User Guide

MMS7xxxxBE EtherCAT All-in-One Servo

Contents

Overview

Applicable Products

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

Table 1: Applicable Products

Item	Applicable Part Number
1	MMS74005BE-OB2PKN-ZHNA0
2	MMS74010BE-OB2PKN-ZHNA0
3	MMS76020BE-OB2PKN-ZHNA0
4	MMS76020BE-OB2PCN-ZHNA0
5	MMS76040BE-OB2PKN-ZHNA0
6	MMS78075BE-OB2PKN-ZHNA0
7	MMS74005BE-OB2PKN-ZHOA0
8	MMS74010BE-OB2PKN-ZHOA0
9	MMS76020BE-OB2PKN-ZHOA0
10	MMS76020BE-OB2PCN-ZHOA0
11	MMS76040BE-OB2PKN-ZHOA0
12	MMS78075BE-OB2PKN-ZHOA0

Safety Warnings

Safety Warnings when Installing/Wiring

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

1. Secure the motor as it may accidentally move, jump, or fall during start-up.
2. Keep hair and loose clothing away from the motor.
3. Do not use the motor in the presence of water, in the presence of corrosive gases, or near combustible materials.
4. Do not use the motor alone in a high-temperature, confined environment; if necessary, ensure that the motor is cooled or dissipated.
5. Do not use the motor in an environment with strong electromagnetic interference.
6. Do not open or disassemble the motor.
7. Connect the motor housing to earth ground when the motor is installed in the system.
8. Do not use the motor in areas of strong vibration.
9. Wiring should be done in strict accordance with the wiring diagram and interface definitions.
10. Ensure that the power supply connected to the motor is fused or otherwise current-limited.
11. Ensure that the motor is installed and wired with the power supply disconnected.
12. Ensure that all cables and connections are securely attached, and follow crimping guidelines set by the manufacturer.
13. The power input side of the motor should have an over-current protector, leakage protector, and emergency stop device.
14. After wiring is complete, check the entire system to ensure that all cables are wired correctly and that there are no dropped screws, metal shavings, spacers, or exposed cables in or around the product.
15. Follow the steps specified in the Electrostatic Discharge Prevention (ESD) procedure to avoid static electricity from the human body damaging the equipment or the circuitry inside the product.

Safety Warnings when Powering Up

1. Avoid contact with the shaft and any additional mechanical parts when operating the motor.
2. Before powering up, ensure that the product is securely installed and wirings are organized.
3. Before powering up, ensure that the power supply to the servo motor meets the product's requirements to avoid damaging the motor or causing accidents.
4. Do not touch any terminals of the product or disassemble any parts of the motor while it is energized.
5. Use the motor at the motor's specified voltage.
6. The protection device/circuit on the power input side of the motor should take into full consideration the actual application scenario of the system and select the appropriate protection range and protection points.

Safety Warnings when Running

1. Never touch the moving parts of the motor while the motor is running.
2. Do not adjust the motor’s gain too aggressively or extremely, and do not adjust the gain while the motor is moving.
3. Use the motor in strict accordance with the motor's specifications to avoid damage to the motor caused by overloading or overheating.
4. Do not touch the motor with your hands while the motor is running, as it may cause burns.

Section 1. Product Information

1.1 Introduction

The MMS7xxxxBE series EtherCAT all-in-one servo are fully integrated servo motors that support EtherCAT communication (see Figure 1). The MMS7xxxxBE series integrates a servo drive, position encoder, permanent magnet synchronous motor (PMSM), EtherCAT communication, and a multi-functional external input/output (I/O) interface. The high level of integration and the compactness of the MMS7xxxxBE series simplifies wiring and reduces costs. The series is available in 40mm, 60mm, and 80mm flange sizes, and covers a power range from 50W to 750W.

The motors can be operated in position, velocity, or torque control mode. The motors can be controlled via an EtherCAT interface with a CANopen over EtherCAT (CoE) protocol. Parameters can be configured via the PC-based host computer program (MotionLAB), which is connected to the motor via the MLink debugging interface. After optimization, the parameters can be saved to the module's non-volatile memory (NVM).

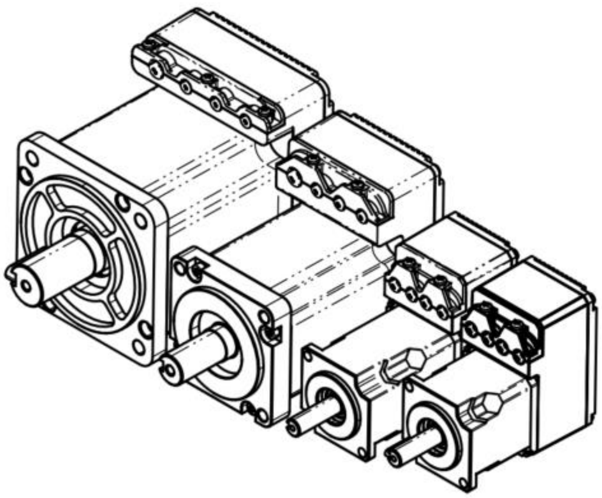


Figure 1: MMS7xxxxBE Series All-in-one Servo

1.2 Products Features

- Field-Oriented Control (FOC)
- Supports 100Mbps EtherCAT Communication, Adopts CoE Protocol, Supports Dynamic PDO, Supports Distributed Clock (DC)
- Conforms to Standard CiA402 Motion Control Protocol, Supports PP, PV, PT, CSP, CSV, CST, and HM Motion Modes
- Integrated High-Resolution Encoder
- Equipped with Motor and Load Parameter Identification and Loop Self-Tuning Function
- Advanced Motion Controller for Smooth Switching Between Different Operating Modes
- General-Purpose I/O for Logic Digital Signal Inputs or Outputs
- Mechanical Characterization Function, 4 Notch Filters for Mechanical Resonance Elimination
- DC Bus Voltage Detection and Limiting Function
- Drive Temperature Detection and Extensive Protection Functions

1.3 Products Series

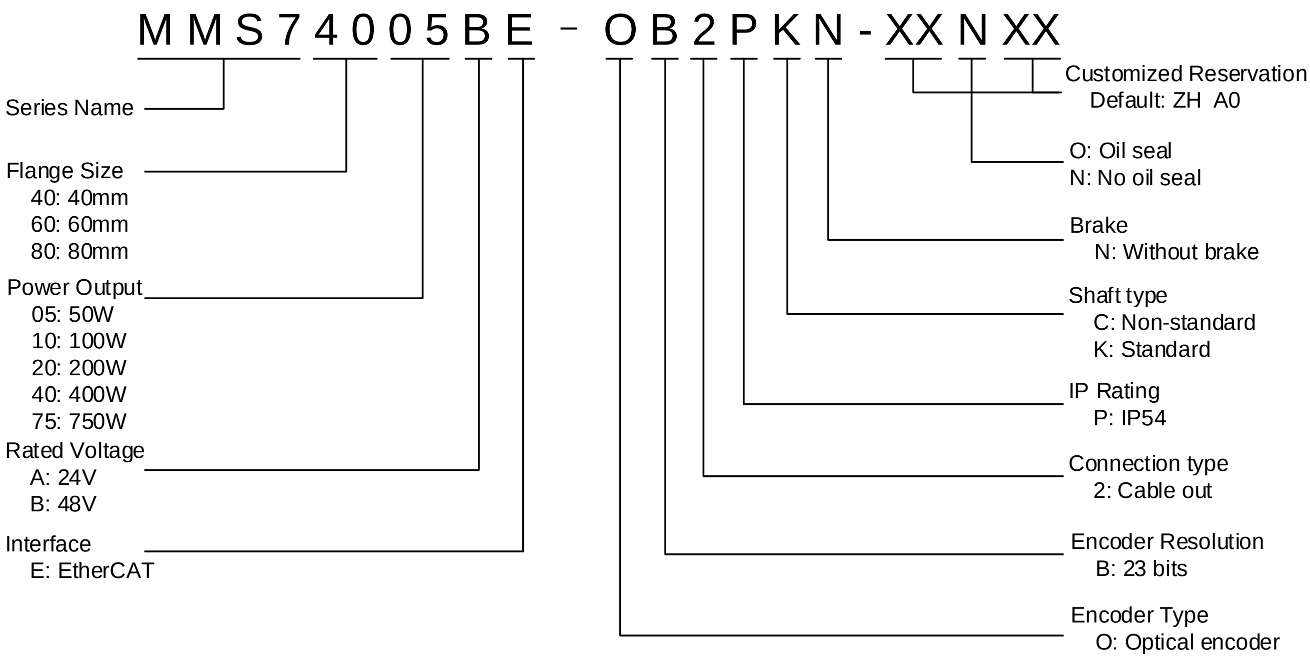
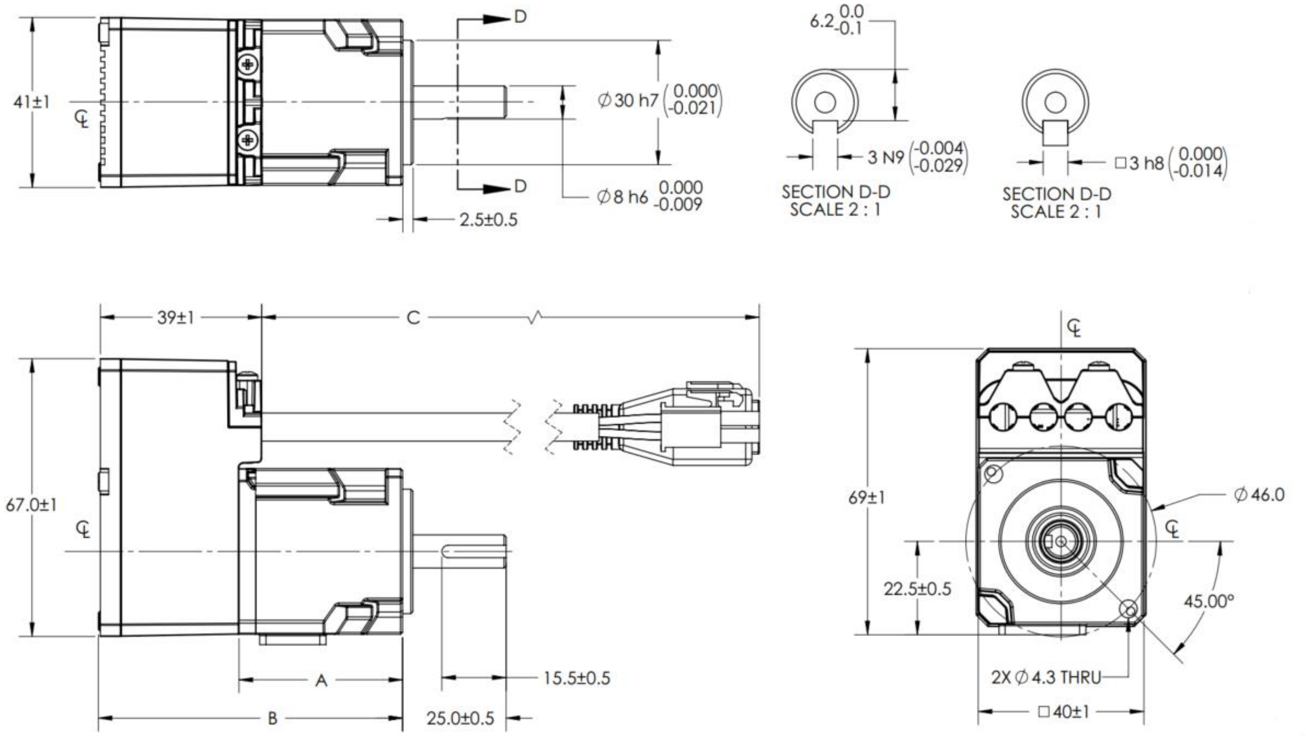


