OTP Threshold

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2041h	00h	OTP threshold	R/W	No	INT16	°C	-40 to +125	85
Bits		**Name**	**Description**					
15:0		OTP threshold	Sets the over-temperature protection (OTP) threshold.					

2042h: Overload Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	01h	Overload enable	R/W	No	UINT8	-	-	0
Bits		**Name**	**Description**					
15:1		RESERVED	Unused.					
0		OVERLOAD_EN	0: Disable overload protection 1: Enable overload protection					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	02h	Overload current threshold	R/W	No	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
15:0		Overload current threshold	Sets the overload protection threshold, which is given in thousandths of the motor rated current.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	03h	Overload time window	R/W	No	UINT16	ms	UINT16	1000
Bits		**Name**	**Description**					
15:0		Overload time window	If the controller detects that the motor current exceeds the overload current threshold for longer than the overload time window, overload protection is triggered. Set the time window to longer than 1s to allow the motor current to exceed the overload current threshold for a short time. This is useful for applications that require a fast response.					

2050h: Voltage Divider

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2050h	01h	Lower divider	R/W	No	UINT16	kΩ	1 to 65535	10
Bits		**Name**	**Description**					
15:0		Lower divider	Sets the voltage divider used for DC link voltage-sense lower resistor.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2050h	02h	Upper divider	R/W	No	UINT16	kΩ	1 to 65535	402
Bits		**Name**	**Description**					
15:0		Upper divider	Sets the voltage divider used for the DC link voltage-sense upper resistor.					

2060h: Electrical Gear Ratio

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2060h	01h	Numerator	R/W	No	UINT32	-	UINT32	1
Bits		**Name**	**Description**					
31:0		Numerator	Sets the electronic gear ratio numerator. Used together with Electronic gear ratio denominator (2060h-02h). The pulses/revolution are defined as 65536 x Electronic_Gear_Ratio_Numerator / Electronic_Gear_Ratio_Denominator.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2060h	02h	Denominator	R/W	No	UINT32	-	UINT32	1
Bits		**Name**	**Description**					
31:0		Denominator	Electrical gear ratio. Used together with Electronic gear ratio numerator (2060h-01h). The pulses/revolution are defined as 65536 x Electronic_Gear_Ratio_Numerator / Electronic_Gear_Ratio_Denominator.					

2070h: Homing Torque Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
Bits		**Name**	**Description**					
15:0		Homing torque	Sets the maximum motor output torque limit during torque limited homing method (object 6098h-00h equals -3 or -2). The homing torque should be set larger than the load torque of the motor during homing process. Otherwise, the motor may not reach the mechanical range limit.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	02h	Homing time	R/W	No	UINT16	ms	UINT16	500
Bits		**Name**	**Description**					
15:0		Homing time	If the motor stalls for a period of time (the homing time) in torque limit homing mode, then the mechanical limit is reached. The controller then treats the current position as the homing position.					

2080h: Impedance Controller Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	01h	Kp	R/W	RPDO	REAL32	-	-	0
Bits		**Name**	**Description**					
31:0		Kp	Sets the proportional gain for the impedance controller.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	02h	Ki	R/W	RPDO	REAL32	-	-	0
Bits		**Name**	**Description**					
31:0		Ki	Sets the integral gain for the impedance controller.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	03h	Kd	R/W	RPDO	REAL32	-	-	0
Bits		**Name**	**Description**					
31:0		Kd	Sets the differential gain for the impedance controller.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	04h	Filter cutoff frequency	R/W	No	REAL32	Hz	-	1000
Bits		**Name**	**Description**					
31:0		Filter cutoff frequency	Sets the filter cutoff frequency of the low-pass filter in impedance controller. Choose an appropriate filter bandwidth according to the test results. A higher filter bandwidth will introduce more speed feedback noise.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	05h	Joint torque limit	R/W	No	REAL32	Nm	-	0
Bits		**Name**	**Description**					
31:0		Joint torque limit	Sets the output torque limit of the impedance controller. This prevents the motor from outputting too much torque, which may damage the mechanical parts or the environment.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	06h	Motor current limit	R/W	RxPDO 4	REAL32	A	-	0
Bits		**Name**	**Description**					
31:0		Joint torque limit	Sets the output torque limit for the impedance controller. This prevents the motor from outputting too much torque, which may damage the mechanical parts of the environment.					

