EZmotion

User Guide

PCN and SCN C2 Series
Motor Driver Modules

Table of Contents

Overview

Applicable Products

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

Table 1: Applicable Products

Item	Applicable Part Number
1	MMP760400-75-C2-1
2	MMP760200-75-C2-1
3	MMP760100-75-C2-1
4	MMS760400-48-C2-1
5	MMS760200-48-C2-1
6	MMP740100-55-C2-1
7	MMP740050-55-C2-1
8	MMS740100-24-C2-1
9	MMS740050-24-C2-1

Section 1. Product Information

1.1 Introduction

The PCN series of motor driver modules are compact, fully integrated servo motor controllers that provide 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-function 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.

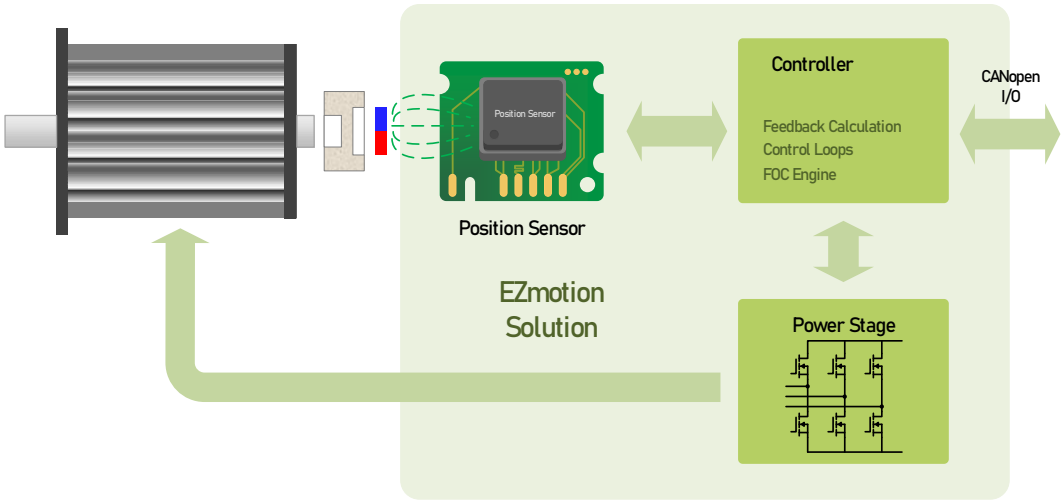


Figure 1: Motor Control Block Diagram

The SCN series of all-in-one smart motors are integrated servo motors with a compact size, providing a total solution for servo control applications. They integrate a servo motor, motor driver module, and I/O interface to provide a complete smart motor solution.

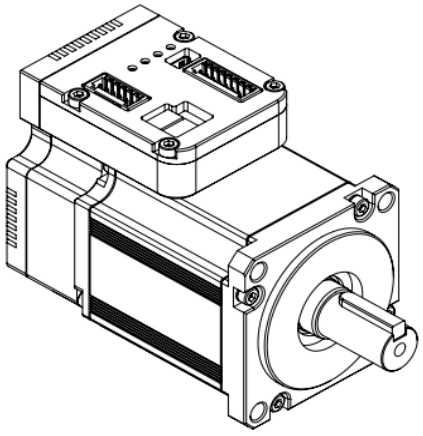


Figure 2: SCN Series All-in-One Smart Motor

The motor can operate in speed, velocity, or torque control modes. The motor is controlled through either a CAN interface with CANopen 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 debugging interface. Once the parameters have been optimized, they can be saved to the module's non-volatile memory (NVM).

To use the PCN series motor driver module with a servo motor, integrate the module and the motor with a magnet at the motor shaft. Connect a USB debugging interface or external pulse inputs to the module, 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
- Field-Oriented Control (FOC)
- CAN Interface with CANopen Protocol
- Supports CiA DSP402 Profile Position (PP), Profile Velocity (PV), Profile Torque (PT), Cyclic Synchronous Position (CSP), Cyclic Synchronous Velocity (CSV), Cyclic Synchronous Torque (CST), and Homing Modes
- Motor and System Parameter Identification and Loop Parameter Auto-Tuning
- AccuFilter for Low Noise and Vibration
- Advanced Motion Controller Enables Smooth Changes between Different Operation Modes
- Two Separate Notch Filters for Elastic Load Optimization
- External Input/Output (I/O) Interface Supports PUL/DIR, PWM/DIR, or A/B Signal Inputs
- General-Purpose I/O for Logic Signal Inputs or Outputs
- DC Voltage Detection and Limit Function
- Brake Control Logic
- Temperature-Sensing
- Rich Protection Functions
- Power, Alarm, and Communication Status Indication

Section 2. Communication

The PCN and SCN series products use the CANopen protocol to exchange messages between the motion controller and the motors.

The CANopen protocol is a popular industrial field bus. CANopen is defined and maintained by CAN in automation (CiA). The devices that follow the CANopen protocol can be connected together.

CANopen is based on a controller area network (CAN) bus. The CAN bus only defines the physical layer standard and data link layer standard in an open system interconnection (OSI) reference model. To use a CAN bus in a real system, define an application layer protocol. The CiA defines the communication profile (DS301, application layer and communication profile), and the device profile for motor control (DS402, device profile drives and motion control).

The module implements both CiA DS301 and DS402 protocols. The key features of CANopen communication profile implementation are listed below:

- 1 Service Data Object (SDO) Server, Supports SDO Download, SDO Upload, SDO Block Download, SDO Block Upload, and SDO Abort Function
- 4 Receive Process Data Objects (RPDOs), 4 Transmit Process Data Objects (TPDOs)
- Network Management (NMT) Object
- Boot-Up Object
- 4 Heartbeat Consumers, 1 Heartbeat Producer
- Emergency Object
- Synchronization Object (SYNC)
- Supports 10kbps, 20kbps, 50kbps, 125kbps, 250kbps, 500kbps, 800bps, and 1000kbps Baud Rate
- Communication Status LED Indication

2.1 CANopen Introduction

2.1.1 CAN Data Frame

The module uses a standard frame with an 11-bit identifier. In the CANopen protocol, it is treated as COB-ID, and it only uses a data frame to transmit information. Figure 3 shows the CANopen data frame format.

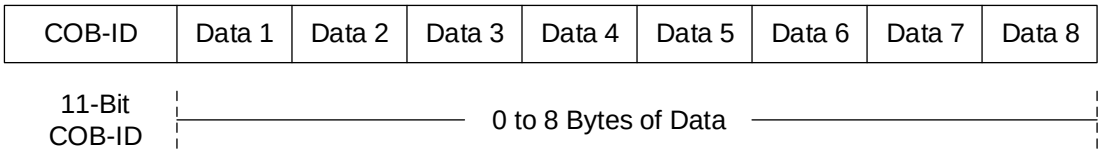


Figure 3: CANopen Data Frame

2.2 Object Dictionary

The object dictionary is a group of objects accessible via the CAN bus network following an orderly, pre-defined method.

Each object is addressed using a 16-bit index and an 8-bit sub-index.

The object dictionary is organized to several different groups (see Table 2 on page 12).

Table 2: Object Dictionary Structure

Index (Hex)	Object
0000h	Not used
0001h~0FFFh	Data types
1000h~1FFFh	Communication profile area
2000h~5FFFh	Manufacturer specific profile area
6000h~9FFFh	Standardized device profile area
A000h~BFFFh	Standardized interface profile area
C000h~FFFFh	Reserved for future use

The module uses the communication profile area (1000h~1FFFh) to implement communication-related objects defined in the DS301 protocol. The manufacturer-specific profile area (2000h~5FFFh) defines and implements vendor-specified motor control functions. The standardized device profile area (6000h~9FFFh) implements motor control functions defined in the DS402 protocol.

For each object, one or more sub-indexes are defined, which means that objects can have multiple parameters. Each parameter can only be accessed by one particular index and sub-index combination.

For example, for DS402's "Control word" object, it can be accessed using index 6040h and sub-index 00h.

2.3 COB-ID

The module uses CAN standard frames with an 11-bit identifier field. Each communication object has a unique COB-ID to indicate which communication object is transmitted.

Table 3 shows common, pre-defined COB-IDs.

Table 3: Pre-Defined COB-ID

Object	COB-ID
NMT	000h
SYNC	080h
Emergency	080h + NODEID
TPDO1	180h + NODEID
RPDO1	200h + NODEID
TPDO2	280h + NODEID
RPDO2	300h + NODEID
TPDO3	380h + NODEID
RPDO3	400h + NODEID
TPDO4	480h + NODEID
RPDO4	500h + NODEID
Default SDO Server to Client	580h + NODEID
Default SDO Client to Server	600h + NODEID
NMT Error Control	700h + NODEID

2.4 Hardware Connection

The physical medium for devices is a differentially driven, two-wire bus line with a common return according to the high-speed transmission specification in IOS 11898. Figure 4 on page 13 shows the CANopen network.

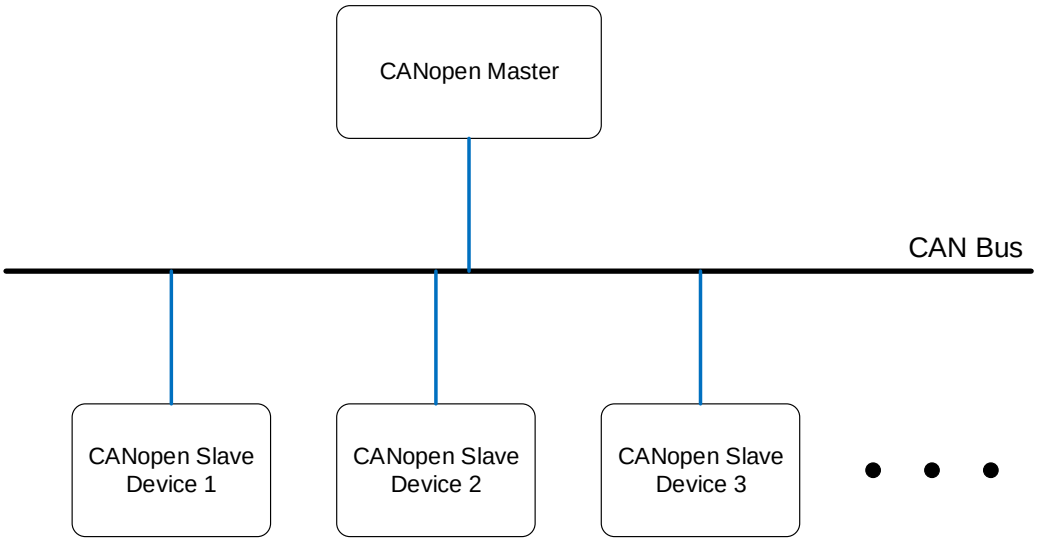


Figure 4: CANopen Network

2.5 Communication Objects

2.5.1 Network Management (NMT)

Network management (NMT) is used for an NMT master to control the NMT slave devices. It follows a master-slave structure. Through the NMT object, nodes are initialized, started, monitored, reset, or stopped. The device's communication status can be one of the following: stopped, pre-operational, operational, and initialization.

Figure 5 shows the NMT communication protocol.

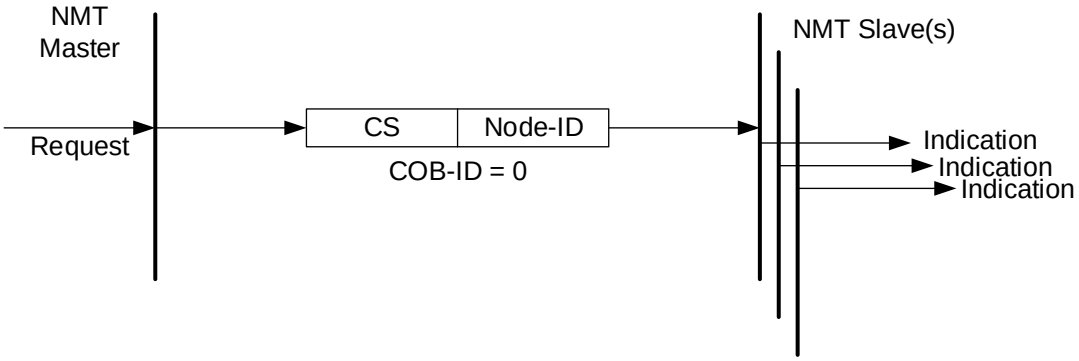


Figure 5: NMT Communication Protocol

Table 4 shows the relationship between NMT command specifier (CS) and the NMT protocol.