Figure 2: Naming Convention

1.4 Mechanical Dimension

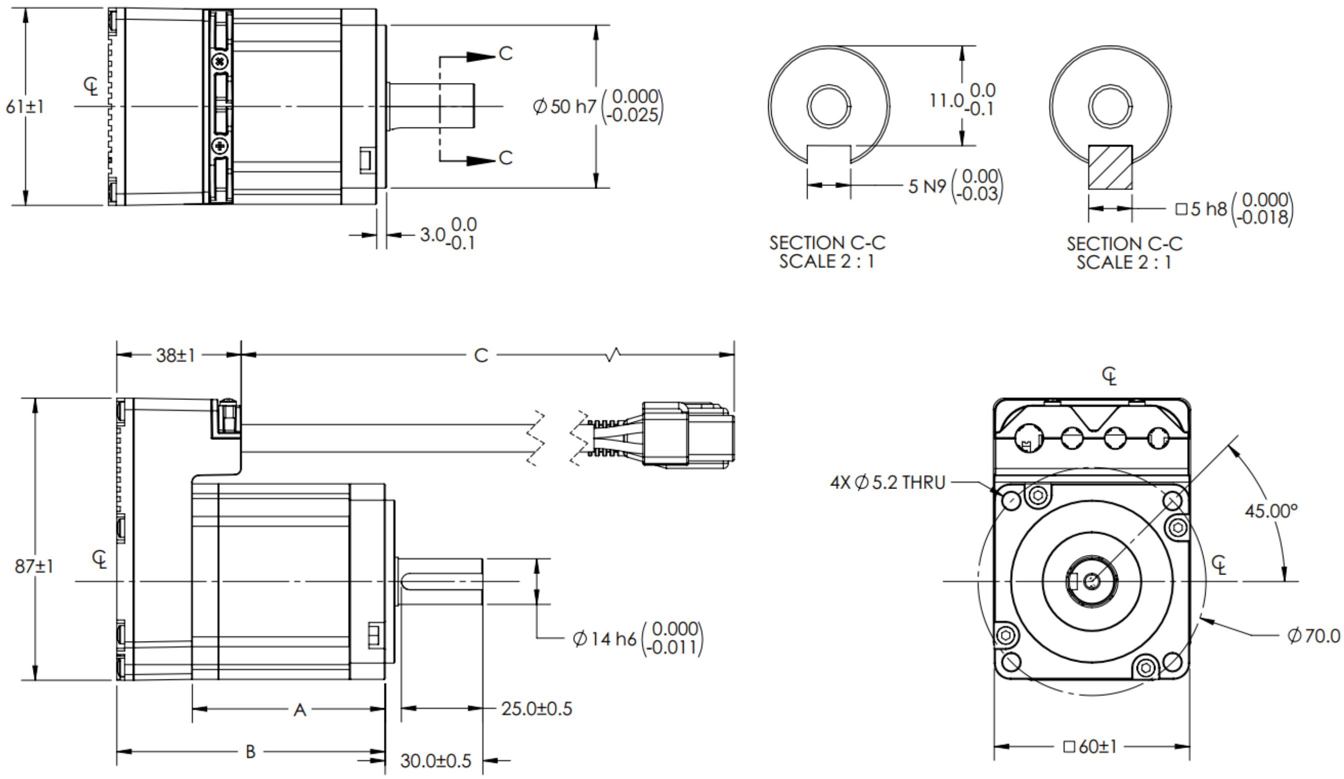
1.4.1 MMS740XXBE-OB2PKN



Part Number	Motor Power	Dimension A (mm)	Dimension B (mm)	Dimension C (mm)
MMS74005BE-OB2PKN	50W	39.5 ± 0.5	74 ± 1	275 ± 25
MMS74010BE-OB2PKN	100W	54.0 ± 0.5	88 ± 1	275 ± 25

Figure 3: MMS740XXBE-OB2PKN Dimensions

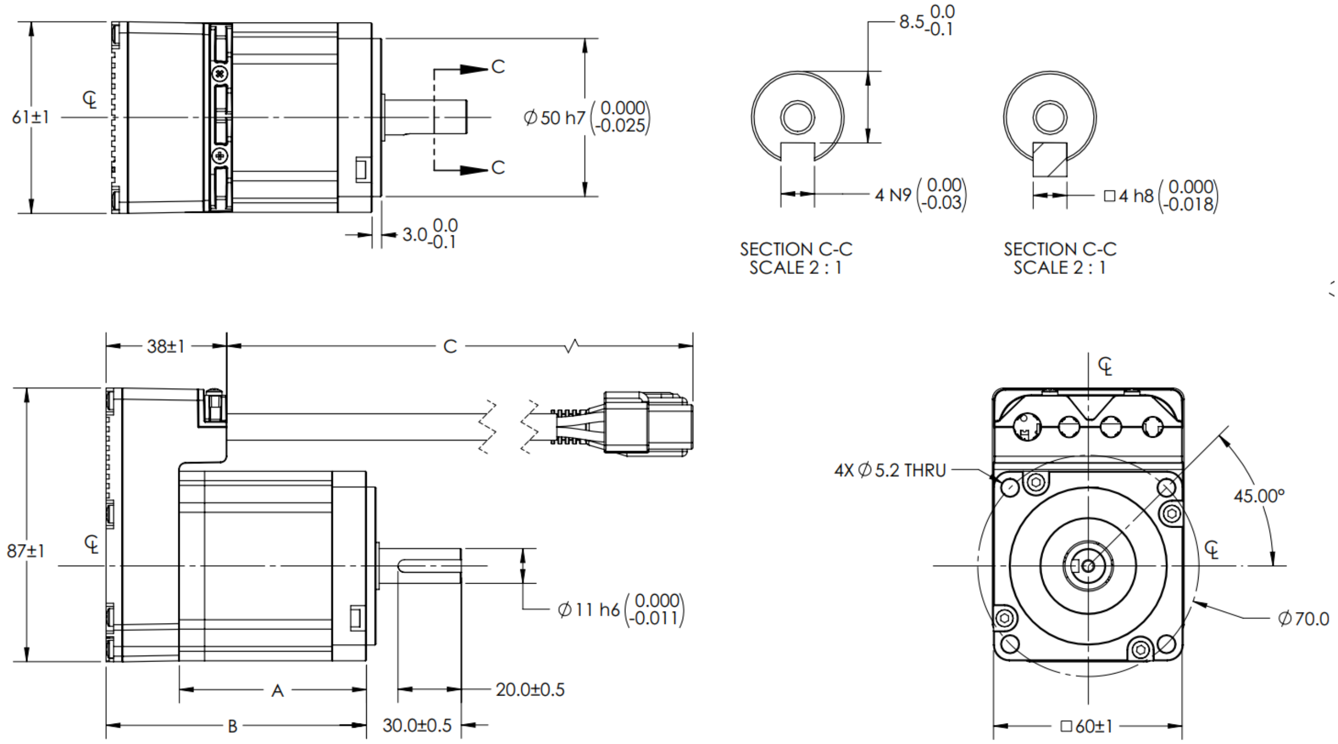
1.4.2 MMS760XXBE-OB2PKN



Part Number	Motor Power	Dimension A (mm)	Dimension B (mm)	Dimension C (mm)
MMS76020BE-OB2PKN	200W	59.2 ± 0.5	82 ± 1	275 ± 25
MMS76040BE-OB2PKN	400W	76.4 ± 0.5	100 ± 1	275 ± 25

Figure 4: MMS760XXBE-OB2PKN Dimensions

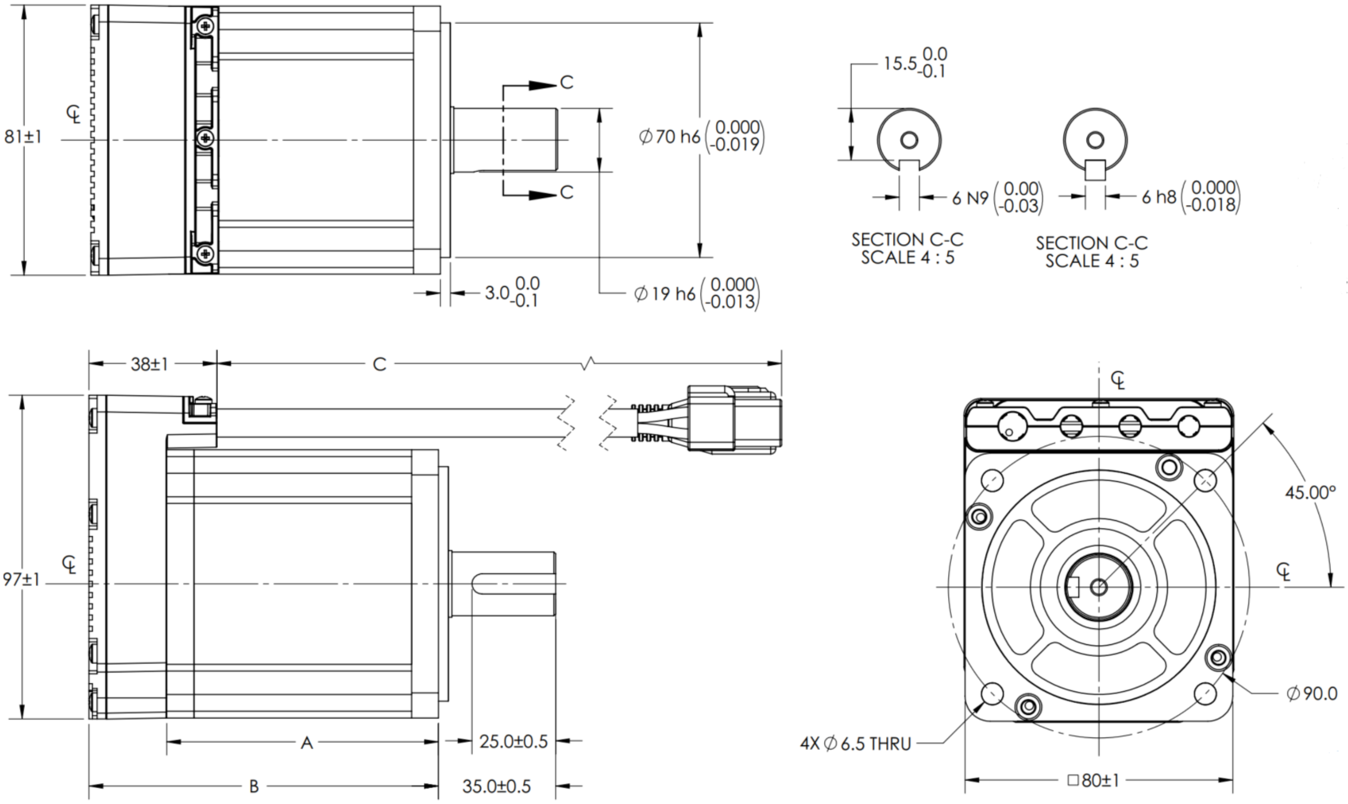
1.4.3 MMS760XXBE-OB2PCN



Part Number	Motor Power	Dimension A (mm)	Dimension B (mm)	Dimension C (mm)
MMS76020BE-OB2PCN	200W	59.2 ± 0.5	82 ± 1	275 ± 25

Figure 5: MMS760XXBE-OB2PCN Dimensions

1.4.4 MMS780XXBE-OB2PKN



Part Number	Motor Power	Dimension A (mm)	Dimension B (mm)	Dimension C (mm)
MMS78075BE-OB2PKN	750W	81.2 ± 0.5	104 ± 1	275 ± 25

Figure 6: MMS780XXBE-OB2PKN Dimensions

1.5 Interface Definition

Note that the direction is from the outside looking toward the motor side, and be careful of incorrect wiring sequences.