2101h: CAN Node ID

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2101	00h	CAN node ID	R/W	No	UINT8	-	1 to 127	0x02
Bits		**Name**	**Description**					
7:0		CAN node ID	Sets the node ID for the CAN bus. This parameter can be stored to the NVM, which allows multiple devices with different node IDs to be connected on the same data bus.					

2102h: CAN Bit Rate

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2101	00h	CAN bit rate	R/W	No	UINT16	kbps		1000
Bits		**Name**	**Description**					
15:0		CAN bit rate	Sets the bit rate used for CAN communication. The controller supports 10kbps, 20kbps, 50kbps, 125kbps, 250kbps, 500kbps and 1Mbps.					

2108h: Brake Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2108h	01h	Brake enable	R/W	No	UINT8	-	0-1	0
Bits		**Name**	**Description**					
7:0		Brake enable	0: Disabled. The motor turns off immediately after the disable operation command is received 1: Enabled. If the motor is in position control mode and the target position is reached, the brake turns off immediately. After the disable operation command is received, the motor continues to remain in position mode for the time defined by brake stop delay The brake has a turn-off time (about several ms). If the motor turns off when the disable operation command is received, the motor shaft may move during the turn-off delay time. This feature prevents that behavior. See Figure 23 on page 46 and Figure 24 on page 46 for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2108h	02h	Brake off speed	R/W	No	UINT16	rpm	0~1000	30
Bits		**Name**	**Description**					
15:0		Brake off speed	If the motor is running at a high speed and an error occurs (or the servo turns off), then the servo turns off immediately and waits for the speed to decrease. The brake turns off when the motor speed is below this value.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2108h	03h	Brake off delay	R/W	No	UINT16	ms	1 to 65535	1000
Bits		**Name**	**Description**					
15:0		Brake off delay	If the motor is running at a high speed and an error occurs (or the servo turns off), then the servo turns off immediately and waits for the speed to decrease. The brake turns off when the delay time exceeds this value.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2108h	04h	Brake stop delay	R/W	No	UINT16	ms	1 to 65535	1
Bits		**Name**	**Description**					
15:0		Brake stop delay	See Index 2108h-01h above for more details.					

6040h: Control Word

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	Yes	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:11		Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
10		Reserved	Unused.					
9		Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:4		Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
3		Enable operation	Enter operation mode.					
2		Quick stop	Enter quick stop mode.					
1		Enable voltage	No effect; the DC power is always enabled.					
0		Switch on	Enable the power stage switch.					

6041h: Status Word

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:14		Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
13:12		Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
9		Remote	If set, parameters may be modified by communication.					
8		Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on pages 21, 24, 26, 28, 31, 34, 38, 39, and 40.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, the driver is in the switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always set to 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs this bit is set.					
2		Operation enabled	Indicates if operation enabled mode is active.					
1		Switch on	Indicates if the driver switch is on.					
0		Ready to switch on	Indicates if the driver is ready to switch.					

605Ah: Quick Stop Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Ah	00h	Quick stop option code	R/W	No	INT16	-	INT16	2
Bits		**Name**	**Description**					
15:0		Quick stop option code	Determines the response if the quick stop function is executed. 0: Disable the drive function 1: Slow down ramp and transition into the switch on disabled state 2: Quick stop ramp and transition into the switch on disabled state 3: Current limit and transition into the switch on disabled state 4: Reserved 5: Slow down the ramp and stay in the quick stop active state 6: Slow the quick stop ramp and stay in the quick stop active state 7: Current limit and stay in quick stop active 8: Reserved					

605Dh: Halt Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Dh	00h	Halt option code	R/W	No	INT16	-	INT16	1
Bits		**Name**	**Description**					
15:0		Halt option code	0: Disable the drive function 1: Slow the down ramp and stay in the operation enable state 2: Execute the quick stop ramp and stay in the operation enable state 3: Current limit and stay in the operation enable state					