Table 4: NMT Protocols Definition

CS	Protocol
1	NMT start remote node.
2	NMT stop remote node.
128	Enter pre-operational mode.
129	Reset node.
130	Reset communication protocol.

Figure 6 on page 14 shows the device's state diagram.

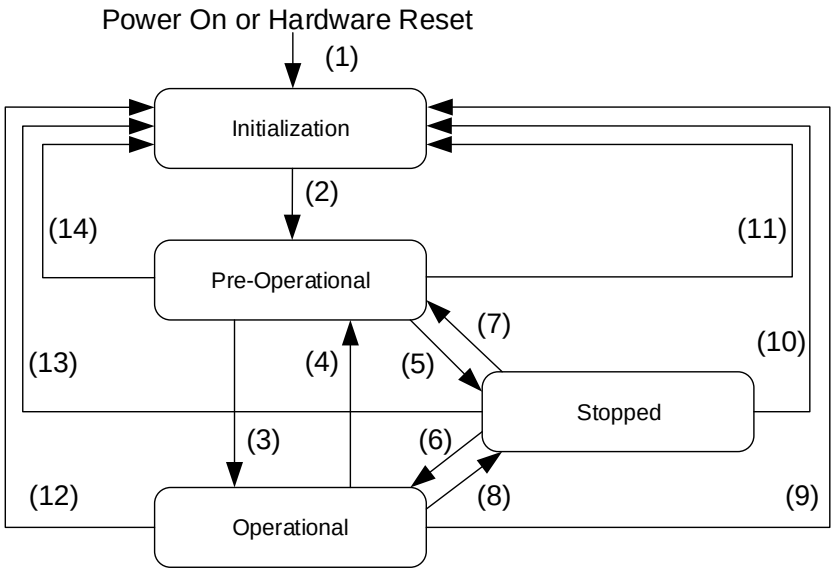


Figure 6: Device State Diagram

Table 5 shows the triggers for the state transitions in Figure 6.

Table 5: Trigger for State Transition

Transition	Trigger Command
1	At power on, the initialization state is entered automatically.
2	Initialization finished. Enter the pre-operational state automatically.
3, 6	Start the remote node command.
4, 7	Enter the pre-operational state command.
5, 8	Stop the remote node command.
9, 10, 11	Reset the node command.
12, 13, 14	Reset the communication command.

Certain objects are not enabled in each state (see Table 6)

Table 6: States and Communication Objects

	Initialization	Pre-Operational	Operational	Stopped
PDO	-	-	✓	-
SDO	-	✓	✓	-
SYNC	-	✓	✓	-
Time Stamp	-	✓	✓	-
Emergency	-	✓	✓	-
Boot-Up	✓	-	-	-
NMT	-	✓	✓	✓

2.5.2 NMT Error Control

Boot-Up

The boot-up protocol signals that an NMT slave has entered the pre-operational state after the initialization state.

Heartbeat

The heartbeat protocol monitors the status of a node. A heartbeat producer transmits a heartbeat message cyclically. One or more heartbeat consumers receive the indication. The relationship between the producer and consumer can be configured via the object dictionary. The heartbeat consumer monitors the reception of the heartbeat data to ensure it has been received within the heartbeat consumer time. If the heartbeat is not received within the heartbeat consumer time, a heartbeat event is generated.

Both the boot-up protocol and heartbeat protocol follow the same producer-consumer protocol (see Figure 7).

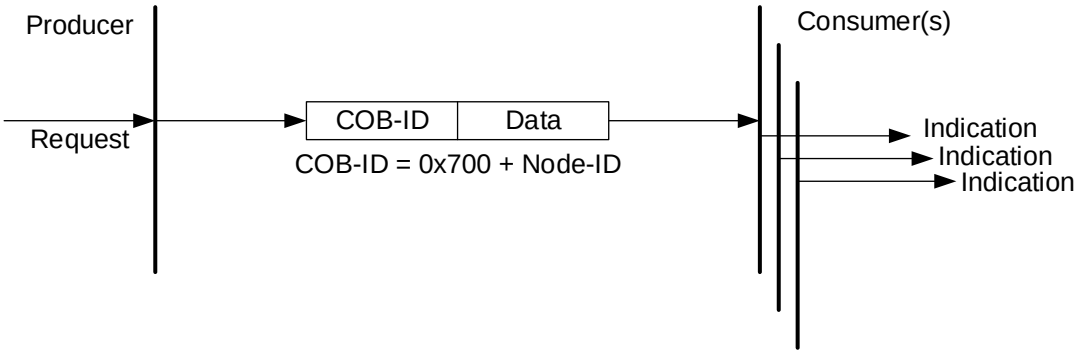


Figure 7: Boot-Up and Heartbeat Protocol

The data indicates the node status (see Table 7).

Table 7: Node Status Code

Data	Status
0	Boot-up
4	Stopped
5	Operational
127	Pre-operational

2.5.3 Service Data Object (SDO)

Service data object (SDO) is a technology that can access all of the entries in a device's object dictionary. SDO uses a client/server model. The service is requested by a client node, and the server node responds to the request. For the protocol details, refer to the CiA DS301 document.

With SDO, the client can download and upload an object dictionary to or from the device to configure the device. SDO is typically used to configure the device parameters. Figure 8 on page 16 shows the flowchart for the network initialization process.

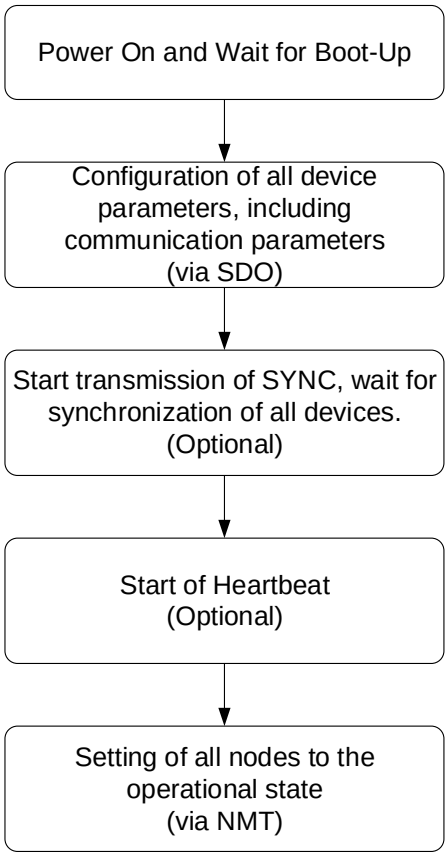


Figure 8: Network Initialization Process Flowchart

2.5.4 Process Data Object (PDO)

Process data objects (PDOs) are used for the real-time data transfer. PDOs use a producer-consumer model. When compared to SDO, PDOs do not need a response frame, and the data length can be between 1 byte and 8 bytes. PDOs are faster than SDO. Figure 9 shows the PDO protocol.

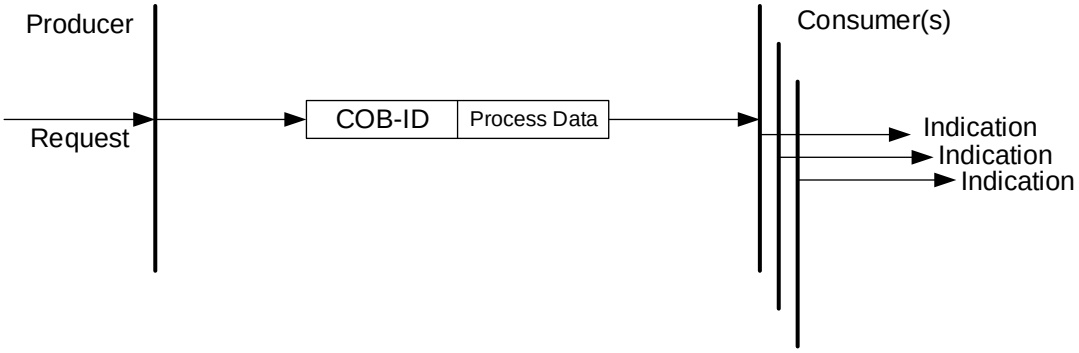


Figure 9: PDO Protocol

There are two kinds of PDOs: transmit process data object (TPDO) and receive process data object (RPDO).

For a TPDO, the device produces a PDO. The TPDO communication parameters are defined by objects 1800h~1803h, which define the transmit type, inhibit time, and event time. The TPDO mapping parameters are defined by objects 1A00h~1A03h, and they define the objects to which each process data byte is mapped. For more details, refer to the CiA DS301 document.

For an RPDO, the device is a PDO consumer. The RPDO communication parameters are defined by objects 1400h~1403h, and they define the RPDO's transmit type. The RPDO mapping parameters are defined by objects 1600h~1603h, and they define the objects to which each process data byte is mapped. When receiving an RPDO, the device maps the corresponding data to the mapped objects. For more details on RPDO, refer to the CiA DS301 document.

Figure 10 shows the process to configure the PDO.

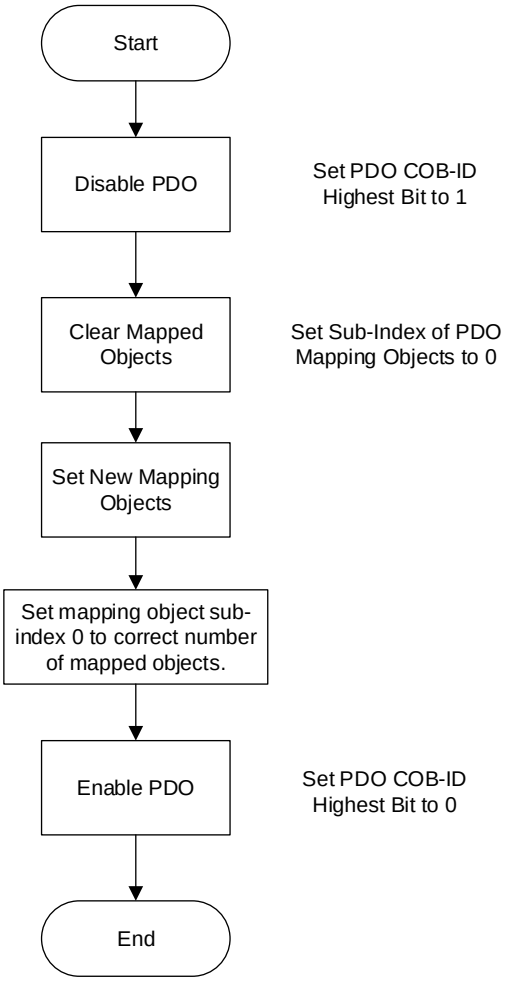


Figure 10: PDO Mapping Configuration

2.5.5 SYNC

The synchronization object (SYNC) is broadcasted periodically by the SYNC producer. The SYNC provides the basic network clock. The time period between the SYNCs is specified by the standard parameter communication cycle period.

2.5.6 Emergency

Emergency objects are triggered when the device experiences an internal error. Emergency uses a producer-consumer model. The device acts as an emergency producer. The data frame, defined as 8 bytes of data, contains the emergency error code, error register (1001h), and manufacturer-specific error field to make it simple to identify the emergency (see Table 8 on page 18).

Table 8: Emergency Object Data

Byte	0	1	2	3	4	5	6	7
Content	Emergency error code (See CiA DS301 for detail)		Error register (object 1001h)	Manufacturer-specific error field				

2.5.7 EDS File

Electronic data sheets (EDS) provide a standardized way to document and describe all the device's object dictionaries. This simplifies CANopen network configuration, and the software developer can handle an EDS following a standard method.

In an EDS file, the file information, device information, and object dictionary are defined. For more details about EDS, refer to CiA DS306 (electronic data sheet specification for CANopen).

Section 3. Operational Mode

3.1 State Machine

3.1.1 Function Description

The module uses a finite state machine to manage the motor controller's state transitions. The state is changed according to the current state, control word or local signals, and fault signals. Figure 11 shows the finite state automation diagram.