1.5.1 MMS740XXBE-OB2PKN

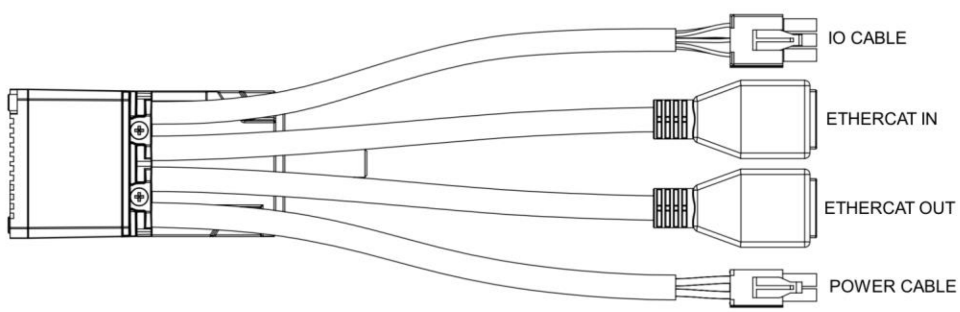


Figure 7: MMS740XXBE Interface Definition

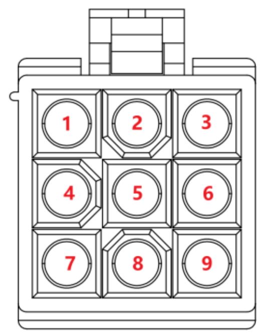
Mating Connector

Table 2: MMS740XXBE Interface List

Interface Name	Mating Connector	Description	Recommended Crimp Size
IO	FL4.14mm 3X3 9P	Female rubber casing	AWG 26 with Molex 638191100 Crimper Tool
	FL4.14 Female Terminal	Female terminal	
ETHERCAT IN	-	Standard RJ45 connector	
ETHERCAT OUT	-	Standard RJ45 connector	
POWER	FL4.14mm 2X2 4P	Female rubber shell	AWG18-AWG19 1.0mm^2 with Molex 638190800 Crimper Tool
	FL4.14 Female Terminal	Female terminal	

I/O Interface Pin Definitions

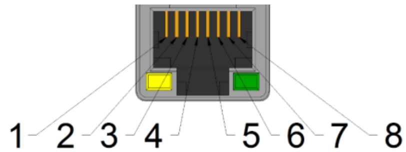
Table 3: MMS740XXBE IO Interface Pin Definitions



Pin Number	Name	Description
1	SHIELD	Shielded
2	NC	No connection
3	DI2	Digital input 2
4	COMO	Output common
5	NC	No connection
6	DI1	Digital input 1
7	DO1	Digital output 1
8	DI3	Digital input 3
9	COMI	Input common

EtherCAT Interface Pin Definitions

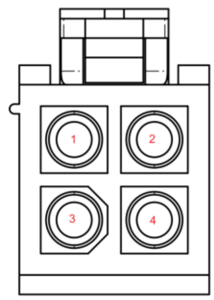
Table 4: MMS740XXBE EtherCAT Interface Pin Definitions



Pin Number	Name	Description
1	TX+	EtherCAT data transmission (positive)
2	TX-	EtherCAT data transmission (negative)
3	RX+	EtherCAT data reception (positive)
4	MLink+	MLink debug port (positive)
5	MLink-	MLink debug port (negative)
6	RX-	EtherCAT data reception (negative)
7	Battery+	Multi-turn absolute encoder battery power supply positive terminal (can be left disconnected when used as a single-turn absolute encoder)
8	Battery-	Multi-turn absolute encoder battery power supply negative terminal (can be left disconnected when used as a single-turn absolute encoder)

Power Interface Pin Definitions

Table 5: MMS740XXBE Power Interface Pin Definitions



Pin Number	Name	Description
1	GND	DC power ground
2	VIN	DC power supply positive
3	PE	Chassis ground
4	R-	External braking resistor terminal, braking resistor is connected between VIN and R-

1.5.2 MMS760XXBE-OB2PKN/MMS760XXBE-OB2PCN

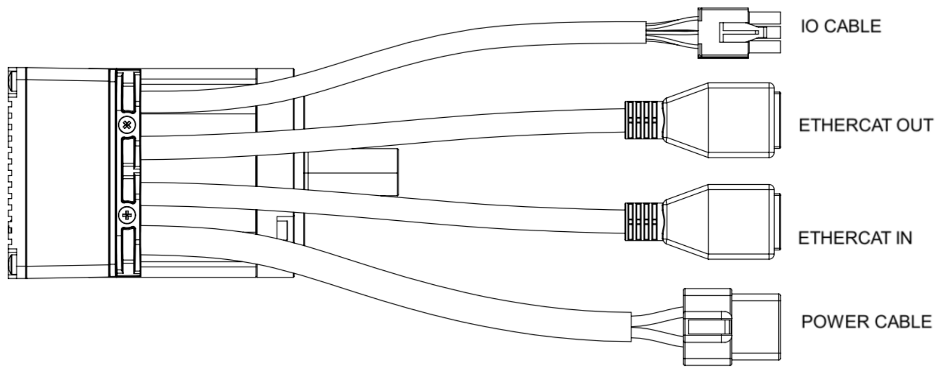


Figure 8: MMS760XXBE Interface Definition

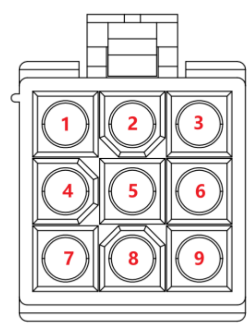
Matching Connector

Table 6: MMS760XXBE Interface List

Pin Number	Name	Description	Recommended Crimp Size
IO	FL4.14mm 3X3 9P	Female rubber casing	AWG26 with Molex 638191100 Crimper Tool
	FL4.14 Female Terminal	Female terminal	
ETHERCAT IN	-	Standard RJ45 connector	
ETHERCAT OUT	-	Standard RJ45 connector	
POWER	HX63090-4P (DJ7041-6.3-21)	Female housings and terminals	AWG14-AWG15 1.5mm^2 with Molex 638190800 Crimper Tool

I/O Interface Pin Definitions

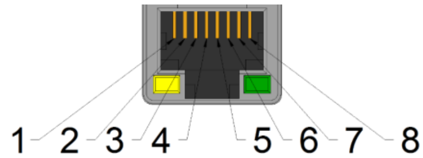
Table 7: MMS760XXBE I/O Interface Pin Definitions



Pin Number	Name	Description
1	SHIELD	Shielded
2	NC	No connection
3	DI2	Digital input 2
4	COMO	Output common
5	NC	No connection
6	DI1	Digital input 1
7	DO1	Digital output 1
8	DI3	Digital input 3
9	COMI	Input common

EtherCAT Interface Pin Definitions

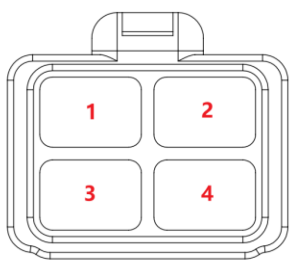
Table 8: MMS760XXBE EtherCAT Interface Pin Definitions



Pin Number	Name	Description
1	TX+	EtherCAT data transmission (positive)
2	TX-	EtherCAT data transmission (negative)
3	RX+	EtherCAT data reception (positive)
4	MLink+	MLink debug port (positive)
5	MLink-	MLink debug port (negative)
6	RX-	EtherCAT data reception (negative)
7	Battery+	Multi-turn absolute encoder battery power supply positive terminal (can be left disconnected when used as a single-turn absolute encoder)
8	Battery-	Multi-turn absolute encoder battery power supply negative terminal (can be left disconnected when used as a single-turn absolute encoder)

Power Interface Pin Definitions

Table 9: MMS760XXBE Power Interface Pin Definitions



Pin Number	Name	Description
1	GND	DC power ground
2	VIN	DC power supply positive
3	PE	Chassis ground
4	R-	External braking resistor terminal, braking resistor is connected between VIN and R-

1.5.3 MMS780XXBE-OB2PKN

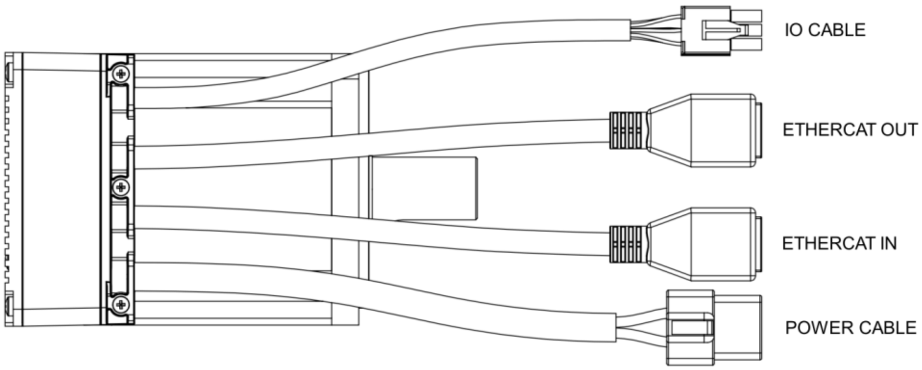


Figure 9: MMS780XXBE Interface Definition

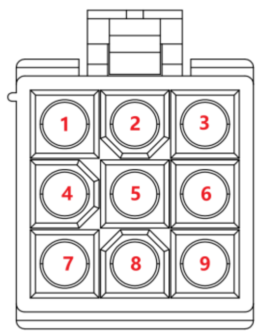
Matching Connector

Table 10: MMS780XXBE Interface List

Pin Number	Name	Description	Recommended Crimp Size
IO	FL4.14mm 3X3 9P	Female rubber casing	AWG26 with Molex 638191100 Crimper Tool
	FL4.14 Female Terminal	Female terminal	
ETHERCAT IN	-	Standard RJ45 connector	
ETHERCAT OUT	-	Standard RJ45 connector	
POWER	HX63090-4P (DJ7041-6.3-21)	Female housings and terminals	AWG14-AWG15 1.5mm^2 with Molex 638190800 Crimper Tool

I/O Interface Pin Definitions

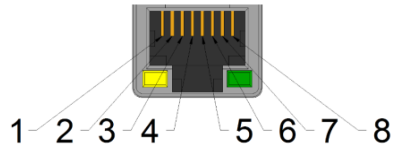
Table 11: MMS780XXBE IO Interface Pin Definitions



Pin Number	Name	Description
1	SHIELD	Shielded
2	NC	No connection
3	DI2	Digital input 2
4	COMO	Output common
5	NC	No connection
6	DI1	Digital input 1
7	DO1	Digital output 1
8	DI3	Digital input 3
9	COMI	Input common

EtherCAT Interface Pin Definitions

Table 12: MMS780XXBE EtherCAT Interface Pin Definitions



Pin Number	Name	Description
1	TX+	EtherCAT data transmission (positive)
2	TX-	EtherCAT data transmission (negative)
3	RX+	EtherCAT data reception (positive)
4	MLink+	MLink debug port (positive)
5	MLink-	MLink debug port (negative)
6	RX-	EtherCAT data reception (negative)
7	Battery+	Multi-turn absolute encoder battery power supply positive terminal (can be left disconnected when used as a single-turn absolute encoder)
8	Battery-	Multi-turn absolute encoder battery power supply negative terminal (can be left disconnected when used as a single-turn absolute encoder)

Power Interface Pin Definitions

Table 13: MMS780XXBE Power Interface Pin Definitions

Pin Number	Name	Description
1	GND	DC power ground
2	VIN	DC power supply positive
3	PE	Chassis ground
4	R-	External braking resistor terminal, braking resistor is connected between VIN and R-

1.6 Parameter List

Table 14: Motor Parameter List

Parameters		Description				
		05	**10**	**20**	**40**	**75**
Basic Parameters	Rated operating voltage (V)	48				
	Input voltage range (V)	24 to 70				
	Continuous output power (W) (0°C to 40°C)	50	100	200	400	750
	Rated Speed (rpm)	3000				
	No-load speed (1) (rpm)	6000	6000	4000	4000	4000
	Continuous output torque (2) (Nm) (0°C to 40°C)	0.16	0.32	0.64	1.27	2.39
	Peak torque (Nm) (3) (<3s)	0.48	0.96	1.92	3.81	7.17
	Moment of inertia (mechanics) (g-cm^2)	35	69	183	500	1600
	Pole pairs	5				
	Encoder type	23-bit multi-turn absolute encoder (can be used as single-turn absolute encoder without battery)				
	Protection class	IP54				
Interface Parameters	DO numbers	1				
	DO maximum load current (mA)	100				
	DO maximum withstanding voltage (V)	36				
	DO output type	Open drain				
	DI numbers	3				
	DI voltage range (V)	18 to 28				
	DI signal highest frequency (kHz)	<10				
	DI Signal (µs)	30				
Mechanical Parameters	Weight (g)	423	545	900	1278	2281
	Positive direction of rotation (viewed from the motor shaft end)	Counterclockwise (on forward command)				
	Cable pull force limit	50 N				
Operating Environment	Operating temperature (°C)	0 to 40, derated for use at greater than 40°C				
	Storage temperature (°C)	-40 to +85				
	Operating humidity	10% to 90% non-condensing				
	Storage humidity	5% to 95% non-condensing				

Table 14: Motor Parameter List *(continued)*

Parameters		Description				
		05	10	20	40	75
EtherCAT	Communications protocol	CoE (PDO, SDO)				
	Synchronization method	DC-distributed clock synchronization, SM synchronization				
	Physical layer	100BASE-TX				
	Baud rate	100Mbps				
	Duplex mode	Full duplex				
	Topology	Linear, circular				
	Transmission medium	Shielded category 5 or above				
	Transmission length	Less than 100m between two nodes				
	Synchronous jitter	<1µs				
	Synchronous manager unit	SM0: Mailbox data output SM1: Mailbox data input SM2: Process Data output SM3: Process data input				
	Process data	Configurable PDO mapping				

Notes:

1) The maximum speed that the motor can reach under no-load conditions without an oil seal under a 48V rated voltage.
2) The maximum torque that can be continuously output by the motor at the rated speed under a 48V rated voltage.
3) The maximum instantaneous (not exceeding 3s) torque that can be output by the motor under a 48V rated voltage.