6060h: Modes of Operation

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6060h	00h	Operation modes	R/W	Yes	INT8	-	-4 to +10	0
Bits		**Name**	**Description**					
7:0		Operation mode	Selects the operating mode. -4: Auto-tuning mode -3: INL calibration mode -2: Rotor aligning mode 1: Profile position mode (PP) 3: Profile velocity mode (PV) 4: Profile torque mode (PT) 6: Homing mode (HOME) 7: Reserved 8: Cyclic synchronous position mode (CSP) 9: Cyclic synchronous velocity mode (CSV) 10: Cyclic synchronous torque mode (CST)					

6061h: Operation Modes Display

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6061h	00h	Operation modes display	RO	TPDO	INT8	-	-4 to +10	-
Bits		**Name**	**Description**					
7:0		Operation modes display	Shows the current operation mode. -4: Auto-tuning mode -3: INL calibration mode -2: Rotor aligning mode 1: Profile position mode (PP) 3: Profile velocity mode (PV) 4: Profile torque mode (PT) 6: Homing mode (HOME) 7: Reserved 8: Cyclic synchronous position mode (CSP) 9: Cyclic synchronous velocity mode (CSV) 10: Cyclic synchronous torque mode (CST)					

6062h: Position Demand Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6062h	00h	Position demand value	RO	TPDO	INT32	INC	INT32	-
Bits		**Name**	**Description**					
31:0		Position demand value	Indicates the position demand output of the trajectory generator to the position control loop (in INC). The driver module has 65536 INC/revolution.					

6063h: Position Actual Internal Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6063h	00h	Position actual internal value	RO	TPDO	INT32	INC	INT32	-
Bits		**Name**	**Description**					
31:0		Position actual internal value	Indicates the actual value of the position sensor, which is the feedback value of position control loop. It is the same as the position's actual value (6063h-00h).					

6064h: Position Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6064h	00h	Position actual value	RO	TPDO	INT32	INC	INT32	-
Bits		**Name**	**Description**					
31:0		Position actual value	Indicates the actual value of the position sensor, which is the feedback value of the position control loop.					

6065h: Following Error Window

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6065h	00h	Following error window	R/W	No	UINT32	INC	UINT32	182
Bits		**Name**	**Description**					
31:0		Following error window	Symmetrically defines a range of tolerated position values for the position demand value. If the position's actual value is out of the following error window, a following error occurs. A following error may occur if: • The motor is blocked • There is an unreachable profile velocity occurs • There are incorrect closed-loop parameters					

6066h: Following Error Timeout

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6066h	00h	Following error time out	R/W	No	UINT32	ms	UINT32	10
Bits		**Name**	**Description**					
15:0		Following error time out	If a following error occurs for longer than the defined timeout time, then “Status word”, bit[13] is set to 1. The motor continues running, and the user can determine the action in this condition.					

6067h: Position Window

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6067h	00h	Position window	R/W	No	UINT32	INC	UINT32	182
Bits		**Name**	**Description**					
31:0		Position window	Defines a symmetrical range of accepted relatively to the target position. If the actual value of the position sensor is within the position window, the target is considered to be reached.					

6068h: Position Window Time

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6068h	00h	Position window time	R/W	No	UINT16	ms	UINT32	10
Bits		**Name**	**Description**					
15:0		Position window time	If the actual position is within the position window during the defined position window time, “Status word”, bit[10] is set to 1.					

606Bh: Velocity Demand Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Bh	00h	Velocity demand value	RO	TPDO	INT32	INC/s	INT32	-
Bits		**Name**	**Description**					
31:0		Velocity demand value	Sets the output of the velocity trajectory generator for the velocity control loop.					

606Ch: Velocity Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Ch	00h	Velocity actual value	RO	TPDO	INT32	INC/s	INT32	-
Bits		**Name**	**Description**					
31:0		Velocity actual value	Indicates the actual motor velocity, which is the feedback input of the velocity control loop.					