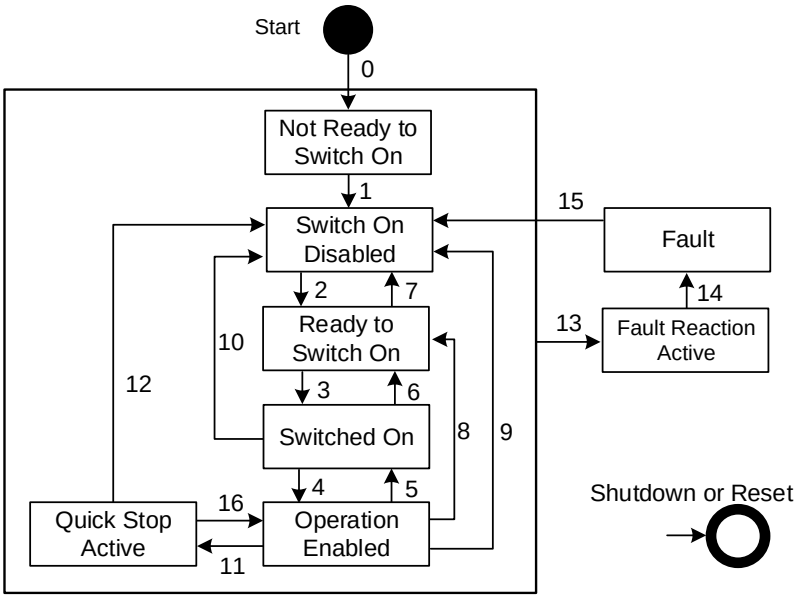


Figure 11: Finite State Automation

Table 9 lists the transition events and actions.

Table 9: Transition Events and Actions

Transition	Event(s)	Action(s)
0	Automatic transition after power-on or reset	Perform self-initialization and self-test.
1	Automatic transition	Communication is activated.
2	Shutdown command	None.
3	Switch-on command	Power stage switches 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 has started.
12	Disable voltage command or quick stop finished	Power stage switches 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 10 lists the relationship between certain transition events and “Control word”, where “0” means that data for this bit is set to 0, “1” means the data for this bit is set to 1, and “x” means that the value can be 0 or 1.

Table 10: Command Coding

Command	“Control Word” Bits					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 to switch on is disabled (see Figure 11 on page 19). 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” and “Enable operation” command) 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	R/W	Yes	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-

3.2 Profile Position (PP) Mode

3.2.1 Function Description

Profile position (PP) 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 12 shows the overall structure for this mode.

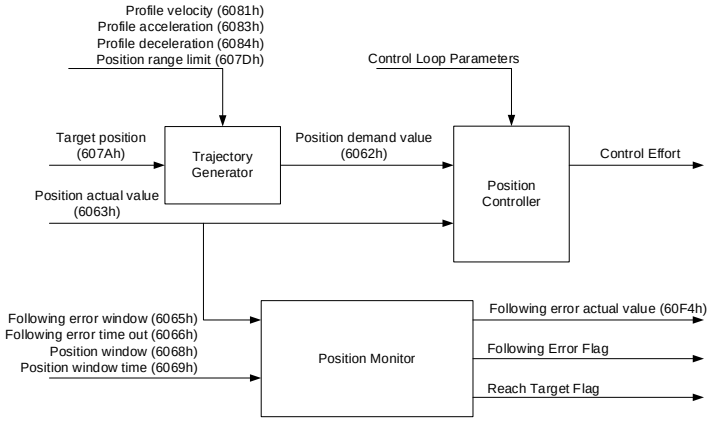


Figure 12: Profile Position Mode Block Diagram

The module uses a trapezoidal profile, with a constant acceleration and deceleration between two set points (see Figure 13).

If the profile velocity (set via 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 (set via 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 (set via 6084h), the motor velocity decreases, so that the velocity is zero once the target position is reached.

If a new position command is issued while the motor speed is decreasing, the trajectory generator increases the motor speed again to ensure that the motor reaches the target position as soon as possible.

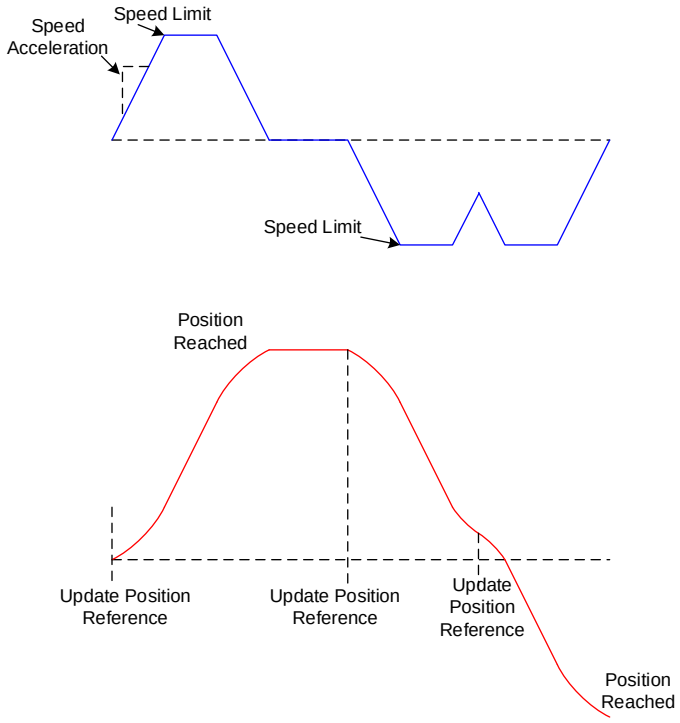


Figure 13: Profile Position Trajectory Generator

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 limit	R/W	No	INT32	INC	INT32	-2^{31}
	02h	Max position 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

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 is still in progress					
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 the position 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. 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

For this example, move the motor position to 10 revolutions and 0 degrees, then change it to 20 revolutions and 0 degrees in PP mode.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x01	Set the mode to profile position mode.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on and enable operation command.
4	607Ah-00h	0x000A0000	Set the target position to 10 rounds and 0 degrees.
5	6040h-00h	0x001F	The new set point is active.
6	6041h-00h	bit[10]	Check the target reach flag.
7	607Ah-00h	0x00140000	Set the target position to 20 rounds and 0 degrees.
8	6040h-00h	0x000F	Clear the new set point active bit.
9	6040h-00h	0x001F	The new set point is 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 14).

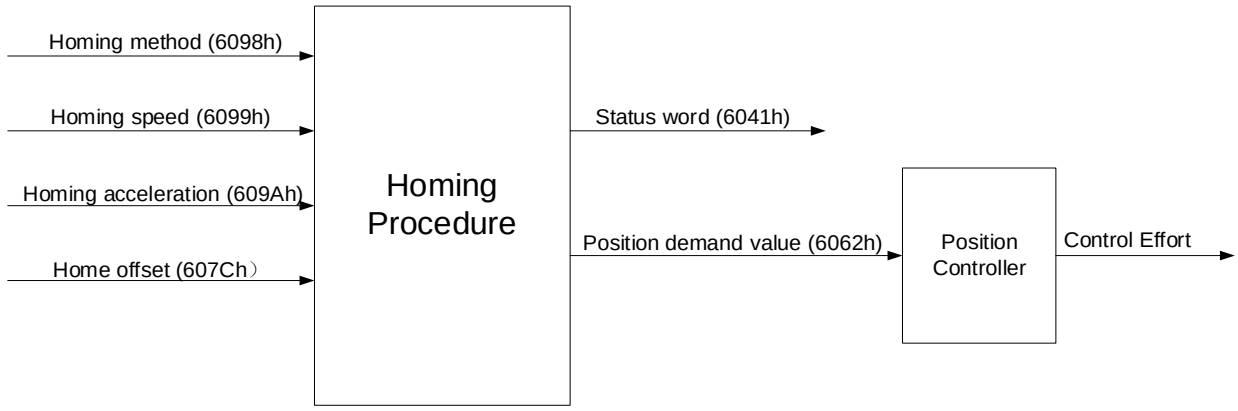


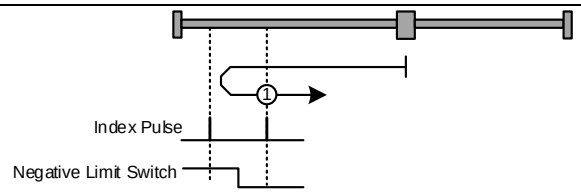
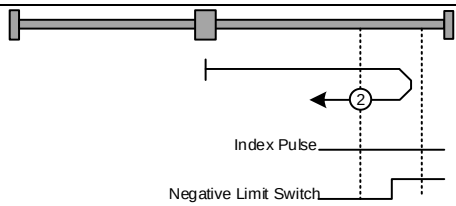
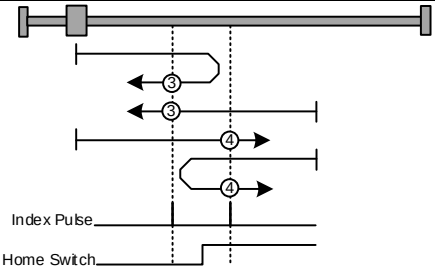
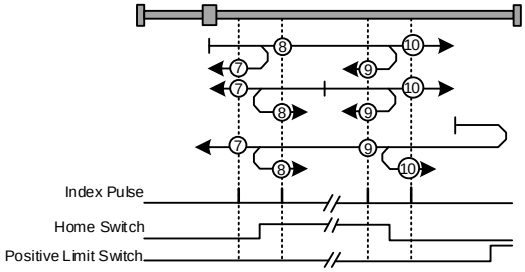
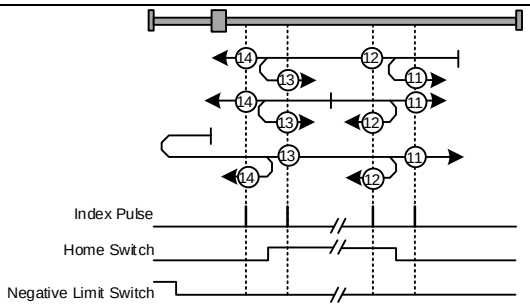
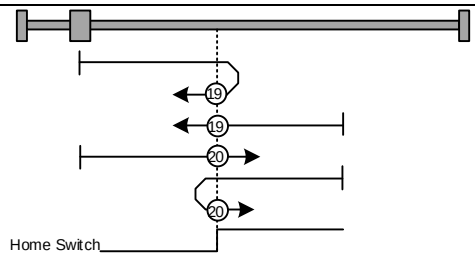
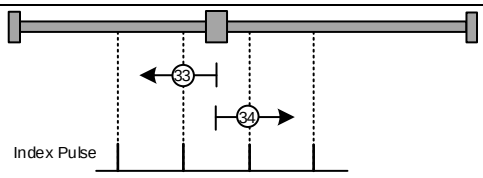
Figure 14: Homing Mode Block Diagram

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 11 lists the description and diagram for each method.

Table 11: 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
2070h	02h	Homing time	R/W	No	UINT16	ms	UINT16	500
2070h	03h	Power-on homing enable	R/W	No	UINT8	-	UINT8	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	-
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 is in progress)					
11		Internal limit active	1: The internal limit has been reached 0: The internal limit has not been 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 homing method 1.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x06	Set the homing mode.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on + enable operation command.
4	6098h-00h	0x01	Set the homing method to 1.
4	6099h-01h	0x00020000	Set the homing speed switch to 120rpm.
5	6099h-02h	0x00010000	Set the homing speed switch to 60rpm.
6	609Ah-00h	0x00320000	Set the homing acceleration to 3000rpm/s.
7	6040h-00h	0x001F	Enable homing operation.

3.4 Profile Velocity (PV) Mode

3.4.1 Function Description

In profile velocity (PV) 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 “Status word” (see Figure 15).