1.7 Optional Accessories

Table 15: Optional Accessories List

Part Number	Items	Description	Number
MMA02-2001	MLink	Debugging tool for connecting the All-in-One servo motor to the MotionLAB host computer.	1
	USB cable	1.5m, USB Type-A to USB Type-B Adapter Cable	1
MMA06-LA50	MMA06-LA50	Regeneration clamp for DC bus voltage protection against regenerated energy causing high DC bus voltage	1
MMA04-2001		Power cable for MMS740XXBE	1 meter
		I/O cable for MMS740XXBE	1 meter
MMA04-2002		Power cable for MMS760XXBE, MMS780XXBE	1 meter
		I/O cable for MMS760XXBE, MMS780XXBE	1 meter

1.8 Supporting Software and Documentation

1.8.1 MotionLAB

EZmotion provides a user-friendly, PC-based graphical user interface (GUI) called MotionLAB, which provides an easy way to configure and test drives (see Figure 10 on page 26).

Figure 10: MotionLAB UI

Download the MotionLAB software and its driver installer from the EZmotion website.

1.8.2 ESI

To establish communication between the MainDevice (motion control MainDevice station) and SubDevice (servo motor) via the EtherCAT, users must add an EtherCAT configuration file (i.e. an EtherCAT SubDevice Information (ESI) file) to the MainDevice.

Download the ESI file from the EZmotion website.

1.9 Description of System Wiring

1.9.1 Position Encoder

The MMS7xxxxBE series all-in-one servo motor incorporates a 23-bit, high-precision, multi-turn absolute encoder, which detects the absolute position of the motor during the mechanical rotation cycle and counts the number of motor revolutions (multi-turns are only valid when the encoder is powered by an external battery). The absolute encoder can be used in all the motor's operating modes, including position, speed, and torque control modes. The electrical zero position of the servo motor is zeroed at the factory, so the user does not need to repeat the positioning and zeroing when using the servomotor.

When the multi-turn encoder is powered by an external battery, the encoder saves the multi-turn position information after the machine is powered off, and the servo motor can retrieve position information when powering on. If there is no external battery power supply, the multi-turn absolute encoder does save the multi-turn value after shutdown and can only be used as a single-turn absolute encoder.

1.9.2 Single-Axis System Wiring Diagram

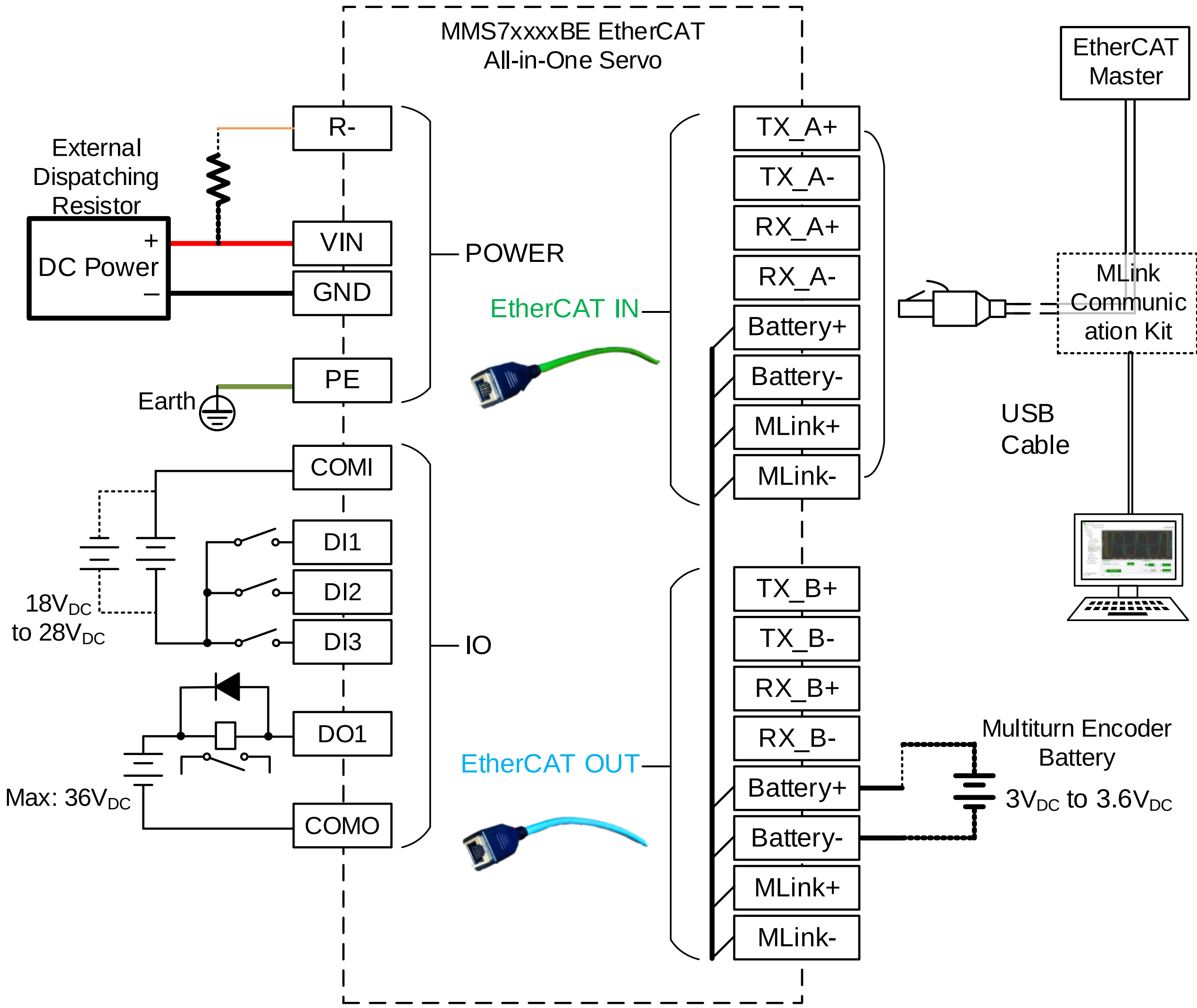


Figure 11: Wiring Diagrams for Standalone System

Follow the steps below for the single-axis system.

1. Use an earth leakage circuit breaker with both overload and short-circuit protection (SCP) on the input power supply side or a special circuit breaker for matching ground protection.
2. If MotionLAB is used to commission the all-in-one servo motor, connect the MLink communication kit in series between the MainDevice and the first SubDevice.
3. When the built-in braking resistor does not allow for enough power, an external braking resistor can be connected, or the MMA06-LA50 accessory can be connected. See Section 4.4.6 on page 52 for the related calculations.
4. If the multi-turn absolute encoder function is required, an external power supply battery of 3.6V is recommended; if the motor is only used as a single-turn absolute encoder, it can be used without a power supply battery.
5. The digital input interface supports NPN and PNP, and the recommended external input signal control power supply is 24V.

6. The recommended external power supply for the digital output interface is 24V. If the load is an inductive load such as a relay, a continuity diode must be connected in reverse parallel. If the load is an optocoupler, a current-limiting resistor must be connected in series.
7. To prevent electric shock, ground the ground terminal.
8. The maximum allowable pulling force of the cable is 50N. Avoid pulling the cable vigorously during the wiring process. Ensure that the bending radius of the cable is longer than 10 times the outer diameter of the cable itself to prevent the core of the cable from breaking due to long-term bending.

1.9.3 Multi-Axis System Wiring Diagram

Use an earth leakage circuit breaker with both overload and short-circuit protection on the input power supply side or a special circuit breaker for matching ground protection.

For multi-axis applications, the MMA06-LA50 regeneration clamp accessory is recommended. This accessory can effectively suppress the voltage increase caused by the motor braking energy, and it can effectively protect the power supply and other equipment from high-voltage damage. The MMA06-LA50 has a wealth of real-time monitoring and alarm functions, and the user can monitor the system operation status in real time. Figure 12 shows the wiring diagram for multi-machine communication.

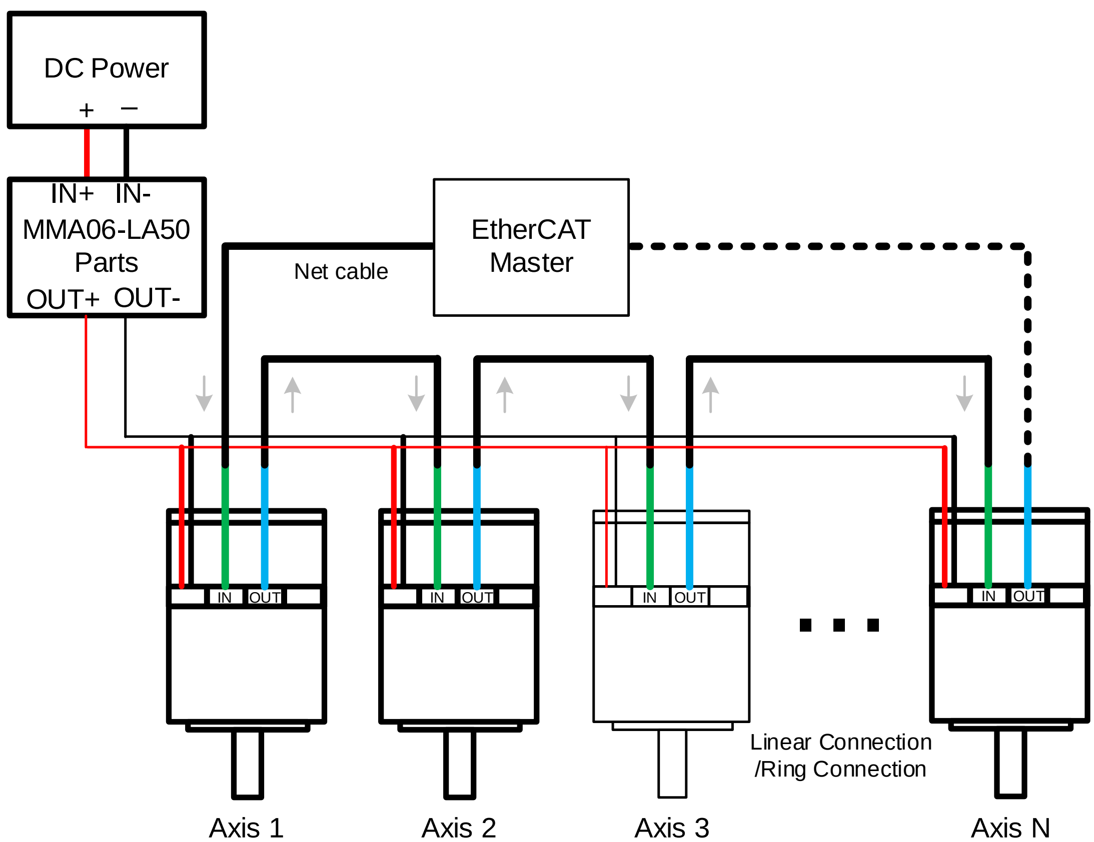


Figure 12: Wiring Diagram of Multi-machine System

When using MotionLAB to monitor and debug the all-in-one servo motor, it is recommended to connect an MLink communication kit between EtherCAT and the first SubDevice to ensure normal communication on the RS485 bus. The EtherCAT communication topology is flexible to connect, and the servo unit has EtherCAT IN and EtherCAT OUT interfaces, so use a linear connection or redundant ring connection topology. The EtherCAT MainDevice, MLink communication kit, and the multi-axis servo unit can be connected using common network patch cables.

1.9.4 I/O Wiring Diagram

Figure 13 shows the digital input circuit diagram. PNP or NPN inputs are supported, but mixed cases (in which the PNP and NPN inputs are both used) are not supported. The recommended external input signal control power supply is between $18V_{DC}$ and $28V_{DC}$.