606Dh: Velocity Window

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Dh	00h	Velocity window	R/W	No	UINT16	INC/s	UINT16	65536
Bits		**Name**	**Description**					
15:0		Velocity window	Monitors whether the target velocity has been reached. If the motor velocity is in the range for longer than the velocity window time, then the target value has been reached.					

606Eh: Velocity Window Time

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Eh	00h	Velocity window time	R/W	No	UINT16	ms	UINT16	10
Bits		**Name**	**Description**					
15:0		Velocity window time	If the difference between the target velocity (606Fh) and actual velocity (606Ch) is within the velocity window (606D) for longer than the velocity window time (606E), the target has been reached.					

606Fh: Velocity Threshold

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Fh	00h	Velocity threshold	R/W	No	UINT16	INC/s	UINT16	65536
Bits		**Name**	**Description**					
15:0		Velocity threshold	Sets the velocity threshold, which measures whether the motor is stationary. See the Velocity Threshold Time (6070h) section below for more details.					

6070h: Velocity Threshold Time

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6070h	00h	Velocity threshold time	R/W	No	UINT16	ms	UINT16	10
Bits		**Name**	**Description**					
15:0		Velocity threshold time	If the actual velocity (606Ch) exceeds the velocity threshold (606Fh) for longer than the velocity threshold time (6070h), the rotor is not stationary.					

6071h: Target Torque

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	100
Bits		**Name**	**Description**					
15:0		Target torque	Sets the input value for the torque controller trajectory generator.					

6072h: Max Torque

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6072h	00h	Max torque	R/W	No	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
15:0		Max torque	Sets the maximum allowable torque in the motor (in thousandths of the rated torque).					

6073h: Max Current

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6073h	00h	Max current	R/W	No	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
15:0		Max current	Sets the maximum allowed torque-creating current in the motor (in thousandths of the rated torque).					

6074h: Torque Demand Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6074h	00h	Torque demand value	RO	TPDO	INT16	‰	-3000 to +3000	-
Bits		**Name**	**Description**					
15:0		Torque demand value	Sets the torque trajectory generator output (in thousandths of the rated torque).					

6077h: Torque Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
Bits		**Name**	**Description**					
15:0		Torque actual value	Indicates the actual motor electrical torque output (in thousandths of the rated torque).					

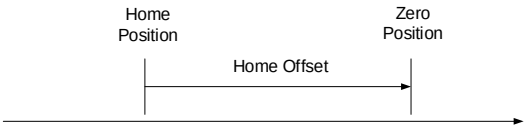
6078h: Current Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6078h	00h	Current actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
Bits		**Name**	**Description**					
15:0		Current actual value	Indicates the actual motor q-axis current (in thousandths of the rated torque).					

607Ah: Target Position

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Ah	00h	Target position	R/W	Yes	INT32	INC	INT32	0
Bits		**Name**	**Description**					
31:0		Target position	Sets the position that the motor should move to in profile position mode. The target position is interpreted as absolute or relative, depending on the absolute/relative flag in “Control word.” In CST mode, the target position is interpreted as an absolute value.					

607Ch: Home Offset

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Ch	00h	Home offset	R/W	No	INT32	INC	INT32	0
Bits		**Name**	**Description**					
31:0		Home offset	Indicates the difference between the zero position for the application and the machine home position (found during homing). Once homing is complete, the zero position is offset from the homing position by adding the home offset to the home position. All of the subsequent, absolute moves shall be taken relative to this new zero position. 					

607Dh: Software Position Limit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Dh	01h	Min position range limit	R/W	No	INT32	INC	INT32	-2^{31}
Bits		**Name**	**Description**					
31:0		Min software position limit	Defines the absolute position limit for the demanded position. The demanded position does not exceed the minimum software position limit.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Dh	02h	Max position range limit	R/W	No	INT32	INC	INT32	$2^{31}-1$
Bits		**Name**	**Description**					
31:0		Max software position limit	Defines the absolute position limit for the demanded position. The demanded position does exceed the maximum software position limit.					