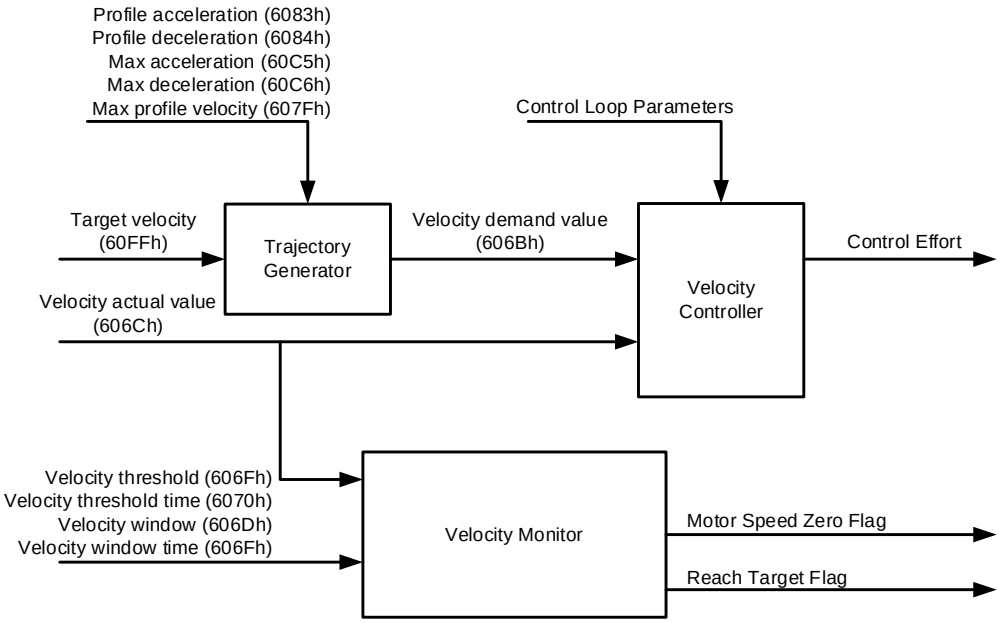


Figure 15: Profile Velocity Mode Block Diagram

A trapezoidal profile is supported (see Figure 16). 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.

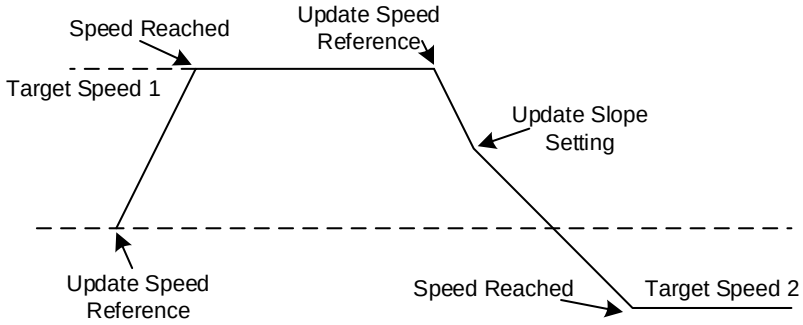


Figure 16: Trapezoidal Speed Profile

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 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		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 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.

3.4.4 Simple Example

For this example, set the motor velocity to 1000rpm in PV 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 (PT) Mode

3.5.1 Function Description

Profile torque (PT) 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 17 shows the PT 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 demanded value and the torque's actual value.

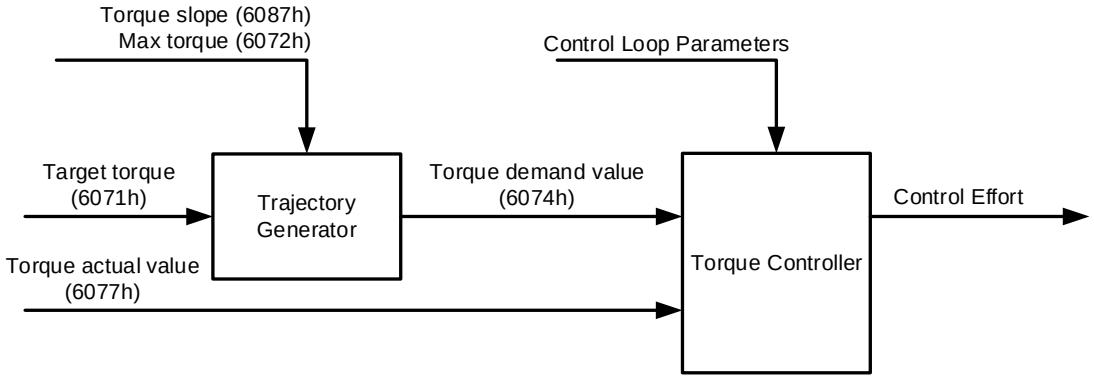


Figure 17: Profile Torque Mode Functional Block Diagram

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	R/W	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 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.

3.5.4 Simple Example

For this example, run the motor in PT mode with a 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 and enable operation command.

3.6 Cyclic Synchronous Position (CSP) Mode

3.6.1 Function Description

In cyclic synchronous position (CSP) mode, the trajectory generator is located in the control device. The controller provides a target position to the driving device. The additional velocity and torque values can be provided by the control system to allow for velocity and torque feed-forward. Figure 18 shows the controller block diagram.

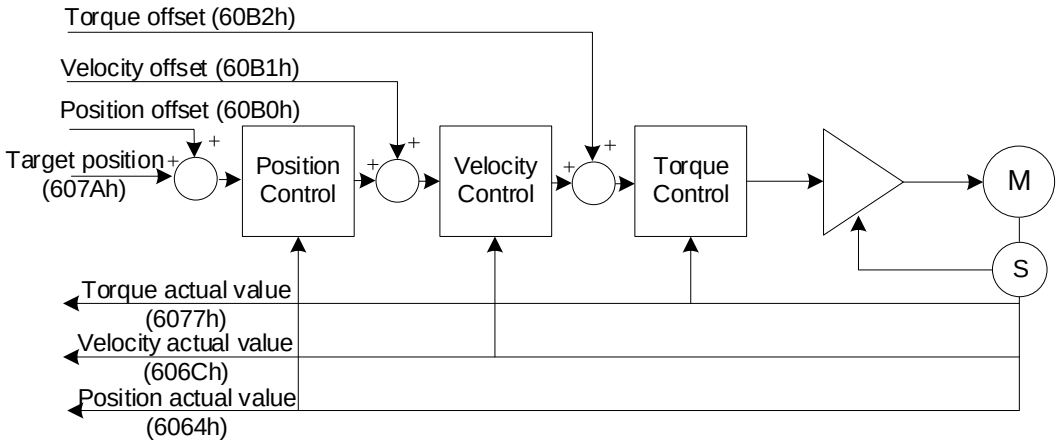


Figure 18: Cyclic Synchronous Position Mode Block Diagram

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	Modes of operation	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Modes of operation 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

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: The target position is used as the input for the position control loop 0: The target position is ignored					
11		Internal limit active	If the 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 (CSV) Mode

3.7.1 Function Description

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

Figure 19 on page 32 shows the CSV mode controller block diagram.

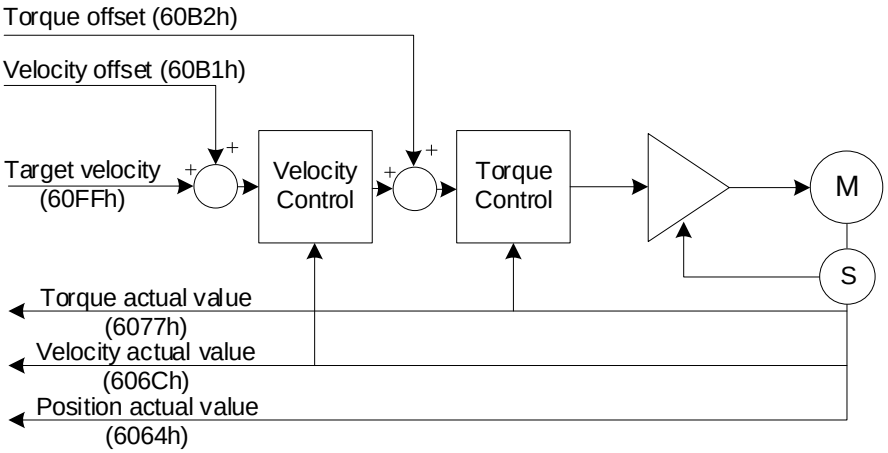


Figure 19: Cyclic Synchronous Velocity Mode Block Diagram

The “Interpolation time period value” (60C2h) command defines the time period between two target velocity updates, 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: The target position is used as the input for the position control loop 0: The target position is 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 (CST) Mode

3.8.1 Function Description

In cyclic synchronous torque (CST) mode, the motion controller provides a target torque to the motor driver module that performs torque control. Optionally, an additional torque value can be provided by the motion controller to allow for a second torque source. Figure 20 shows the block diagram for CST mode.

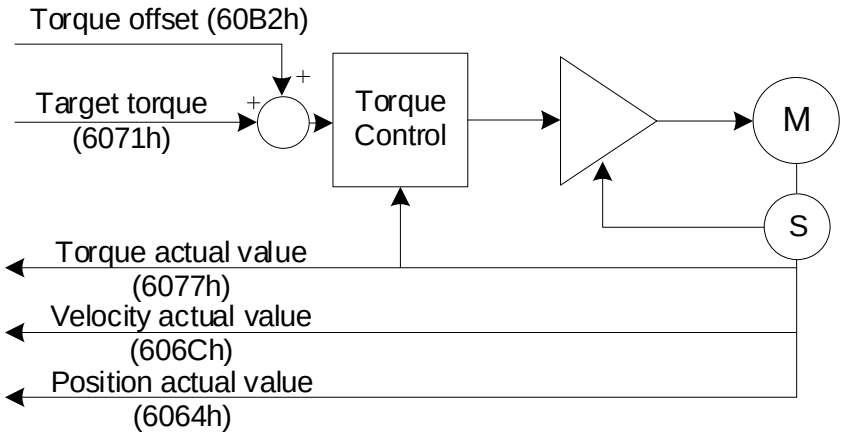


Figure 20: Cyclic Synchronous Torque Mode Block Diagram

The “Interpolation time period value” (60C2h) command defines the time period between two target velocity updates, 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	Modes of operation	R/W	Yes	INT8	-	-4 to +10	0
6061h	00h	Modes of operation 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

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: The target position is used as the input for the position control loop 0: The target position is 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, 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 I/O-Controlled Multi-Position Mode

3.9.1 Function Description

I/O-controlled multi-position mode supports changing the target position according to the I/O signal levels. To use this mode, some of the I/Os must be selected as Multi-Point 1, Multi-Point 2 and Multi-Point 3. For the I/O function definitions, see the 2030h-01h section on page 79 and the 2030h-10h section on page 82.

The target position, profile velocity, profile acceleration, and profile deceleration can be set separately for each stage. Table 12 on page 35 shows the relationship between the I/O levels and selected target velocity. For example, when Multi-Point 3 is 0, Multi-Point 2 is 1, and Multi-Point 1 is 1, stage 2 is selected. The motor moves as 2111h-02h, 2112h-02h, and 2114h-02h in the defined profile.

To use I/O control as the system enable source, set “Enable source” (2032h), bit[0] to 1, then the start/stop of the motor can be controlled by the I/O level.

Table 12: Relationship between I/O Levels and Selected Stage Number

Multi-Point3	Multi-Point2	Multi-Point1	Stage number
0	0	0	No change, remains at the previous selection
0	0	1	0
0	1	0	1
0	1	1	2
……			
1	1	1	6

3.9.2 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	DI1 function	R/W	No	UINT8	-	0 to 6	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 6	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 6	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
	05h	DI5 function	R/W	No	UINT8	-	0 to 4	4
	06h	DI6 function	R/W	No	UINT8	-	0	0
	07h	DI7 function	R/W	No	UINT8	-	0	0
	08h	DI8 function	R/W	No	UINT8	-	0	0
	09h	DO1 function	R/W	No	UINT8	-	0 to 3	0
	0Ah	DO2 function	R/W	No	UINT8	-	0 to 3	0
	0Bh	DO3 function	R/W	No	UINT8	-	0	0
	0Ch	DO4 function	R/W	No	UINT8	-	0 to 3	3
	0Dh	DO5 function	R/W	No	UINT8	-	0	0
	0Eh	DO6 function	R/W	No	UINT8	-	0	0
	0Fh	DO7 function	R/W	No	UINT8	-	0	0
	10h	DO8 function	R/W	No	UINT8	-	0	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Command source	R/W	No	UINT16	-	-	0
2110h	00h~06h	Multi-target position	R/W	No	INT32	INC	INT32	0
2111h	00h~06h	Multi-profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2112h	00h~06h	Multi-profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2113h	00h~06h	Multi-profile velocity	R/W	No	UINT32	INC/s	UINT32	0

3.9.3 Simple Example

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x03	Set the mode to profile velocity mode.
2	2002h-08h	0x04	Set the command type to I/O.
3	2030h-(01h~10h)	-	Select the I/O functions. At least one multi-point function should be selected.
4	2031h-00h	-	Select the I/O polarities according to the requirements.
5	2110h-(00h~06h)	-	Set the target position for each stage.
6	2111h-(00h~06h)	-	Set the profile acceleration for each stage.
7	2112h-(00h~06h)	-	Set the profile deceleration for each stage.
8	2113h-(00h~06h)	-	Set the profile velocity for each stage.
9	200Dh-00h	0x65766173	Store the parameters to the NVM.