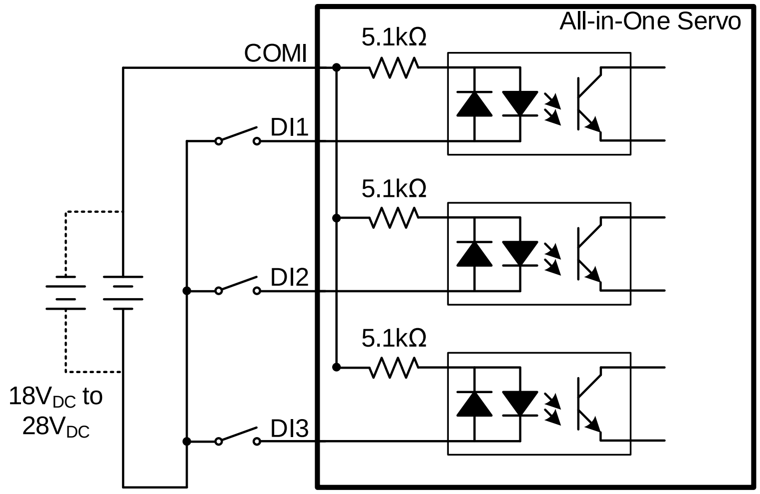


Figure 13: Digital Input Circuit Diagram

Figure 14 shows the digital output circuit diagram when the load is a relay. Reverse-parallelize the current-continuing diodes at both ends of the relay, or the driver may be damaged.

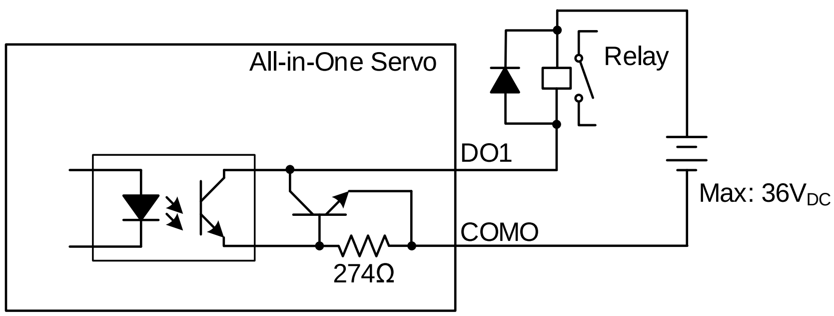


Figure 14: Digital Output Circuit (Relay)

Figure 15 shows the digital output circuit diagram when the load is an optocoupler. Connect the current-limiting resistors in series. The maximum load current allowed for the DO interface is 100mA, and the maximum voltage is 36V.

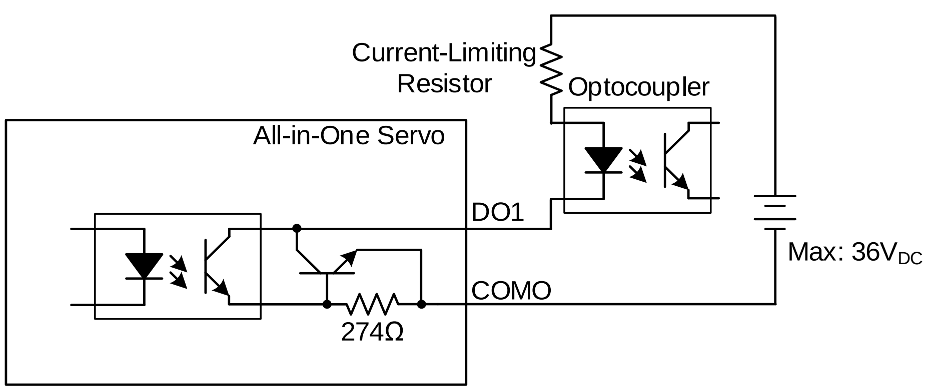


Figure 15: Digital Output Circuit (Optocoupler)

Section 2. Communication

2.1 EtherCAT Introduction

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

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

The distributed clock technique ensures that all the SubDevice devices are synchronized, and that the jitter is below 1µs. Table 16 shows the main implemented EtherCAT features.

Table 16: EtherCAT SubDevice Settings

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

2.1.1 EtherCAT State Machine (ESM)

The EtherCAT State Machine (ESM) coordinates with both the MainDevice and SubDevices during start-up and operation. The interactions between the MainDevice and SubDevice result in changes of states, which are related to writes that are made to the application layer control word: AL Ctrl (0x0120) (see Figure 16).

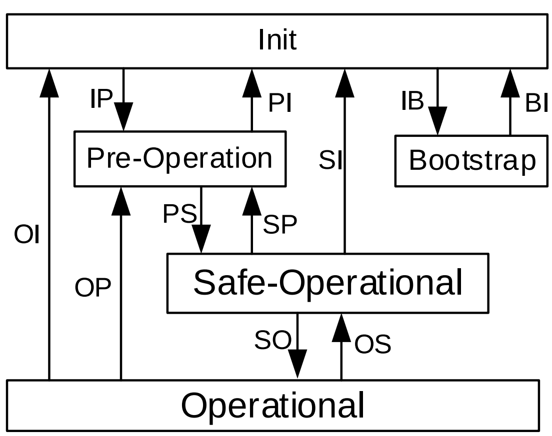


Figure 16: EtherCAT State Machine

Upon the initialization of the data layer and application layer, the ESM enters the initialization (Init) state, which defines the root of the communication relationship between the MainDevice and SubDevice in the application layer. In the application layer, there is no direct communication between the MainDevice and

SubDevice. The MainDevice uses the Init state to initialize a configuration register and to set and configure the sync manager.

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

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

If the output buffer settings are complete and the actual outputs have been delivered to the SubDevice, the operational state can be entered. The SubDevice's application delivers the actual input data, and the MainDevice's application provides the output data.

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

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

2.1.2 Distributed Clock (DC)

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

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

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

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

2.1.3 CANopen over EtherCAT (CoE)

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

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

Figure 17 on page 32 shows the application layer structure.

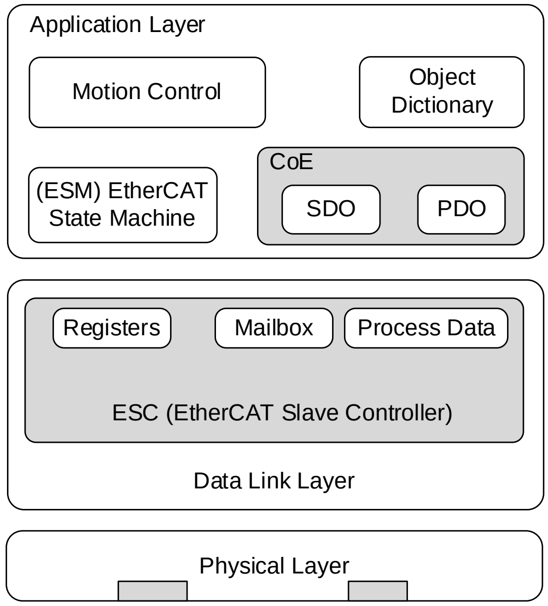


Figure 17: EtherCAT Communication Model

2.1.4 Process Data (PDO)

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

- Reception PDO (RPDO): RPDO is produced by the MainDevice to send control commands to SubDevices.
- Transmission PDO (TPDO): TPDO is produced by the SubDevice to report the SubDevice's status and other information.

The variable-mapped RPDO and the four variable-mapped TPDOs can be selected according to the operation mode. The RPDO mapping objects are defined by the objects 1600h~1603h, and the TPDO mapping objects are defined by the objects 1A00h~1A03h. The maximum number of mapping objects supported for each PDO is 12.

Table 17 and Table 18 on page 33 show the default mapping objects for each PDO, where this document uses abbreviation PP (profile position), CSP (cyclic synchronous position), PV (profile velocity), CSV (cyclic synchronous velocity), PT (profile torque), and CST (cyclic synchronous torque).

Table 17: RPDO Default Mapping Objects

PDO Object Index	Sub-Index	Entry Value	Description
1600h (Supports PP and CSP)	01h	60400010h	Control word
	02h	60600008h	Modes of operation
	03h	607A0020h	Target position
	04h	60B80010h	Touch probe function
	05h	60FE0120h	Digital outputs
1601h (Supports PP, PV, CSP, and CSV)	01h	60400010h	Control word
	02h	60600008h	Modes of operation
	03h	607A0020h	Target position
	04h	60FF0020h	Target velocity
	05h	60B80010h	Touch probe function
	06h	60FE0120h	Digital outputs

Table 17: RPDO Default Mapping Objects *(continued)*

PDO Object Index	Sub-Index	Entry Value	Description
1602h (Supports PP, PV, PT, CSP, CSV, and CST)	01h	60400010h	Control word
	02h	60600008h	Modes of operation
	03h	607A0020h	Target position
	04h	60FF0020h	Target velocity
	05h	60710010h	Target torque
	06h	60B80010h	Touch probe function
	07h	60FE0120h	Digital outputs
1603h (Support PP and CSP)	01h	60400010h	Control word
	02h	607A0020h	Target position

Table 18: TPDO Default Mapping Objects

PDO Object Index	Sub-Index	Entry Value	Description
1A00h (Support PP, CSP)	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60610008h	Modes of operation display
	04h	60640020h	Position actual value
	05h	60B90010h	Touch probe status
	06h	60BA0020h	Touch probe 1 rising edge position value
	07h	60BC0020h	Touch probe 2 rising edge position value
	08h	60FD0020h	Digital inputs
1A01h (Support PP, PV, CSP, CSV)	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60610008h	Modes of operation display
	04h	60640020h	Position actual value
	05h	606C0020h	Velocity actual value
	06h	60B90010h	Touch probe status
	07h	60BA0020h	Touch probe 1 rising edge position value
	08h	60BC0020h	Touch probe 2 rising edge position value
	09h	60FD0020h	Digital inputs
1A02h (Support PP, PV, PT, CSP, CSV, CST)	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60610008h	Modes of operation display
	04h	60640020h	Position actual value
	05h	606C0020h	Velocity actual value
	06h	60770010h	Torque actual value
	07h	60B90010h	Touch probe status
	08h	60BA0020h	Touch probe 1 rising edge position value
	09h	60BC0020h	Touch probe 2 rising edge position value
	0Ah	60FD0020h	Digital inputs
1A03h (Support PP, CSP)	01h	603F0010h	Error code
	02h	60410010h	Status word
	03h	60640020h	Position actual value

The actual used PDO can be configured by the objects 1C12h~1C13h. The 1C12h object sets the RPDO that is actually used, and any one of 1600h to 1603h can be selected. The 1C13h object sets the TPDO that is actually used, and any one of 1A00h to 1A03h can be selected. If there is a need to add or delete mapped objects, the relevant PDO mappings are configured automatically during the MainDevice 's start-up after the EtherCAT MainDevice has completed the set-up, and before the SubDevices switch from the pre-operation state to the operation state.

The following process is followed when the MainDevice configures the PDO. This process is usually done automatically by the EtherCAT MainDevice and the user does not need to configure it manually.

Follow the steps below to configure the PDO mapping group:

1. Write 0 to the 00h sub-index of the 1C12h or 1C13h object to clear the original mapping group.
2. The 01h sub-index of 1C12h or 1C13h writes the number of the mapping group to be mapped. 1600h~1603h are selectable for 1C12h, while 1A00h~1A03h selectable for 1C13h.
3. Write 1 to the 00h sub-index of the 1C12h or 1C13h object.

Follow the steps below to configure the PDO mapping object:

1. Write 0 to the 00h sub-index of the mapping group (e.g. 1600h).
2. Write the mapping content to the 01h-0Ch subindex. The mapping content is 32 bits. The high 16 bits are the index of the object to be mapped, the middle 8 bits are the sub-index of the object to be mapped, and the last 8 bits are the number of bits of the object to be mapped.

2.1.5 EtherCAT SubDevice Information (ESI)

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

2.1.6 Explicit Device Identification

The use of EtherCAT Device Identification is to identify an EtherCAT SubDevice explicitly. This is necessary for the following use cases:

- Hot Connect applications

Within some applications it might be useful to connect or disconnect parts of the network. In this case the MainDevice must have the possibility to identify which part of the network is available

- Prevention against cable swapping

If at least two identical devices are used in one application it might be necessary to prevent the mix-up of these devices by cable swapping.