607Eh: Polarity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Eh	00h	Polarity	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7		Position polarity	Indicates whether the demanded position value should be multiplied by 1 or -1. This flag has no influence on homing mode. This bit is used for profile position (PP) mode and cyclic sync position (CSP) mode. 0: Multiply by 1 1: Multiply by -1					
6		Velocity polarity	Use for profile velocity (PV) mode and cyclic sync velocity (CSV) mode. 0: Multiply by 1 1: Multiply by -1					
5:0		RESERVED	Unused.					

607Fh: Max Profile Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Fh	00h	Max profile velocity	R/W	No	UINT32	INC/s	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Max profile velocity	Sets the maximum allowed profile velocity in each direction. This object limits the target velocity in profile velocity mode.					

6080h: Max Motor Speed

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Fh	00h	Max motor speed	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Max motor speed	This object limits the maximum speed loop reference for speed control mode. It takes effect for both PV and CSV mode.					

6081h: Profile Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6081h	00h	Profile velocity	R/W	No	UINT32	INC/s	UINT32	655360
Bits		**Name**	**Description**					
31:0		Profile velocity	Returns the profile velocity, which is the velocity that is normally obtained at the end of the acceleration ramp during a profiled move. It is valid for both directions of motion.					

6083h: Profile Acceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6083h	00h	Profile acceleration	R/W	No	UINT32	INC/s2	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Profile acceleration	Sets the acceleration during a profile move.					

6084h: Profile Deceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6084h	00h	Profile deceleration	R/W	No	UINT32	INC/s2	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Profile deceleration	Sets the deceleration during a profile move.					

6085h: Quick Stop Deceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6085h	00h	Quick stop deceleration	R/W	No	UINT32	INC/s2	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Quick stop deceleration	Set the deceleration ramp during a halt or quick stop period.					

6086h: Motion Profile Type

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6086h	00h	Motion profile type	R/W	No	INT16	-	0	0
Bits		**Name**	**Description**					
15:0		Motion profile type	0: Linear ramp profile Others: Reserved					

6087h: Torque Slope

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6087h	00h	Torque slope	R/W	No	UINT32	‰/s	UINT32	3000
Bits		**Name**	**Description**					
15:0		Torque slope	Indicates the motor's actual q-axis current (in thousandths of the rated torque).					

6088h: Torque Profile Type

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6088h	00h	Torque profile type	R/W	No	INT16	-	0	0
Bits		**Name**	**Description**					
15:0		Torque profile type	0: Linear ramp profile Others: Reserved					

6098h: Homing Method

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6098h	00h	Homing method	R/W	No	INT8	-	0 - 35	1
Bits		**Name**	**Description**					
7:0		Homing method	-3: Homing clockwise with limited torque -2: Homing counterclockwise with limited torque -1: Reserved 0: No homing operation required 1~35: Methods 1–35 (see the Homing Mode section on page 22 for more details)					

6099h: Homing Speeds

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6099h	01h	Homing speed switch	R/W	No	UINT32	INC/s	UINT32	0
Bits		**Name**	**Description**					
31:0		Homing speed switch	Sets the homing speed during a search for switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6099h	02h	Homing speed zero	R/W	No	UINT32	INC/s	UINT32	0
Bits		**Name**	**Description**					
31:0		Homing speed zero	Sets the homing speed during a search for zero.					

609Ah: Homing Acceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
609Ah	00h	Homing acceleration	R/W	No	UINT32	INC/s2	UINT32	0
Bits		**Name**	**Description**					
31:0		Homing acceleration	Sets the acceleration and deceleration during homing.					

60B0h: Position Offset

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B0h	00h	Position offset	R/W	RPDO	INT32	INC	INT32	0
Bits		**Name**	**Description**					
31:0		Position offset	The position offset should be an absolute value. It can be used to control the motor with relative values with regard to the target position.					

60B1h: Velocity Offset

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B1h	00h	Velocity offset	R/W	RPDO	INT32	INC/s	INT32	0
Bits		**Name**	**Description**					
31:0		Velocity offset	In cyclic synchronous position mode, the velocity offset is the value for velocity feed-forward. This object is an optional selection, and can be used if a small following error is required.					