After repowering the motor, it should be configured to I/O-controlled multi-position mode. Pull the ENA signal high to start the motor, then change the I/O levels of Multi-Point1, Multi-Point2, and Multi-Point3. The motor moves according to the pre-defined profile.

3.10 I/O-Controlled Multi-Velocity Mode

3.10.1 Function Description

I/O-controlled multi-velocity mode supports changing target velocity according to the I/O signal levels. To use this mode, some of the I/Os must be selected as Multi-Point 1, Multi-Point2 and Multi-Point3. For the I/O function definitions, see the 2030h-01h section on page 79 and the 2030h-10h section on page 82.

The target velocity, profile acceleration and profile deceleration can be set separately for each stage. Table 12 on page 35 shows the relationship between the I/O levels and selected target velocity. For example, when Multi-Point3 is 0, Multi-Point2 is 1, and Multi-Point1 is 1, stage 2 is selected. The motor moves as 2111h-02h, 2112h-02h, and 2114h-02h in the defined profile.

To use I/O control as the system enable source, set “Enable source” (2032h), bit[0] to 1, then the start/stop of the motor can be controlled by the I/O level.

3.10.2 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	DI1 function	R/W	No	UINT8	-	0 to 6	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 6	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 6	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
	05h	DI5 function	R/W	No	UINT8	-	0 to 4	4
	06h	DI6 function	R/W	No	UINT8	-	0	0
	07h	DI7 function	R/W	No	UINT8	-	0	0
	08h	DI8 function	R/W	No	UINT8	-	0	0
	09h	DO1 function	R/W	No	UINT8	-	0 to 3	0
	0Ah	DO2 function	R/W	No	UINT8	-	0 to 3	0
	0Bh	DO3 function	R/W	No	UINT8	-	0	0
	0Ch	DO4 function	R/W	No	UINT8	-	0 to 3	3
	0Dh	DO5 function	R/W	No	UINT8	-	0	0
	0Eh	DO6 function	R/W	No	UINT8	-	0	0
	0Fh	DO7 function	R/W	No	UINT8	-	0	0
	10h	DO8 function	R/W	No	UINT8	-	0	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Command source	R/W	No	UINT16	-	-	0
2111h	00h~06h	Multi-profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2112h	00h~06h	Multi-profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2114h	00h~06h	Multi-target velocity	R/W	No	INT32	INC/s	INT32	0

3.10.3 Simple Example

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x03	Set the mode to profile velocity mode.
2	2002h-08h	0x04	Set the command type to I/O.
3	2030h-(01h~10h)	-	Select the I/O functions. At least one multi-point function should be selected.
4	2031h-00h	-	Select the I/O polarities according to the requirements.
5	2111h-(00h~06h)	-	Set the profile acceleration for each stage.
6	2112h-(00h~06h)	-	Set the profile deceleration for each stage.
7	2114h-(00h~06h)	-	Set the target velocity for each stage.
8	200Dh-00h	0x65766173	Store the parameters to the NVM.

After repowering the motor, it should be configured to I/O-controlled multi-position mode. Pull the ENA signal high to start the motor, then change the I/O levels of Multi-Point1, Multi-Point2, and Multi-Point3. The motor moves according to the pre-defined profile.

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 must only set a few basic motor and driver parameters (e.g. 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. The loop control parameters are also updated according to the identified results. Figure 21 shows the block diagram.

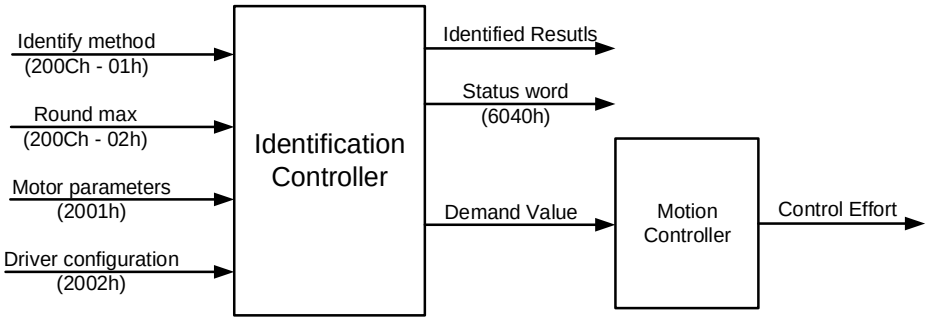


Figure 21: Parameter Identification Block Diagram

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 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		Auto-tuning status	1: Finished 0: Ongoing 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 a range-limited method. The motor rated current is 9A, the rated voltage is 36V, the rated speed is 3000rpm, and the number of 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. Set the acceleration and deceleration revolutions to 10, and set the identify inertia revolution to 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 revs 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 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 to compensate the INL.

4.2.1 Function Description

To obtain the angle error between the sensor angle and the real mechanical angle, determine the reference angle. The driver module controls the motor to multiple even divided points in one mechanical revolution, and then records the angle error between the magnet sensor and mechanical angle (see Figure 22). The driver module generates a lookup table based on the angle error and uses the lookup table to compensate the INL during operation.

Use MotionLAB software to perform the INL calibration.

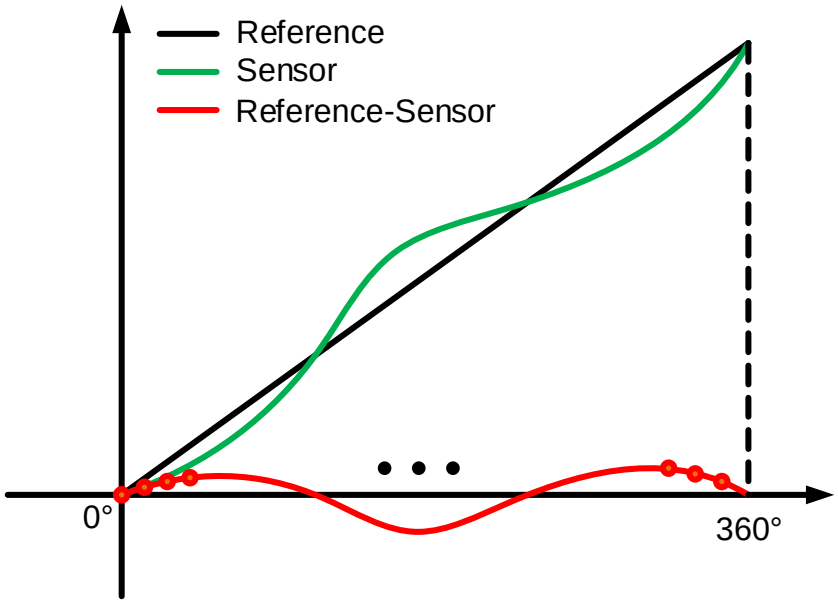


Figure 22: INL Calibration Principle

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

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 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.					

4.3 Rotor Alignment

4.3.1 Function Description

To detect the rotor position, attach a magnet at the motor's shaft (see Figure 23). 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's biased angle compared to the rotor's permanent magnet flux.

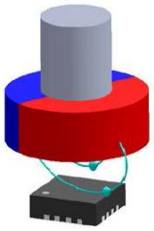


Figure 23: Sensing the Rotor Position

The device implements the find 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 GUI software provides an automatic theta-bias function. After setting the biased current, send the find theta bias command. The controller should automatically follow the necessary steps.

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 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		Rotor aligning status	1: Rotor aligning finished 0: Rotor aligning is ongoing or has not started					
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 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.					

4.3.4 Simple Example

For this example, perform rotor alignment using a 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 biased current to 500‰ of the rated current.
2	6040h-00h	0x0006	Shutdown command.
3	6040h-00h	0x000F	Switch on and enable operation command.
4	6040h-00h	0x080F	Enable rotor alignment.
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

For applications that need a simple control interface (e.g. 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 can be 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.

In PV mode, the real motor speed is the target velocity multiplied by the PWM duty cycle.

In PT 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 an excellent adjustment resolution. The DIR input can control the velocity or torque direction. The polarity of the DIR input signal can be selected via “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 inputted 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 A/B signal logic (see Figure 24).

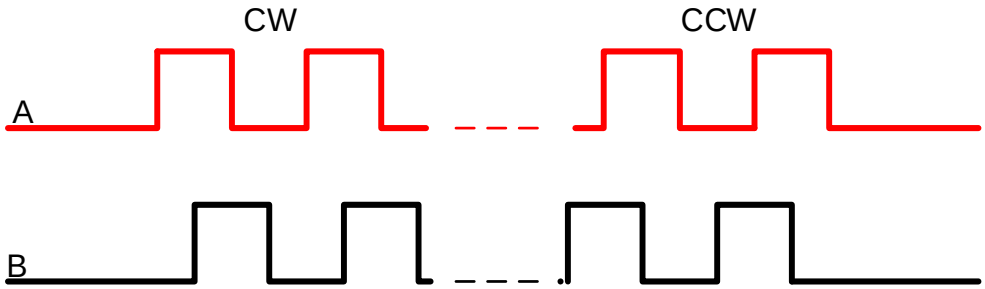


Figure 24: Quadrature Signal Logic

4.4.4 I/O Functions

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 68 for more information about the I/O functions 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	DI1 function	R/W	No	UINT8	-	0 to 6	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 6	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 6	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
	05h	DI5 function	R/W	No	UINT8	-	0 to 4	4
	06h	DI6 function	R/W	No	UINT8	-	0	0
	07h	DI7 function	R/W	No	UINT8	-	0	0
	08h	DI8 function	R/W	No	UINT8	-	0	0
	09h	DO1 function	R/W	No	UINT8	-	0 to 3	0
	0Ah	DO2 function	R/W	No	UINT8	-	0 to 3	0
	0Bh	DO3 function	R/W	No	UINT8	-	0	0
	0Ch	DO4 function	R/W	No	UINT8	-	0 to 3	3
	0Dh	DO5 function	R/W	No	UINT8	-	0	0
	0Eh	DO6 function	R/W	No	UINT8	-	0	0
	0Fh	DO7 function	R/W	No	UINT8	-	0	0
	10h	DO8 function	R/W	No	UINT8	-	0	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Command source	R/W	No	UINT16	-	-	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

For this example, set the pulses per revolution to 4000.

Steps	Index and Sub-Index	Data	Description
1	6060h-00h	0x01	Set the 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-02h	0x00	Set DI2 to the PUL function.
6	2030h-01h	0x00	Set DI1 to the DIR function.
7	2030h-03h	0x00	Set DI3 to the ENA function.
8	2031h-00h	0x0000	Set the PUL/DIR/ENA polarity to non-inverted.
9	200Dh-00h	0x65766173	Store the parameters to the NVM.
10	200Dh-00h	0x626F6F74	Reset the system command or reset power.

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

For this example, set the velocity to 3000rpm when the PWM duty cycle 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-02h	0x00	Set DI2 to the PUL function.
5	2030h-01h	0x00	Set DI1 to the DIR function.
6	2030h-03h	0x00	Set DI3 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 NVM.

9	200Dh-00h	0x626F6F74	Reset the system command or reset power.

After setting these values, 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 25 shows the block diagram.

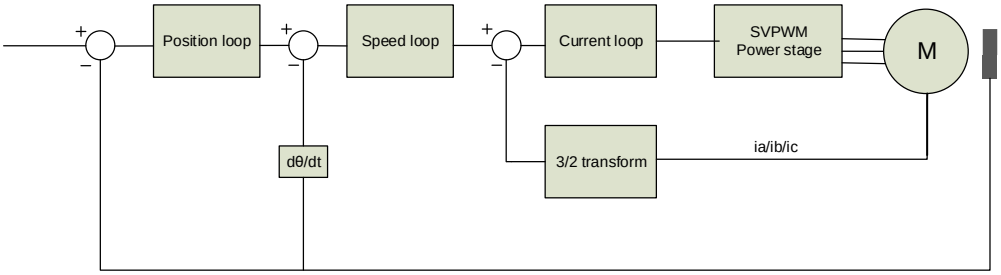


Figure 25: Control Loop Block Diagram

EZmotion provides an easy-to-use GUI to help engineers design and tune the loop parameters. Download the MotionLAB GUI 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 the 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 proportional (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 between 10Hz and 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 speed limit	R/W	No	UINT32	rpm	UINT32	3000
2005h	07h	Speed loop current limit	R/W	No	UINT16	‰	UINT16	15
2005h	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000

4.5.3 Simple Example

For this 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 speed loop output below 3000‰ of 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 enabled 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 option settings.