The “Explicit ID” (object 2109h) can be used optionally for unique addressing .The users can change the address of the SubDevice by modifying the device identification value.

When users set the “Explicit ID”, the value should be set uniquely within a network configuration. And the value = 0 is invalid, the length of the value should be 2 bytes.

2.2 Connect to EtherCAT MainDevice

There are various EtherCAT MainDevice solutions available for connecting and controlling EtherCAT SubDevices, one example is Beckhoff’s TwinCAT. This section demonstrates how to connect devices to an EtherCAT MainDevice.

To run TwinCAT, Visual Studio and TwinCAT must first be installed on a computer with an Intel Ethernet card. For more information, refer to Beckhoff’s TwinCAT Installation Guide.

2.2.1 Network Connection

An EtherCAT network can support up to 65535 devices. The network structure is flexible and supports line, bus, tree, and star topologies. Each motor driver module with an EtherCAT interface has two EtherCAT ports: one for the input and one for the output. This means that different SubDevices can be connected in a line without additional hubs (see Figure 18 on page 35). Hubs can be used to achieve tree, star, or other topologies.

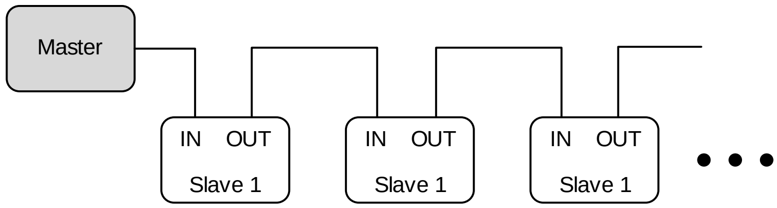


Figure 18: EtherCAT Line Topology

2.2.2 Connection Guidance Using the Beckhoff MainDevice TwinCAT as an Example

1. Copy the ESI file to the EtherCAT installation folder. For example, if using TwinCAT 3.1, the folder should be "<TwinCAT Install Dir>/3.1/Config/Io/EtherCAT".
2. Connect the Ethernet port of the PC to the EtherCAT IN port of the first SubDevice.
3. If necessary, connect the EtherCAT OUT port of the first device to the EtherCAT IN port of the second SubDevice.
4. Power up the SubDevice.
5. Open TwinCAT by clicking on the TwinCAT icon in the lower right corner and selecting "TwinCAT XAE" (see Figure 19).

Figure 19: Open up TwinCAT

1. Create a TwinCAT project.
   a. Select File > New > Project > TwinCAT XAE Project (XML format).
   b. Set the project name and select the file save location, then click OK to create the project.
2. Scan the devices.
   a. In solution explorer, right-click I/O > Devices, then select scan (see Figure 20).

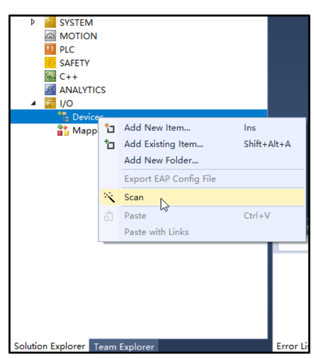


Figure 20: Scan Device

   b. If the computer has more than one available port, select the correct Ethernet port (see Figure 21 on page 36).

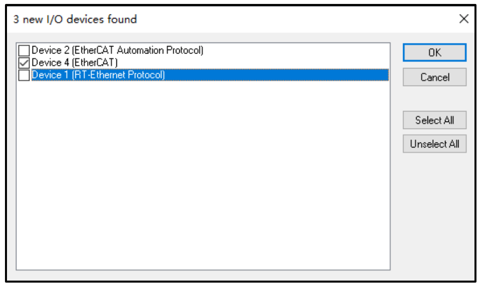


Figure 21: Choose the Correct Ethernet Port

c. If TwinCAT asks to scan the boxes, click "Yes." After a successful scan, the devices should be listed (see Figure 22).

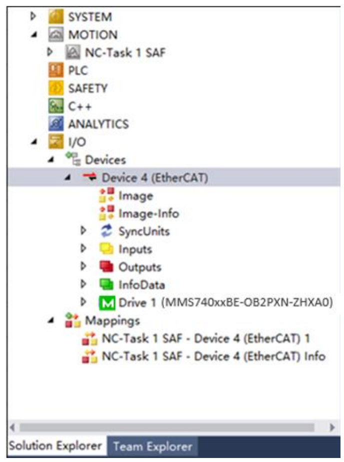


Figure 22: Device List

2.3 Related Objects

Table 19: PDO Mapped Object

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	RPDO Mapping 1							
	00h	Number of mapped objects	RO	No	UINT8	-	-	05h
	01h	Mapped object 1	R/W	No	UINT32	-	-	60400010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60600008h
	03h	Mapped object 3	R/W	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60B80010h
1600h	05h	Mapped object 5	R/W	No	UINT32	-	-	60FE0120h
	06h	Mapped object 6	R/W	No	UINT32	-	-	0
	07h	Mapped object 7	R/W	No	UINT32	-	-	0
	08h	Mapped object 8	R/W	No	UINT32	-	-	0
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0

Table 19: PDO Mapped Object *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1601h	**RPDO Mapping 2**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	06h
	01h	Mapped object 1	R/W	No	UINT32	-	-	60400010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60600008h
	03h	Mapped object 3	R/W	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60FF0020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	60B80010h
	06h	Mapped object 6	R/W	No	UINT32	-	-	60FE0120h
	07h	Mapped object 7	R/W	No	UINT32	-	-	0
	08h	Mapped object 8	R/W	No	UINT32	-	-	0
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0
1602h	**RPDO Mapping 3**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	07h
	01h	Mapped object 1	R/W	No	UINT32	-	-	60400010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60600008h
	03h	Mapped object 3	R/W	No	UINT32	-	-	607A0020h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60FF0020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	60710010h
	06h	Mapped object 6	R/W	No	UINT32	-	-	60B80010h
	07h	Mapped object 7	R/W	No	UINT32	-	-	60FE0120h
	08h	Mapped object 8	R/W	No	UINT32	-	-	0
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0

Table 19: PDO Mapped Object *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	RPDO Mapping 4							
1603h	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	Mapped object 1	R/W	No	UINT32	-	-	60400010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	607A0020h
	03h	Mapped object 3	R/W	No	UINT32	-	-	0
	04h	Mapped object 4	R/W	No	UINT32	-	-	0
	05h	Mapped object 5	R/W	No	UINT32	-	-	0
	06h	Mapped object 6	R/W	No	UINT32	-	-	0
	07h	Mapped object 7	R/W	No	UINT32	-	-	0
	08h	Mapped object 8	R/W	No	UINT32	-	-	0
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0
	TPDO Mapping 1							
1A00h	00h	Number of mapped objects	RO	No	UINT8	-	-	08h
	01h	Mapped object 1	R/W	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60410010h
	03h	Mapped object 3	R/W	No	UINT32	-	-	60610008h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60640020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	60B90010h
	06h	Mapped object 6	R/W	No	UINT32	-	-	60BA0020h
	07h	Mapped object 7	R/W	No	UINT32	-	-	60BC0020h
	08h	Mapped object 8	R/W	No	UINT32	-	-	60FD0020h
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0

Table 19: PDO Mapped Object *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1A01h	**TPDO Mapping 2**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	Mapped object 1	R/W	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60410010h
	03h	Mapped object 3	R/W	No	UINT32	-	-	60610008h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60640020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	606C0020h
	06h	Mapped object 6	R/W	No	UINT32	-	-	60B90010h
	07h	Mapped object 7	R/W	No	UINT32	-	-	60BA0020h
	08h	Mapped object 8	R/W	No	UINT32	-	-	60BC0020h
	09h	Mapped object 9	R/W	No	UINT32	-	-	60FD0020h
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0
1A02h	**TPDO Mapping 3**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	0Ah
	01h	Mapped object 1	R/W	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60410010h
	03h	Mapped object 3	R/W	No	UINT32	-	-	60610008h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60640020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	606C0020h
	06h	Mapped object 6	R/W	No	UINT32	-	-	60770010h
	07h	Mapped object 7	R/W	No	UINT32	-	-	60B90010h
	08h	Mapped object 8	R/W	No	UINT32	-	-	60BA0020h
	09h	Mapped object 9	R/W	No	UINT32	-	-	60BC0020h
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	60FD0020h
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0

Table 19: PDO Mapped Object *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1A03h	**TPDO Mapping 4**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	04h
	01h	Mapped object 1	R/W	No	UINT32	-	-	603F0010h
	02h	Mapped object 2	R/W	No	UINT32	-	-	60410010h
	03h	Mapped object 3	R/W	No	UINT32	-	-	60610008h
	04h	Mapped object 4	R/W	No	UINT32	-	-	60640020h
	05h	Mapped object 5	R/W	No	UINT32	-	-	0
	06h	Mapped object 6	R/W	No	UINT32	-	-	0
	07h	Mapped object 7	R/W	No	UINT32	-	-	0
	08h	Mapped object 8	R/W	No	UINT32	-	-	0
	09h	Mapped object 9	R/W	No	UINT32	-	-	0
	0Ah	Mapped object 10	R/W	No	UINT32	-	-	0
	0Bh	Mapped object 11	R/W	No	UINT32	-	-	0
	0Ch	Mapped object 12	R/W	No	UINT32	-	-	0
1C12h	**SyncManager 2 Assigned PDO**							
	00h	Max subindex	R/W	No	UINT16	-	-	1
	01h	RPDO assignment mapping group number	R/W	No	UINT16	-	-	1603h
1C13h	**SyncManager 3 Assigned PDO**							
	00h	Max subindex	R/W	No	UINT16	-	-	1
	01h	TPDO assignment mapping group number	R/W	No	UINT16	-	-	1A03h

2.4 MLink Introduction

To facilitate user debugging, the motor's operation status can be monitored in real time, and the motor's parameters can be configured in real time. MotionLAB communicates with servo motors through MLink, which is an application layer communication protocol developed by EZmotion based on the RS485 protocol. MLink allows users to configure, debug, and monitor multiple motors through the MLink bus.

The servo motor is connected to the PC through the communication kit to achieve communication with the debugging software (MotionLAB). The servo motor's communication parameters, which contain the parity check and baud rate, must match the MLink for correct communication. For more information on this interface, refer to the MotionLAB Quick Start Manual.

The motor supports three types of parity checks: odd parity, even parity, and no parity. The default parity for MLink and the servo motor is even parity.

The baud rate supports 9600bps to 5Mbps, and the default baud rate of both MLink and the servo motor is 2.5Mbps. When using the servo motor, ensure that its baud rate and parity check mode match what is set via MLink.

The servo motor's default address is 1. For bus type multi-axis MLink communication, connect each motor with MotionLAB separately and assign different SubDevice addresses for each motor to prevent an address from conflicting with the default address. Afterward, connect the servo motors with different addresses to the MLink bus to obtain a multi-axis configuration with debugging and monitoring functions. The parity check mode, baud rate, and SubDevice address can be configured via MotionLAB debugging software.

Section 3. Functional Overview

Table 20: MMS7XXXXBE Function Summary

Function	Overview
Profile Position Mode (PP)	The position is given by the host computer via the bus. The servo motor plans the position commands and completes the positioning process.
Profile Velocity Mode (PV)	The velocity is given by the host computer via the bus The servo motor plans the velocity command and completes the velocity control.
Profile Torque Mode (PT)	The torque is given by the host computer via the bus. The servo motor plans the torque command and completes the torque control.
Homing Mode (HM)	The host computer sets the homing parameters through the bus, and the servo motor returns to the zero position automatically.
Cyclic Synchronized Position Mode (CSP)	The host computer plans the position command trajectory and gives commands periodically through the bus, and the servo motor completes the positioning process.
Cyclic Synchronized Velocity Mode (CSV)	The host computer plans the speed command trajectory and gives commands periodically through the bus, and the servo motor completes the speed control.
Cyclic Synchronized Torque Mode (CST)	The host computer plans the position command trajectory and gives commands periodically through the bus, and the servo motor completes the torque control.
Impendence Mode (IM)	The host computer sets the torque bias via the bus. The servo motor plans the torque output and completes the control.
JOG Mode	In the pointing operation mode (jogging), the user presses the jog button in MotionLAB, and the servo motor rotates continuously with the set control parameters; when the button is released, the servo motor stops moving.
User Unit Setting	Users can set the user unit for the motor input command/output parameter display according to the actual motion mechanism in use.
High Resolution Positional Accuracy	23-bit absolute position encoder.
Multi-Turn Absolute Position Encoders	By powering the encoder with a battery, multi-turn absolute position information can be recorded.
Touch Probe	Locks the motor position information when the external input signal changes.
EtherCAT Variable Mapped PDO	Users can configure the PDO objects they need through the EtherCAT MainDevice.
Position Limit	Limit the position range of motor movement.
Velocity Limit	Limit the speed of the motor.
Torque Limit	Limit the positive and negative torque of the motor.
Acceleration Limit	Limit the maximum acceleration and deceleration speed during motor movement.
Modulo Positioning	Modular motion, taking the modulus of the motor's positioning, and the position actual value will be limited within a defined model range.
Position Command Limit	Limit the commanded position range. The motor will operate within the set commanded position range.
Placement Judgment Setting	Position deviation thresholds and time windows can be set for the motor to consider positioning complete, and speed deviation thresholds and time windows for speed control complete.