60B2h: Torque Offset

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
Bits		**Name**	**Description**					
15:0		Torque offset	Torque offset can be used as torque feed-forward in this mode. It is optional to perform cyclic synchronous position control.					

60C2h: Interpolation Time Period

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60C2h	01h	Interpolation time period value	R/W	No	UINT8	-	1 to 255	1
Bits		**Name**	**Description**					
7:0		Interpolation time period value	Determines the interpolation time period with 60C2h-02h. For example, if 60C2h-01h is 1 and 60C2h-02h is -3, then the interpolation time period is 1^(-3)s = 1ms. The loop calculation period is 50µs. There are 20 calculation cycles in one interpolation period, and the motor control module interpolates the position/velocity and torque command linearly to make the motion smoothly.					
Index	**Sub-Index**	**Description**	**Access**	**PDO**	**Data Type**	**Unit**	**Range**	**Default**
60C2h	02h	Interpolation time index	R/W	No	INT8	-	-4 to -3	-3
Bits		**Name**	**Description**					
7:0		Interpolation time index	See 60C2h-01h on page 91 for more details.					

60C5h: Max Acceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60C5h	00h	Max acceleration	R/W	No	UINT32	INC/s2	UINT32	2^{32}-1
Bits		**Name**	**Description**					
31:0		Max acceleration	Sets the maximum acceleration to prevent damage and limit the maximum acceleration to an acceptable value.					

60C6h: Max Deceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60C6h	00h	Max deceleration	R/W	No	UINT32	INC/s2	UINT32	2^{32}-1
Bits		**Name**	**Description**					
31:0		Max deceleration	Sets the maximum deceleration to prevent damage and limit the maximum deceleration to an acceptable value.					

60F4h: Following Error Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60F4h	00h	Follow error actual value	RO	TPDO	INT32	INC	INT32	-
Bits		**Name**	**Description**					
31:0		Following error actual value	Represents the actual value of the following error.					

60FFh: Target Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FFh	00h	Target velocity	R/W	Yes	IN32	INC/s	INT32	0
Bits		**Name**	**Description**					
31:0		Target velocity	Sets the input for the trajectory generator in profile velocity mode.					

Section 8. Connect To EtherCAT Master

There are multiple EtherCAT master solutions that can be used to connect and control EtherCAT slave devices. One example is TwinCAT from Beckhoff and the open-source EtherCAT master SOEM. For example, use the TwinCAT to show how to connect the devices to the EtherCAT master.

8.1 TwinCAT

To run TwinCAT, first install Visual Studio and TwinCAT to the computer with an Intel Ethernet card. Refer to the TwinCAT installation guide from Beckhoff for more information.

8.1.1 Connection Guide

1. Copy the ESI file to EtherCAT installation folder. For example, if using TwinCAT 3.1, the folder should be “<TwinCAT Install Dir>/3.1/Config/Io/EtherCAT”.
2. Connect the Ethernet port of the computer to the EtherCAT IN port of the first slave device.
3. If required, connect the EtherCAT OUT port of the first device to the EtherCAT IN port of the second device.
4. Power the slave devices.
5. Open TwinCAT by clicking the TwinCAT Icon at the right bottom corner and selecting “TwinCAT XAE”.

Figure 30: Open TwinCAT

6. Create a TwinCAT project.
   a. Select File > New > Project > TwinCAT XAE Project (XML format)
   b. Set the project name and select the location to which the file should be saved, the click “OK” to create the project.
7. Scan the devices.
   a. In Solution Explorer, right-click I/O > Devices, then choose Scan (see Figure 31 on page 94).