4.6.1 Halt Option

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

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

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

If the halt option is set to 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 falls below the brake speed threshold.

If the quick stop option is set from 5 to 7, the status stays in the quick stop active state once the motor velocity falls 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 I/O and BRAKE pins. The signal polarity can be configured (see the I/O Functions section on page 44 for more details).

The brake control logic is divided into several situations, described below.

Servo On

When the motor enters operation enabled mode, the brake is active after about 4ms (see Figure 26).

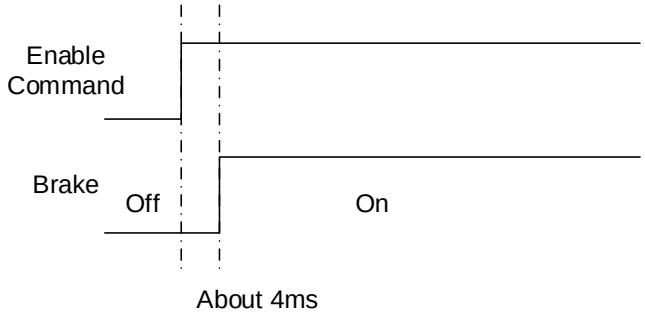


Figure 26: Brake Servo On Logic

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's turn-off delay time, especially in a system with vertical movement. Set "Brake enable" to 1 to avoid this behavior (see Figure 27).

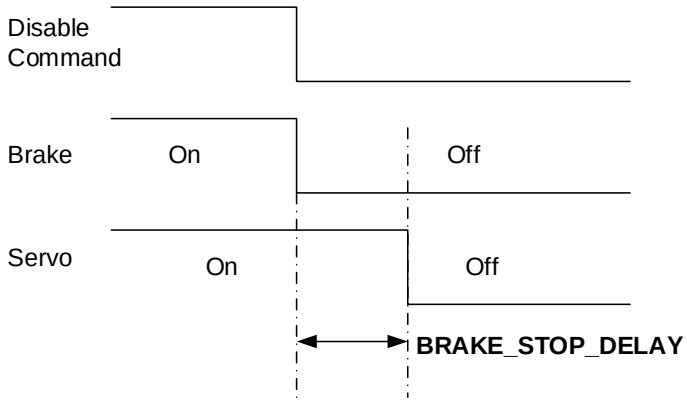


Figure 27: Brake Servo Off Logic ("Brake Enable" Set to 1)

Servo Off ("Brake Enable" Set to 0)

If users do not want a delay time between the disable operation command and when the servo turns off, set "Brake enable" to 0. The servo turns off immediately after the disable operation command is received (see Figure 28 on page 49).

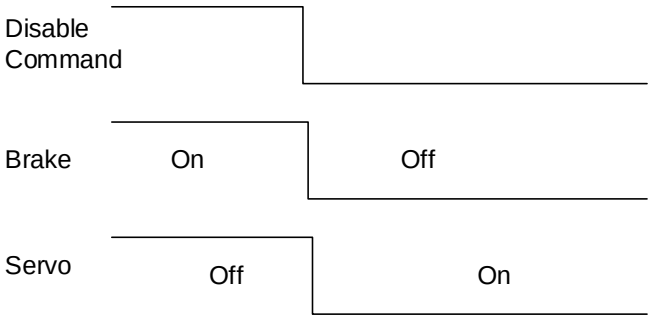


Figure 28: Brake Servo Off Logic ("Brake Enable" Set to 0)

Disable Operation (Or Error)

If a disable operation command is received during high-speed operation (or an error occurs), the servo turns off immediately. 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 (see Figure 29).

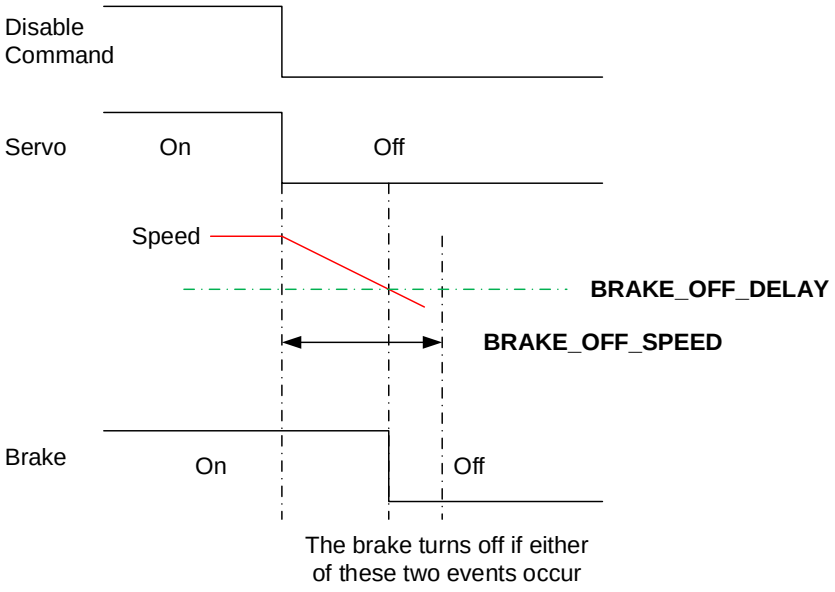


Figure 29: Brake Logic if an Error Occurs or Operation Is Disabled

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

For this example, if the motor is working in PV 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 the 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 an error. Figure 30 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 changes, the speed reference changes immediately, without the position control loop delay. This makes the position response faster and minimizes the position following error.

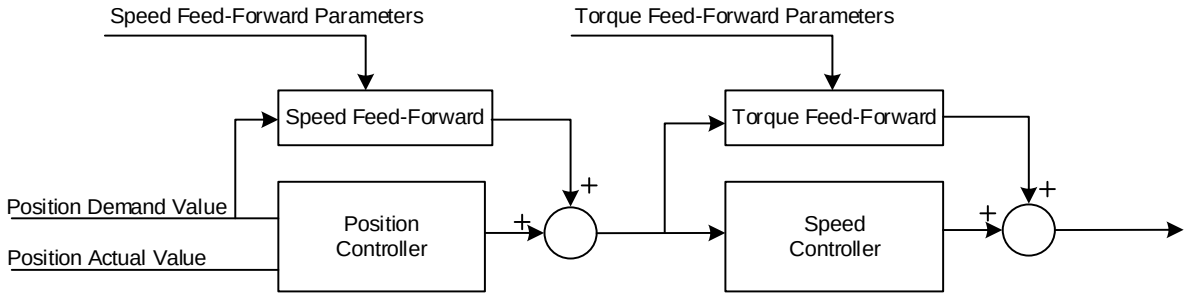


Figure 30: Feed-Forward Block Diagram

The speed feed-forward gain (2004h-06h) and speed feed-forward time constant (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) to 0.

Torque Feed-Forward

Torque feed-forward can make the speed loop control response faster (see Figure 30). 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 will change 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) to 0.

Decoupling

From the voltage equations (Equation (3) and Equation (4)) of a PMSM motor, the $-\omega \times L_Q \times I_Q$ and $\omega \times (L_Q \times I_Q + \Psi_F)$ parts — 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:

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

$$U_Q = R \times I_Q + L_Q \times \frac{dI_Q}{dt} + \omega \times (L_Q \times I_Q + \Psi_F) \quad (4)$$

The decoupling gain object (set via 2004h-02h) and speed decoupling time constant object (set via 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 31 shows the decoupling block diagram.

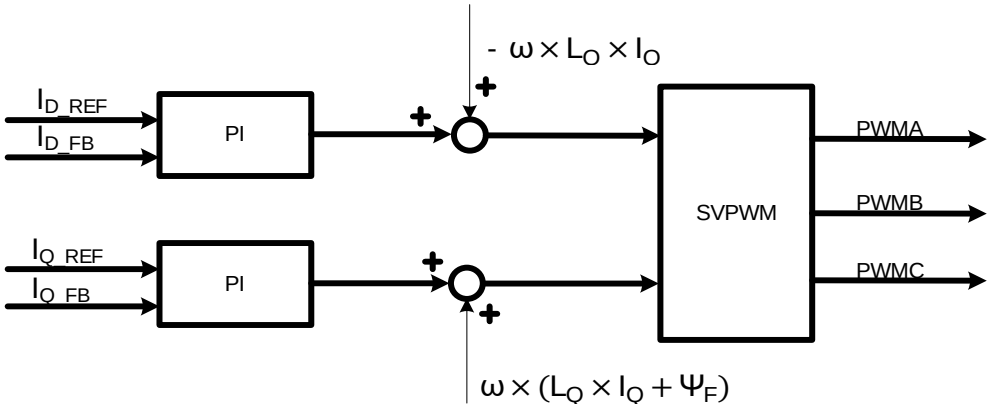


Figure 31: Decoupling Block Diagram

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 to be 10 times greater 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’s first bandwidth and second bandwidth should be set below the noise level. It is typically recommended to set the filter bandwidth to be 5 to 10 times greater than the speed loop bandwidth.

Notch Filter

If the system has a resonant frequency, there may be a significant 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. The 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 device 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	R/W	No	UINT8	%	0 to 200	100
	07h	Speed feed-forward filter time constant	R/W	No	UINT16	ms	UINT16	0
2007h	01h	Position filter bandwidth	R/W	No	UINT16	Hz	100 to 2000	200
	02h	Speed filter 1 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
	05h	Speed filter 2 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
2008h	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

4.7.4 Simple Example

For this 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-05h	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 identifies controller versions. The “Controller part number” (2000h-01h), “Motor part number” (object 2000h-02h), “Encoder part number” (object 2000h-03h), “Firmware version” (object 2000h-04h) and “Hardware version” (object 2000h-05h) objects are read-only. These objects identify the device version.

4.8.2 Motor Parameters

Motor parameters are used for control loop design, among other operational functions. The user can set basic motor parameters and allow for other detailed parameters to be identified automatically (see the Parameter Identification section on page 38). If parameter identification cannot be performed, the user should set the motor parameters (set via 2001h) before running the motor.

4.8.3 Current-Sense Parameters

Current-sense parameters are used for motor phase current-sensing. The proper current-sense resistor and amplifier gain should be set to achieve the correct current feedback.

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

$$P = I_{RMS}^2 \times R_{cs} \tag{9}$$

A good rule of thumb is to leave a 50% margin for the power rating to guarantee that the device can operate normally at high temperatures. Using Figure 32, the amplifier gain (G) can be calculated with Equation (10):

$$G = \frac{R_1}{R_2 + R_3} \tag{10}$$

Where R_1 is fixed to 20kΩ and R_2 is fixed to 1kΩ. This means that R_3 can be used to adjust G.

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

$$I_{MAX} \times R_{CS} \times G < 1.65V \tag{11}$$

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 of a 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 32 shows the current-sense diagram.

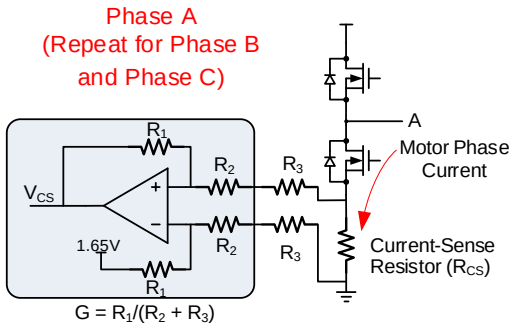


Figure 32: Current-Sense Diagram

The device 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 device 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 specifications as well as operational conditions, such as the operating voltage and current. For applications with a MOSFET, a dead time between 200ns and 500ns is typically sufficient.

4.8.5 Voltage-Sense 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 33 shows how to set the voltage resistor dividers. Ensure that the voltage on the VDC pin is below 3.3V at the maximum DC link voltage.