Table 20: MMS7XXXXBE Function Summary *(continued)*

Function	Overview
Gain Switching	Multiple gains of the servo motor loop, as well as switching points and switching slopes, can be set to apply to different working conditions.
Stiffness Adjustment	Supports normalized adjustment using stiffness gain, allowing multiple gain parameters to be adjusted by simply adjusting the stiffness.
Position Feedback Filter	The position information is filtered to suppress position sampling noise and achieve smooth motor operation.
Velocity Feedback Filter	The velocity information is filtered to suppress speed measurement noise and enables smooth operation under the motor.
Mechanical Characterization	Used in conjunction with MotionLAB, the resonance point of a mechanical system can be measured and analyzed.
Mechanical Resonance Suppression	The servo motor has 4 notch filters to suppress mechanical resonance.
Command Feed-Forward	Speed feed-forward, torque feed-forward, improve dynamic response speed and reduce positional deviation.
Shutdown Options	Configurable motor shutdown method.
Fault Protection	Multiple fault detection and protection functions.
EtherCAT Watchdog	If the all-in-one servo is in the servo on state and the EtherCAT communication between the MainDevice and the SubDevice servo is disconnected during normal communication, the EtherCAT watchdog reports an error.
Alarm History Record	The motor will record the last 20 fault alarm records, which can still be saved when the power is turned off. The records can be viewed and cleared via MotionLAB.
Input and Output Signal Configuration	Inputs can be configured as a variety of control signals, and outputs can be configured as a variety of flag signals.
Input and Output Status Display	The I/O status can be configured and monitored via the communication bus.
Braking Resistor	The servo motor contains a low-power braking resistor, and an external braking resistor interface is reserved.
Parameter Identification	Provides a variety of operating conditions to identify the motor and system parameters.
Parameter Comparison	The set-up parameters are compared to the running parameters via the MotionLAB, highlighting the different parameters.
Debug and Operating Platform	The MotionLAB software that comes with the MMS7xxxxBE product provides a motor debugging and operating platform, which can be downloaded from the Ezmotion official website. Users can perform a large number of settings and control operations through MotionLAB.
Position Zeroing	Setting for the current position to the zero/home position inside the motor.

Section 4. Operation and Commissioning

4.1 Trial Operation Flowchart

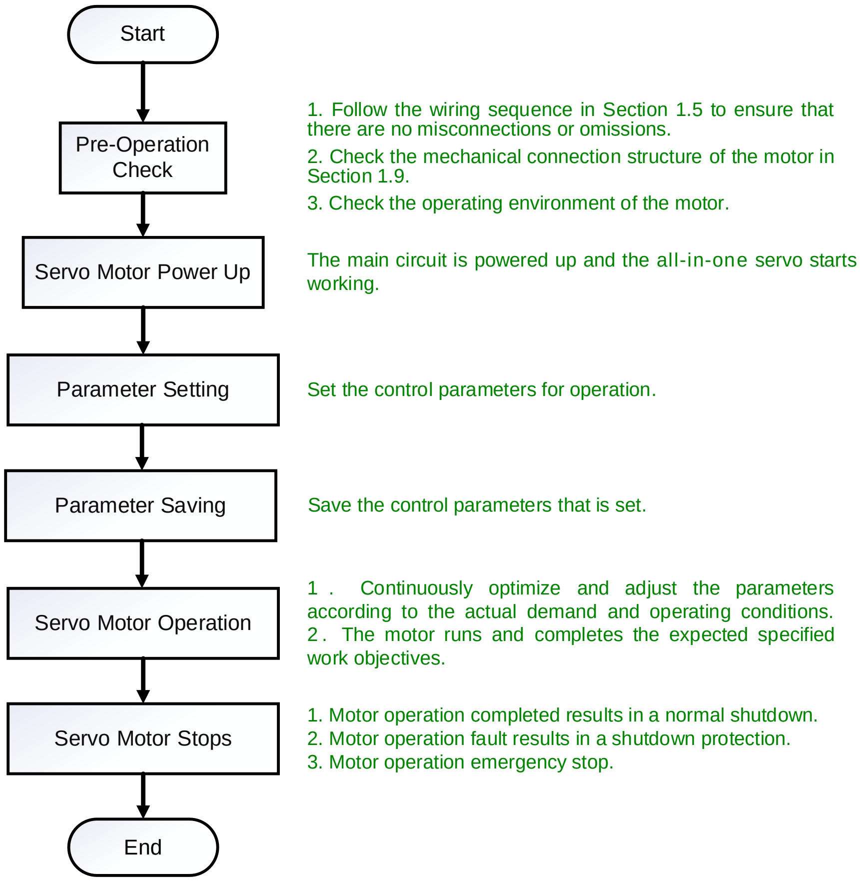


Figure 23: Trial Operation Flowchart

4.2 Pre-Operation Check

Before start-up and servo motor operation, follow the guidelines below:

1. Ensure that the power input connector (VIN, GND, R-, and PE) for the all-in-one servo is correctly connected, and ensure that the female connector of the all-in-one motors is correct
2. Ensure that the EtherCAT interface of the all-in-one servo is correctly connected. The EtherCAT network port of the all-in-one servo follows the standard network cable interface protocol (T-568B) and uses 100Mbps Ethernet communication. To use EtherCAT and MLink communication at the same time, see Section 1.9.2 on page 27 to connect the MLink communication kit in series between the MainDevice and the first SubDevice for the transfer of the two communication methods.
3. Ensure that the I/O interface of the all-in-one servo is connected correctly. The input voltage of DI must be within its limits, and DO1's external pull-up voltage and current must be within the tolerance range. Ensure that the INPUT polarity is the same as the effective polarity of the motor configuration INPUT, and ensure that the COMO is grounded
4. Reliably ground the all-in-one servo.
5. Ensure that all outgoing cables are stressed within their limits.
6. Ensure that there are no objects outside the servo unit that have a risk of causing a short circuit.
7. Ensure that the mounting, shaft, and mechanical connections of the servo motor are reliable.

4.3 Servo Motor Start-Up

If the power input of the servo motor is correctly wired and the power supply is switched on, the green power LED on the motor should light up; meanwhile, the red fault indicator should not light up, indicating that the servo motor is working normally and waiting for EtherCAT or MLink to provide a control signal.

If the red fault LED indicator is on, connect to MotionLAB to check the specific fault and its cause.

If the green power indicator does not light up, check the wiring of the power input connector.

Figure 24 shows the timing diagram for servo start-up.

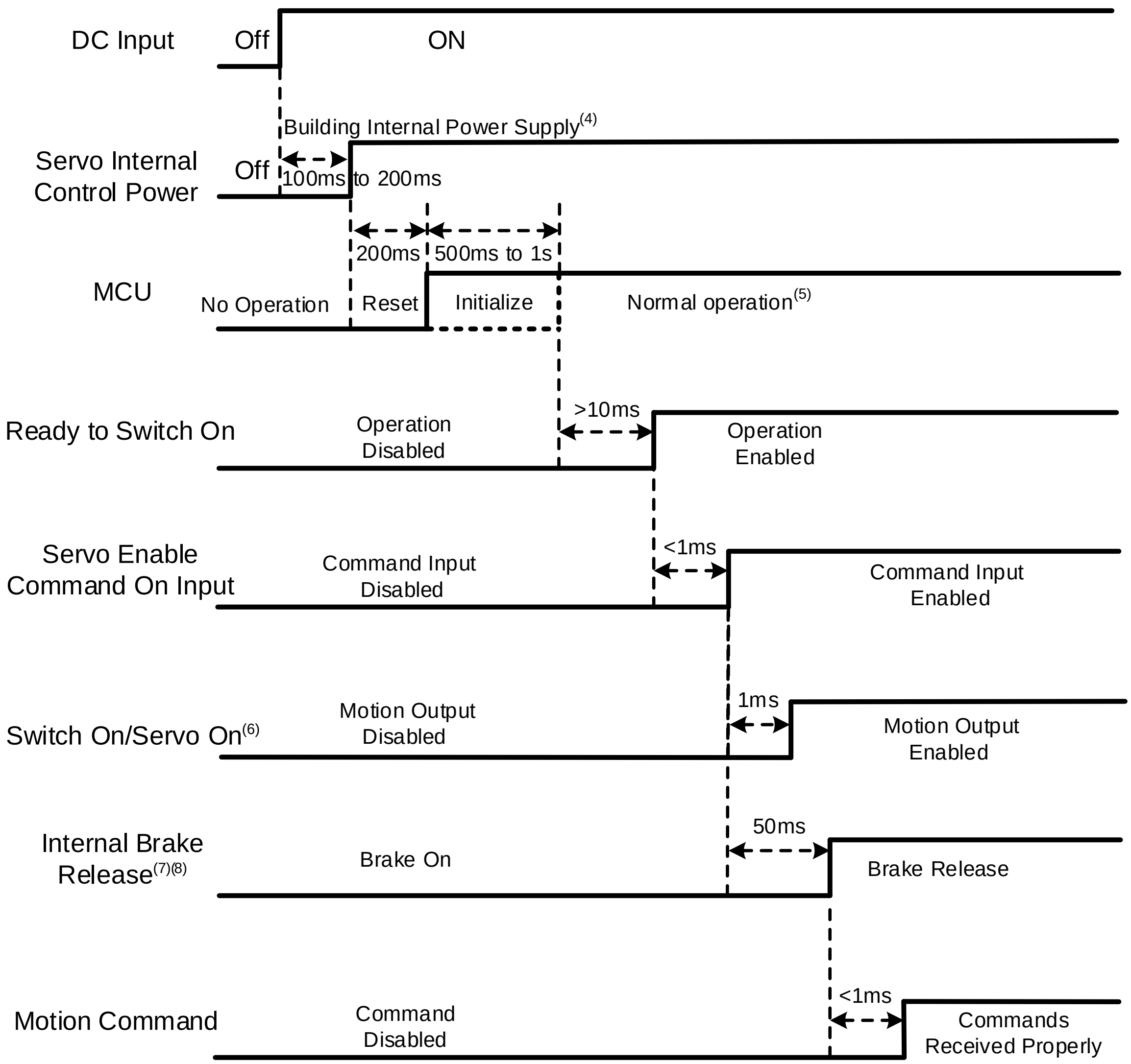


Figure 24: Start-Up Timing Diagram

Notes:

4) After the internal control power supply establishes the internal voltage, wait for the master MCU to initialize before protection functions are activated.
5) When the external DC input is powering up, the all-in-one servo can operate normally after the initialization of the master MCU.
6) “Switch On/Servo On” means that the motor has reached a state where it can be servo-enabled for output, after which it can normally receive control commands from the user.
7) The all-in-one servo is divided into two versions: one without a built-in holding brake, and a second with a built-in brake. If the motor is the version without an internal brake, ignore this part of the timing diagram.
8) Motor with brake version: Motion control commands can be issued to run the motor only after the built-in brake is released.
   a. Motor without brake: Motion control commands can be issued to run the motor only when the servo enable output is working properly.

4.4 Parameter Settings

After the servo motor is powered up and the motor system starts to work normally, the user can adjust the settings for the servo motor's electronic gear ratio, polarity, user unit, external I/O, protection, and energy drain according to their own needs before the test run. This allows the motor to meet the application's functional requirements and maintain safe and stable operation.