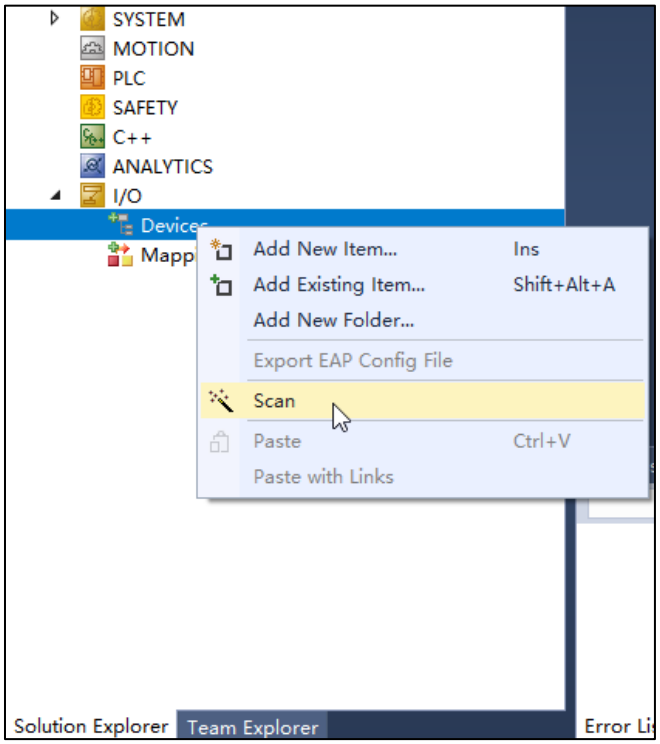


Figure 31: Scan Devices

b. If the computer has multiple available pots, select the correct Ethernet port (see Figure 32).

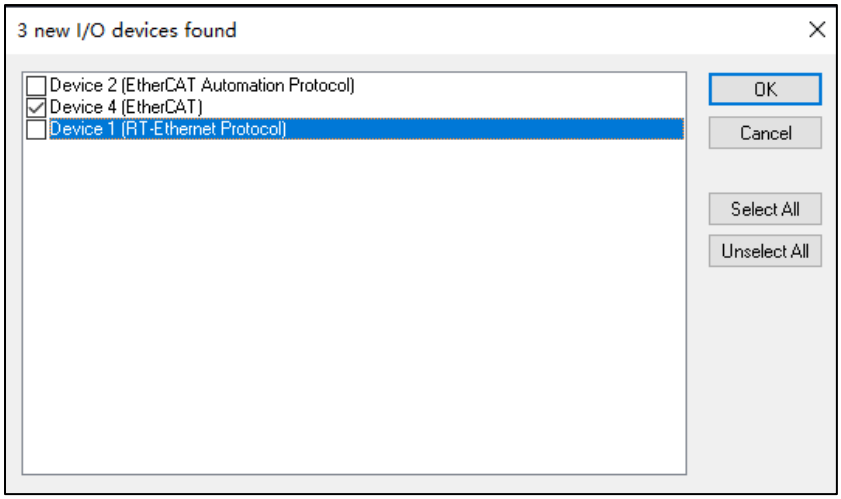


Figure 32: Select the Correct Ethernet port

c. Click “Yes” if TwinCAT asks if you want to scan boxes. After being successfully scanned, the devices should be listed (see Figure 33 on page 95).

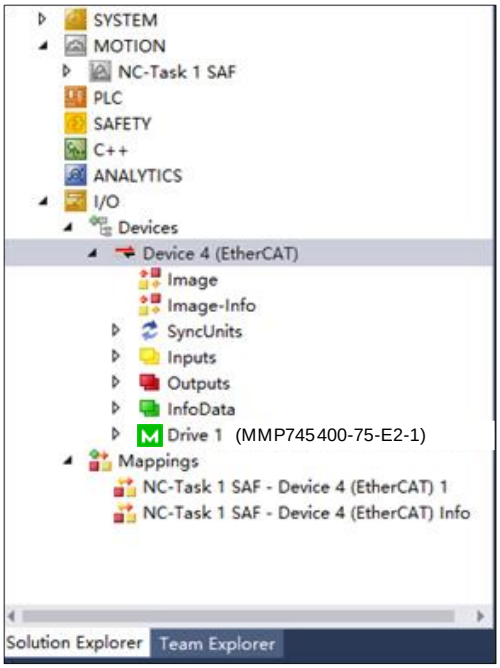


Figure 33: Device List

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	10/5/2022	Initial Release	-