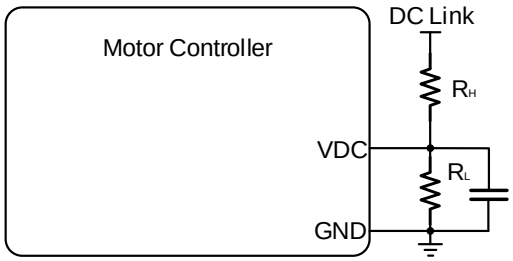


Figure 33: Voltage Divider

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	Firmware version	RO	No	UINT16	-	-	-
	05h	Hardware version	RO	No	UINT16	-	-	-
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 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	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
	09h	Driver type	R/W	No	UINT8	-	0	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
2050h	01h	Lower divider	R/W	No	UINT16	kΩ	1 to 65535	10
	02h	Upper divider	R/W	No	UINT16	kΩ	1 to 65535	402

4.8.7 Simple Example

For this example, set the pre-driver type to the GLx + GHx type, and set the dead time to 500ns.

Steps	Index and Sub-Index	Data	Description
1	2002h-09h	0x00	Select the 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 the driver module's NVM, certain function codes can be sent to object 200Dh to trigger specific functions. The functions and function codes 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 the control parameters to the controller's NVM.
Restore default parameters	0x64616F6C	Restore all the 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 the supported command above	0

4.9.3 Simple Example

For this 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 device has rich protection functions to avoid unexpected failures and external component damage. The fault type can be determined from the value of the “Error status” (200Bh-0Bh). During a fault, the ALARM signal outputs a low-level voltage, and the fault indication LED illuminates.

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 the 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 of “Error status” (200Bh-0Bh) is set when the DC link voltage drops below “UVLO threshold” (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 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 to the VDC pin is sensed by a voltage divider. The correct divider voltage should be set via “Lower divider” (2050h-01h) and “Upper divider” (2050h-02h). 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 “Lock speed threshold” (200B-05h) and the angle that the motor shaft turns during the “Lock time window” (200Bh-06h) is below the “Lock position threshold” (set via 200Bh-04h) in PV mode, then rotor-lock protection is triggered.

If the target position is not reached, and the angle that the motor shaft turns during the “Lock time window” (200Bh-06h) is below the “Lock position threshold” (200Bh-04h) in PP mode, then rotor-lock protection is triggered.

If rotor-lock protection is triggered, the lock bit of “Error status” (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) may occur if the components on the board are damaged or if a short circuit occurs. If OCP occurs, the device shuts down the power stage to avoid further damage to the system.

If any phase current exceeds the OCP threshold, then OCP is triggered, the OCP bit of “Error status” (200Bh-0Bh) is set, and the controller enters a fault state.

5.1.6 Overload Protection (OLP)

To avoid damaging the mechanical system and the motor, overload protection (OLP) is triggered if the output torque exceeds the “Overload current threshold” (2042h-02h) and lasts for longer than the “Overload time window” (2042h-03h). The controller shuts down the power stage so that electrical power is not delivered to the motor or mechanical system.

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

If OLP is triggered, the overload bit of “Error status” (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 Errors

To clear an 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 the 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 a fault state, the fault indication LED is illuminated. See the 200Bh-0Bh section on page 76 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 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 to 3000	3000
	03h	Overload time window	R/W	No	UINT16	ms	UINT16	1000
2050h	01h	Lower divider	R/W	No	UINT16	kΩ	1 to 65535	10
	02h	Upper divider	R/W	No	UINT16	kΩ	1 to 65535	402

5.5 Simple Example

For this example, set the OCP threshold to 2A and enable OCP.

Steps	Index and Sub-Index	Data	Description
1	200Bh-02h	0x0002	Set the OCP current 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
1000h	00h	Device type	RO	No	UINT32	-	-	0x04020192
1001h	00h	Error register	RO	TPDO	UINT8	-	-	0
1002h	00h	Manufacture status	RO	No	UINT32	-	-	0
1003h	00h	Number of errors	R/W	No	UINT8	-	0 to 254	0
	01h~08h	Standard error field	RO	No	UINT32	-	-	0
1005h	00h	COB-ID SYNC	R/W	No	UINT32		-	0x80
1006h	00h	Communication cycle period	R/W	No	UINT32	µs	UINT32	0
1007h	00h	Synchronous window length	R/W	No	UINT32	µs	UINT32	0
1008h	00h	Manufacturer device name	CONST	No	String	-	-	MMS
1009h	00h	Manufacturer hardware version	CONST	No	String	-	-	1.00
100Ah	00h	Manufacture software version	CONST	No	String	-	-	1.00
1010h	**Store Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	1	1
	01h	Save all parameters	R/W	No	UINT32	-	-	-
1011h	**Restore Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	1	1
	01h	Restore all parameters	R/W	No	UINT32	-	-	-
1014h	00h	COB-ID EMCY	RO	No	UINT32	-	-	0x80 + NoDEID
1015h	00h	Inhibit time EMCY	R/W	No	UINT16	100µs	UINT16	0
1016h	**Consumer Heartbeat Times**							
	00h	Max sub-index	RO	No	UINT8	-	4	4
	01h~04h	Consumer heartbeat time	R/W	No	UINT32	ms	UINT32	0
1017h	00h	Producer heartbeat time	R/W	No	UINT16	ms	UINT16	0
1018h	**Identify Objects**							
	00h	Max sub-index	RO	No	UINT8	-	4	4
	01h	Vender-ID	RO	No	UINT32	-	-	0x0000EEEE
	02h	Product code	RO	No	UINT32	-	-	0x00001234
	03h	Revision number	RO	No	UINT32	-	-	0x00010001
	04h	Serial number	RO	No	UINT32	-	-	0x00000000
1029h	**Error Behavior Objects**							
	00h	No. of error classes	RO	No	UINT8	-	6	6
	01h	Communication	R/W	No	UINT8	-	-	0
	02h	Communication other	R/W	No	UINT8	-	-	0
	03h	Communication passive	R/W	No	UINT8	-	-	1
	04h	Generic	R/W	No	UINT8	-	-	0
	05h	Device profile	R/W	No	UINT8	-	-	0
	06h	Manufacturer specific	R/W	No	UINT8	-	-	0
1200h	**SDO Server Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	COB-ID client to server	RO	No	UINT32	-	-	0x600 + NODEID
	02h	COB-ID server to client	RO	No	UINT32	-	-	0x580 + NODEID

1400h	**First RPDO Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	COB-ID used by RPDO	R/W	No	UINT32	-	-	0x200 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	0 to 255	255
1401h	**Second RPDO Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	COB-ID used by RPDO	R/W	No	UINT32	-	-	0x300 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	0 to 255	254
1402h	**Third RPDO Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	COB-ID used by RPDO	R/W	No	UINT32	-	-	0x400 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	0 to 255	254
1403h	**Fourth RPDO Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	COB-ID used by RPDO	R/W	No	UINT32	-	-	0x500 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	0 to 255	254
1600h	**First RPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x01
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60400010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x00000000
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1601h	**Second RPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60400010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x60600008
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1602h	**Third RPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60400010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x607A0020
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000

1603h	**Fourth RPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60400010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x60FF0020
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1800h	**First TPDO Communication Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	0x05
	01h	COB-ID used by TPDO	R/W	No	UINT32	-	-	0x180 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	-	255
	03h	Inhibit time	R/W	No	UINT16	ms	-	100
	04h	Compatibility entry	CONST	No	UINT8	-	-	0
	05h	Event timer	R/W	No	UINT16	ms	-	0
1801h	**Second TPDO Communication Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	0x05
	01h	COB-ID used by TPDO	R/W	No	UINT32	-	-	0x280 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	-	254
	03h	Inhibit time	R/W	No	UINT16	ms	-	100
	04h	Compatibility entry	CONST	No	UINT8	-	-	0
	05h	Event timer	R/W	No	UINT16	ms	-	0
1802h	**Third TPDO Communication Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	0x05
	01h	COB-ID used by TPDO	R/W	No	UINT32	-	-	0x380 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	-	254
	03h	Inhibit time	R/W	No	UINT16	ms	-	100
	04h	Compatibility entry	CONST	No	UINT8	-	-	0
	05h	Event timer	R/W	No	UINT16	ms	-	0
1803h	**Fourth TPDO Communication Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	0x05
	01h	COB-ID used by TPDO	R/W	No	UINT32	-	-	0x480 + NODEID
	02h	Transmission type	R/W	No	UINT8	-	-	254
	03h	Inhibit time	R/W	No	UINT16	ms	-	100
	04h	Compatibility entry	CONST	No	UINT8	-	-	0
	05h	Event timer	R/W	No	UINT16	ms	-	0
1A00h	**First TPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x01
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60410010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x00000000
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000

1A01h	**Second TPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60410010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x60610008
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1A02h	**Third TPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60410010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x60640020
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1A03h	**Fourth TPDO Mapping Parameters**							
	00h	Number of mapped objects	R/W	No	UINT8	-	-	0x02
	01h	Mapped object 1	R/W	No	UINT32	-	-	0x60410010
	02h	Mapped object 2	R/W	No	UINT32	-	-	0x606C0020
	03h	Mapped object 3	R/W	No	UINT32	-	-	0x00000000
	04h	Mapped object 4	R/W	No	UINT32	-	-	0x00000000
	05h	Mapped object 5	R/W	No	UINT32	-	-	0x00000000
	06h	Mapped object 6	R/W	No	UINT32	-	-	0x00000000
	07h	Mapped object 7	R/W	No	UINT32	-	-	0x00000000
	08h	Mapped object 8	R/W	No	UINT32	-	-	0x00000000
1F80h	00h	NMT startup	R/W	No	UINT32	-	-	0

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 Configurations**							
	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 Configurations**							
	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 to 2000	1000
	06h	Position loop speed limit	R/W	No	UINT32	INC/s	UINT32	3276800
	07h	Speed loop current 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 filter 1 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
	03h	Reserved	-	-	-	-	-	-
	04h	Reserved	-	-	-	-	-	-
	05h	Speed filter 2 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 Parameters**							
	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	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 to 16	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 x s	-	0
	0Ch	Identified T_F	RO	No	UINT32	mNm	-	0
200Dh	00h	Special command	R/W	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

2030h	**I/O Functions**							
	00h	Max sub-index	RO	No	UINT8	-	8	8
	01h	DI1 function	R/W	No	UINT8	-	0 to 6	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 6	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 6	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
	05h	DI5 function	R/W	No	UINT8	-	0 to 4	4
	06h	DI6 function	R/W	No	UINT8	-	0	0
	07h	DI7 function	R/W	No	UINT8	-	0	0
	08h	DI8 function	R/W	No	UINT8	-	0	0
	09h	DO1 function	R/W	No	UINT8	-	0 to 3	0
	0Ah	DO2 function	R/W	No	UINT8	-	0 to 3	0
	0Bh	DO3 function	R/W	No	UINT8	-	0	0
	0Ch	DO4 function	R/W	No	UINT8	-	0 to 3	3
	0Dh	DO5 function	R/W	No	UINT8	-	0	0
	0Eh	DO6 function	R/W	No	UINT8	-	0	0
	0Fh	DO7 function	R/W	No	UINT8	-	0	0
	10h	DO8 function	R/W	No	UINT8	-	0	0
2031h	00h	I/O polarity	R/W	No	UINT16	-	-	0
2032h	00h	Command Source	R/W	No	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	**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
	03h	Power-on homing enable	R/W	No	UINT8	-	UINT8	0
2101h	00h	CAN Node ID	R/W	No	UINT8		-	0x02
2102h	00h	CAN bit rate	R/W	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
2110h	00h~06h	Multi-target position	R/W	No	INT32	INC	INT32	0
2111h	00h~06h	Multi-profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2112h	00h~06h	Multi-profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	0
2113h	00h~06h	Multi-profile velocity	R/W	No	UINT32	INC/s	UINT32	0
2114h	00h~06h	Multi-target velocity	R/W	No	INT32	INC/s	INT32	0

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 to 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 time out	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	-	-	0x00000 3AD

Section 7. Object Details

This section provides 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 the 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 the 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 the 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. The wrong value can 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 motor's output torque per ampere current. The current unit is A_{RMS} (the root mean square current in amperes).					

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 resistance (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 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, then 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 the 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's 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's 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.					

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's 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.					
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	Decoupling 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 percentage 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 percentage 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 filter time constant	Determines the rising time constant of the torque feed-forward value to avoid the 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 10Hz to 100Hz; this value should be 5 to 10 times smaller than the speed loop bandwidth (set via 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 greater than the position loop bandwidth (set via 2005h-01h), and 5 to 10 times smaller than the torque loop bandwidth (set via 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 value 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 to 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 greater than the speed loop bandwidth (set via 2005h-03h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	06h	Position loop speed limit	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Position loop speed 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 current limit	R/W	No	UINT16	‰	UINT16	15
Bits		**Name**	**Description**					
15:0		Speed loop current 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 to 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 greater than the position loop bandwidth.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	02h	Speed filter 1 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
Bits		**Name**	**Description**					
15:0		Speed filter 1 bandwidth	To minimize the phase delay caused by the filter, set this value to be 5 to 10 times greater than the speed loop bandwidth.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	05h	Speed filter 2 bandwidth	R/W	No	UINT16	Hz	100 to 2000	1000
Bits		**Name**	**Description**					
15:0		Speed filter 2 bandwidth	To minimize the phase delay caused by the filter, set this value to be 5 to 10 times greater 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		Notch 2 enable	Enables notch filter 2.					
0		Notch 1 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.					

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) protection 1: Enable UVLO protection					
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 threshold	R/W	No	UINT16	V	8 to 30	12
Bits		**Name**	**Description**					
15:0		UVLO 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 the motor returns to the operation enable state after the protection retry time.					

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 falls 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 within the allowed range 1: The position is out of range					
4		OVERLOAD	0: Overload protection (OLP) has not been triggered 1: OLP 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 to 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 less than half of the identified max revolutions (set via 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 (set via 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 inductor identification 4: Identifying D-axis inductor 5: Identifying Q-axis inductor 6: Finding theta bias 7: Identifying torque constant (range unlimited) 8: Identifying inertia (range unlimited) 9: Identifying inertia for the second time (range unlimited) 10: Identifying torque constant (range-limited) 11: Identifying inertia (range unlimited) 12: Identification complete 13: Homing 14: Identifying acceleration design 15: Identifying error handling 16: Identifying error					

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

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	09h	Identified K_T	RO	No	UINT32	mNm/A	-	0
Bits		**Name**	**Description**					
31:0		Identified K_T	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 T_F	RO	No	UINT32	mNm	-	0
Bits		**Name**	**Description**					
31:0		Identified T_F	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	I_D	RO	TPDO	INT16	mA	INT16	0
Bits		**Name**	**Description**					
15:0		I_D	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	I_Q	RO	TPDO	INT16	mA	INT16	0
Bits		**Name**	**Description**					
15:0		I_Q	Sets the quadrature axis current of the motor, which is proportional to the motor's output torque.					

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	04h	U_Q	RO	TPDO	INT16	mV	INT16	0
Bits		**Name**	**Description**					
15:0		U_Q	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 the object value and the 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 filtering, 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.					

2030h: I/O Functions

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	01h	DI1 function	RW	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		DI1 function	Selects the DI1 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	02h	DI2 function	RW	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		DI2 function	Selects the DI2 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	03h	DI3 function	RW	No	UINT8	-	0 to 6	0
Bits		**Name**	**Description**					
7:0		DI3 function	Selects the DI3 function. 0: ENA 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	04h	DI4 function	RW	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		DI4 function	Selects the DI4 function. 0: Homing enable 1: Negative switch 2: Positive switch 3: Home switch					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	05h	DI5 function	R/W	No	UINT8	-	0 to 4	4
Bits		**Name**	**Description**					
7:0		DI5 function	Selects the DI5 function. 0: Not used 1: Negative switch 2: Positive switch 3: Home switch 4: UART RX					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	06h	DI6 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DI6 function	Selects the DI6 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	07h	DI7 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DI7 function	Selects the DI7 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	08h	DI8 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DI8 function	Selects the DI8 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	09h	DO1 function	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		DO1 function	Selects the DO1 function. 0: PEND. 1: Alarm 2: Brake 3: Point 1 reached, this can be used in I/O-controlled position mode					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Ah	DO2 function	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		DO2 function	Selects the DO2 function. 0: PEND 1: Alarm 2: Brake 3: Point 2 reached, this can be used in I/O-controlled position mode					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Bh	DO3 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DO3 function	Selects the DO3 function. 0: Brake					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Ch	DO4 function	R/W	No	UINT8	-	0 to 3	3
Bits		**Name**	**Description**					
7:0		DO4 function	Selects the DO4 function. 0: PEND 1: Alarm 2: Brake 3: UART TX					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Dh	DO5 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DO5 function	Selects the DO5 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Eh	DO6 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DO6 function	Selects the DO6 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	0Fh	DO7 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DO7 function	Selects the DO7 function. This object is reserved for future use.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	10h	DO8 function	R/W	No	UINT8	-	0	0
Bits		**Name**	**Description**					
7:0		DO8 function	Selects the DO8 function. This object is reserved for future use.					

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		DO8 polarity	0: Non-inverted 1: Inverted					
14		DO7 polarity	0: Non-inverted 1: Inverted					
13		DO6 polarity	0: Non-inverted 1: Inverted					
12		DO5 polarity	0: Non-inverted 1: Inverted					
11		DO4 polarity	0: Non-inverted 1: Inverted					
10		DO3 polarity	0: Non-inverted 1: Inverted					
9		DO2 polarity	0: Non-inverted 1: Inverted					
8		DO1 polarity	0: Non-inverted 1: Inverted					
7		DI8 polarity	0: Non-inverted 1: Inverted					
6		DI7 polarity	0: Non-inverted 1: Inverted					
5		DI6 polarity	0: Non-inverted 1: Inverted					
4		DI5 polarity	0: Non-inverted 1: Inverted					
3		DI4 polarity	0: Non-inverted 1: Inverted					
2		DI3 polarity	0: Non-inverted 1: Inverted					
1		DI2 polarity	0: Non-inverted 1: Inverted					
0		DI1 polarity	0: Non-inverted 1: Inverted					

2032h: Command Source

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2032h	00h	Command source	R/W	No	UINT16	-	-	0
Bits		**Name**	**Description**					
15:2		Reserved	Not used					
1		Homing source	Selects the motor homing command source. 0: Data bus 1: I/O signal					
0		Enable source	Selects the 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 (OLP) 1: Enable OLP					

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 OLP threshold, which is given in thousandths of the motor's 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, OLP is triggered. Set the time window to be 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 the 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 the electronic gear ratio denominator (set via 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 the electronic gear ratio numerator (set via 2060h-01h). The pulses/revolution are defined as 65536 x Electronic_Gear_Ratio_Numerator / Electronic_Gear_Ratio_Denominator.					

2070h: Homing 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 the torque-limited homing method (object 6098h-00h equals -3 or -2). The homing torque should be set to exceed the load torque of the motor during the 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.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	03h	Power-on homing enable	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
15:0		Power-on homing enable	0: Disable homing operation after power-on 1: Enable homing operation after power-on					

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 to 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 brake stop delay time The brake has a turn-off time (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 42 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 to 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 the 2108h-01h section above for more details.					

2110h: Multi-Target Position

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2110h	00h~06h	Multi-target position	R/W	No	INT32	INC	INT32	0
Bits		**Name**	**Description**					
31:0		Multi-target position	Sets the target position in I/O-controlled multi-position mode. See section 3.9.1 on page 35 for the relationship between the I/O levels and selected stage number.					

2111h: Multi-Profile Acceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2111h	00h~06h	Multi-profile acceleration	R/W	No	UINT32	INC/s^2	UINT32	0
Bits		**Name**	**Description**					
31:0		Multi-profile acceleration	Sets the profile acceleration for each stage. This is used for both I/O-controlled multi-position mode and I/O-controlled multi-velocity mode.					

2112h: Multi-Profile Deceleration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2112h	00h~06h	Multi-profile deceleration	R/W	No	UINT32	INC/s^2	UINT32	0
Bits		**Name**	**Description**					
31:0		Multi-profile deceleration	Sets the profile deceleration for each stage. This is used for both I/O-controlled multi-position mode and I/O-controlled multi-velocity mode.					

2113h: Multi-Profile Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2113h	00h~06h	Multi-profile velocity	R/W	No	UINT32	INC/s	UINT32	0
Bits		**Name**	**Description**					
31:0		Multi-profile velocity	Sets the profile velocity for each stage.					

2114h: Multi-Target Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2114h	00h~06h	Multi-target velocity	R/W	No	INT32	INC/s	INT32	0
Bits		**Name**	**Description**					
31:0		Multi-target velocity	Sets the selected target velocity in I/O-controlled multi-velocity mode. See section 3.10.1 on page 36 for the relationship between the I/O levels and selected stage number.					

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		Manufacturer specific	For more details, see the “Control Word” and “Status Word” sections of each operation mode.					
10		Reserved	Unused.					
9		Operation mode specific	For more details, see the “Control Word” and “Status Word” sections of each operation mode.					
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 “Control Word” and “Status Word” sections of each operation mode.					
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 “Control Word” and “Status Word” sections of each operation mode.					
13:12		Operation mode specific	For more details, see the “Control Word” and “Status Word” sections of each operation mode.					
11		Internal limit active	If the position limit is reached, this bit is set.					
10		Operation mode specific	For more details, see the “Control Word” and “Status Word” sections of each operation mode.					
9		Remote	If set, parameters may be modified by communication.					
8		Manufacture specific	For more details, see the “Control Word” and “Status Word” sections of each operation mode.					
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 whether operation enabled mode is active.					
1		Switch on	Indicates whether the driver switch is on.					
0		Ready to switch on	Indicates whether 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 to the switch on disabled state 2: Quick stop ramp and transition to the switch on disabled state 3: Current limit and transition to the switch on disabled state 4: Reserved 5: Slow down the ramp and remain in the quick stop active state 6: Slow the quick stop ramp and remain in the quick stop active state 7: Current limit and remain in the quick stop active state 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 remain in the operation enable state 2: Execute the quick stop ramp and remain in the operation enable state 3: Current limit and remain in the operation enable state					

6060h: Operation Modes

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 (PP) mode +3: Profile velocity (PV) mode +4: Profile torque (PT) mode +6: Homing (HOME) mode +7: Reserved +8: Cyclic synchronous position (CSP) mode +9: Cyclic synchronous velocity (CSV) mode +10: Cyclic synchronous torque (CST) mode					

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 (PP) mode +3: Profile velocity (PV) mode +4: Profile torque (PT) mode +6: Homing (HOME) mode +7: Reserved +8: Cyclic synchronous position (CSP) mode +9: Cyclic synchronous velocity (CSV) mode +10: Cyclic synchronous torque (CST) mode					

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 the position control loop. It is the same as the position's actual value (set via 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 timeout	R/W	No	UINT32	ms	UINT32	10
Bits		**Name**	**Description**					
15:0		Following error timeout	If a following error occurs for longer than the defined timeout time, then "Status word," bit[13] is set to 1. In this condition, the motor continues running, and the user can determine the action.					

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 acceptance relative 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 (set via 606Fh) and actual velocity (set via 606Ch) is within the velocity window (606Dh) for longer than the velocity window time (set via 606Eh), 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 6070h: Velocity Threshold Time 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 (set via 606Ch) exceeds the velocity threshold (set via 606Fh) for longer than the velocity threshold time (set via 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 motor's maximum allowable torque (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 motor's maximum allowed torque-creating current (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).					

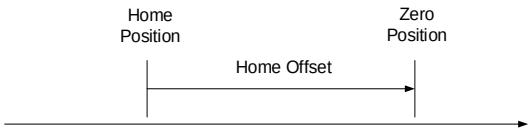
6078h: Current Actual Value

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 PP 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 are 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 limit	R/W	No	INT32	INC	INT32	-2^{31}
Bits		**Name**	**Description**					
31:0		Min 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 limit	R/W	No	INT32	INC	INT32	$2^{31} - 1$
Bits		**Name**	**Description**					
31:0		Max 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	-	UINT8	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 PP mode and cyclic synchronous position (CSP) mode. 0: Multiply by +1 1: Multiply by -1					
6		Velocity polarity	Use for PV mode and cyclic synchronous 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
6080h	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/s^2	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/s^2	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/s^2	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Quick stop deceleration	Sets 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 to 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 23 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/s^2	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 CSP 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 smooth.					

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 the 60C2h-01h section above 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/s^2	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/s^2	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 PV mode.					

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	5/10/2023	Initial Release	-
1.1	9/26/2023	Added the MMP740100-55-C2-1, MMP740050-55-C2-1, MMS740100-24-C2-1, and MMS740050-24-C2-1 to Table 1	8