4.4.1 User Unit Settings

The MMS7xxxxBE series servo motors provide a user-defined unit setting function, which allows the user to set the user unit for the motor input command/output parameter display according to the actual motion mechanism in use.

Figure 25 shows a linear motion structure with a rotary motor driving a screw. The actual distance rotated and moved by the motor is set by setting the user unit when the input position command is 1 user unit.

For linear motion structures where a rotary motor drives a screw, electronic gear ratios are typically used to set the actual distance that the motor rotates and moves when the input position command is 1 pulse.

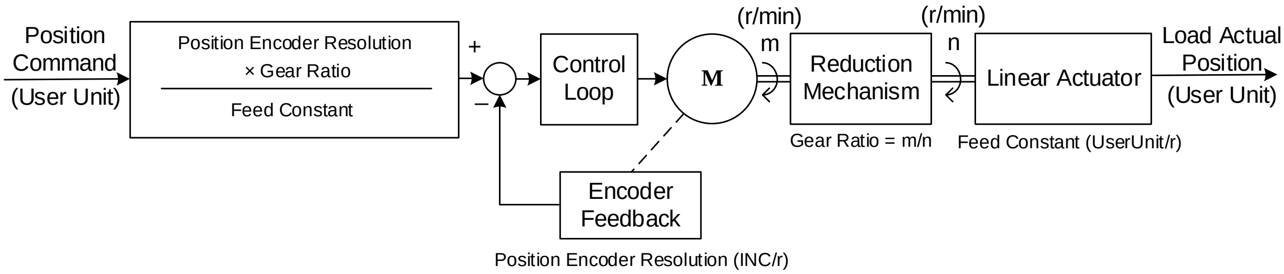


Figure 25: Motor Drive Schematic

Setting the user unit generally requires setting the feed constant (object 6092h), gear ratio (object 6091h), and position encoder resolution (object 608Fh).

The feed constant represents the displacement of the user unit at the position corresponding to 1 revolution of load axis movement, which can be calculated with Equation (1):

$$\textit{Feed Constant}\ \text{(UserUnit/r)} = \frac{\textit{Feed}\ \text{(6092h-01h)}}{\textit{Driving Shaft Revolutions}\ \text{(6092h-02h)}} \tag{1}$$

The gear ratio indicates the ratio of the input speed and output speed of the gear mechanism, which corresponds to the number of revolutions that the motor shaft must move when the load shaft rotates by 1 revolution in the motor drive system, and can be estimated with Equation (2):

$$\textit{Gear Ratio} = \frac{\textit{Motor Shaft Revolutions}\ \text{(6091h-01h)}}{\textit{Driving Shaft Revolutions}\ \text{(6091h-02h)}} \tag{2}$$

The position encoder resolution represents the increment of the encoder at the position corresponding to 1 revolution of the motor rotation, which can be calculated with Equation (3):

$$\textit{Position Encoder Resolution}\ \text{(INC/r)} = \frac{\textit{Encoder Increments}\ \text{(608Fh-01h)}}{\textit{Motor Revolutions}\ \text{(608Fh-02h)}} \tag{3}$$

According to the above conversion formula, the relationship between the load position feedback and motor position feedback can be estimated with Equation (4):

$$\textit{Load Actual Position}\ \text{(UserUnit)} = \frac{\textit{Position Interal Value}\ \text{(INC)} \times \textit{Feed Constant}\ \text{(UserUnit/r)}}{\textit{Position Encoder Resolution}\ \text{(INC/r)} \times \textit{Gear Ratio}} \tag{4}$$

The conversion formula for the user-defined units to internal encoder units can be calculated with Equation (5):

$$\textit{Position Internal Demand}\ (\text{INC}) = \textit{Postion Demand}\ (\text{UserUnit}) \times \frac{\textit{Position Encoder Resolution}\ (\text{INC/r}) \times \textit{Gear Ratio}}{\textit{Feed Constant}\ (\text{UserUnit/r})} \quad (5)$$

The command resolution represents the number of pulses entered into the position command of the user unit for each additional pulse of the internal position command. It can be estimated with Equation (6):

$$\textit{Command Resolution}\ (\text{UserUnit/INC}) = \frac{\textit{Postion Demand}\ (\text{UserUnit})}{\textit{Position Internal Value}\ (\text{INC})} = \frac{\textit{Feed Constant}\ (\text{UserUnit/r})}{\textit{Position Encoder Resolution}\ (\text{INC/r}) \times \textit{Gear Ratio}} \quad (6)$$

In this all-in-one servo system, the position encoder resolution (608Fh) is a fixed value, and the user can set the gear ratio (6091h) and the feed constant (6092h) according to the structure of the drive system. The feed constant should be as large as possible to improve the command resolution.

The relationship between the load speed and motor speed can be calculated with Equation (7):

$$\textit{Load Speed}\ (\text{UserUnit/s}) = \frac{\textit{Motor Speed}\ (\text{INC/s}) \times \textit{Feed Constant}\ (\text{UserUnit/r})}{\textit{Position Encoder Resolution}\ (\text{INC/r}) \times \textit{Gear Ratio}} = \frac{\textit{Motor Speed}\ (\text{rpm}) \times \textit{Feed Constant}\ (\text{UserUnit/r})}{60 \times \textit{Gear Ratio}} \quad (7)$$

The relationship between load acceleration and motor acceleration can be estimated with Equation (8):

$$\textit{Load Acceleration}\ (\text{UserUnit/s}^2) = \frac{\textit{Motor Acceleration}\ (\text{INC/s}^2) \times \textit{Feed Constant}\ (\text{UserUnit/r})}{\textit{Position Encoder Resolution}\ (\text{INC/r}) \times \textit{Gear Ratio}} = \frac{\textit{Motor Acceleration}\ (\text{rpm/s}) \times \textit{Feed Constant}\ (\text{UserUnit/r})}{60 \times \textit{Gear Ratio}} \quad (8)$$

Related Objects

Table 21: Related Objects of User Unit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
608Fh	01h	Encoder increments	R/W	No	UINT32	INC	UINT32	65536
	02h	Motor revolutions	R/W	No	UINT32	REV	UINT32	1
6090h	01h	Encoder increments per second	R/W	No	UINT32	INC/s	UINT32	65536
	02h	Motor revolutions per second	R/W	No	UINT32	REV/s	UINT32	1
6091h	01h	Motor revolutions	R/W	No	UINT32	REV	UINT32	1
	02h	Shaft revolutions	R/W	No	UINT32	REV	UINT32	1
6092h	01h	Feed	R/W	No	UINT32	UserUnit	UINT32	65536
	02h	Shaft revolutions	R/W	No	UINT32	REV	UINT32	1

4.4.2 Input/Output Settings

Servo motors are available with external I/Os for applications that require a simple control interface.

The servo motor provides three input interfaces for the external control signal connections, such as the home switch, negative limit switch, positive limit switch, and touch probe function. There is one output interface to output signals from the motor, such as alarms and statuses when a target is reached.

Each I/O incorporates a variety of functions that can be selected based on application requirements. For more information on I/O functions (object 2030h) and polarity selection (object 2031h-01h). For the I/O function, the user can set the function of different input interfaces through the "I/O function" (object 2030h) and configure whether it is normally open or normally closed in the I/O polarity 2031-01h register, see Section 9 on page 122.

MotionLAB provides a convenient interface for external I/O control and monitoring, allowing users to monitor the I/O status in real time through the software interface. The interface also includes an enable simulation option; after configuring the I/O functions, users can provide a virtual signal to simulate the external input/output through MotionLAB to enable " IO simulation enable" (2031h-02h), and then configure the I/O status via "IO simulation value" (2031-03h), which is convenient for users to debug. Figure 26 shows the I/O monitor interface. For more information on this interface, refer to the MotionLAB Quick Start Manual.

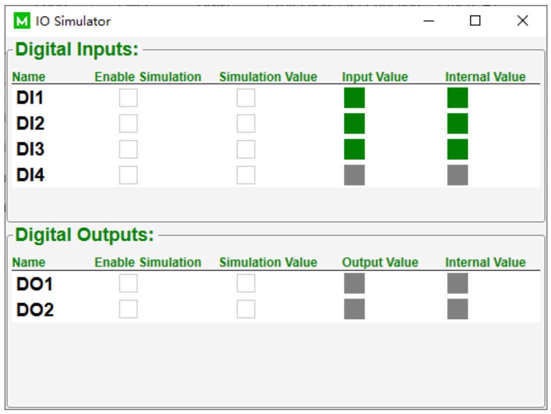


Figure 26: I/O Monitor Interface

The "Digital inputs" (object 60FDh) shows the current input status, where bit[16] represents DI1, bit[17] represents DI2, and bit[18] represents DI3.

The "Physical outputs" (object 60FEh-01h) can control the current digital output status, where bit[16] controls DO1, bit[17] controls DO2. The "Bits mask" (60FEh-02h) is the enable bit for each digital output, where bit[16] enables DO1 output, bit[17] enables DO2 output. If the corresponding bit from "Bits mask" is set to 1, then users can control the forced digital output by writing "Physical outputs". If the corresponding bit of "Bits mask" is set to 0, the forced digital output will not take effect, and the state of corresponding DO will be determined by configured I/O functions and polarity.

"Digital inputs" (60FDh) and "Digital outputs" (60FEh) represent the actual physical state and do not enable I/O simulation.

Related Objects

Table 22: Related Objects of I/O Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	01h	DI1 function	R/W	No	UINT8	-	0 to 4	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 4	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 4	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 4	0
	05h	DO1 function	R/W	No	UINT8	-	0 to 4	0
	06h	DO2 function	R/W	No	UINT8	-	0 to 4	0
2031h	01h	I/O polarity	R/W	No	UINT16	-	-	0
	02h	IO simulation enable	R/W	No	UINT16	-	-	0
	03h	IO simulation value	R/W	No	UINT16	-	-	0
60FDh	00h	Digital inputs	RO	TPDO	UINT32	-	UINT32	-
60FEh	01h	Physical outputs	R/W	TPDO	UINT32	-	UINT32	-
	02h	Bit mask	R/W	TPDO	UINT32	-	UINT32	-

4.4.3 Limit Settings

Before operation and debugging, to avoid system damage or adverse effects brought about by adjusting parameters during operation or improper use by users, it is necessary to set the allowed movement range.

The MMS7xxxxBE series of all-in-one servo motors have a wealth of integrated software limitations, including the software position limit (object 607Dh), motor running speed limitation (object 607Fh), positive torque limit (object 60E0h), negative torque limit (object 60E1h), maximum current (object 6073h), maximum acceleration (object 60C5h), and maximum deceleration (object 60C6h). Users can limit the motor motion according to the actual use requirements to protect the entire motion control system.

Meanwhile, under the profile position mode and cyclic synchronized position (CSP) mode operation, the direction of the motor's rotation can be set by the object's 607Eh polarity. The direction of the motor's rotation can be adjusted without changing the positive (counter clockwise) or negative (clockwise) polarity of the input command. The corresponding position information and speed information is synchronized with the change of polarity.

The positive torque limit and negative torque limit indicate the configured maximum positive and negative torque in the motor. The value shall be given per thousand of rated torque.

The maximum current limit the maximum current that the motor can output in all motion modes.

The maximum profile velocity refers to the maximum speed allowed inside the motor in profile velocity (PV) mode. The output speed does not exceed this value when the motor is actually running in this mode.

The software position limit refers to the internal position feedback of the servo motor, which is compared to the set limit value. If this limit is exceeded, the stopping operation process is executed immediately. This function is effective in both profile position (PP) mode and cyclic synchronized position (CSP) mode.

The maximum speed limit includes the maximum speed of the motor in PV mode, cyclic synchronized velocity (CSV) mode, and JOG mode.

The maximum acceleration and maximum deceleration limits determine the maximum acceleration and deceleration for the motor in PV, CSV, and JOG modes.

Related Objects

Table 23: Related Objects of Limit Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6073h	00h	Max current	R/W	RPDO	UINT16	‰	0 to 3000	3000
607Dh	01h	Min position limit	R/W	RPDO	INT32	UserUnit	INT32	-2^{31}
	02h	Max position limit	R/W	RPDO	INT32	UserUnit	INT32	2^{31}
607Eh	00h	Polarity	R/W	No	UINT8	-	UINT8	0
607Fh	00h	Max profile velocity	R/W	RPDO	UINT32	UserUnit/s	UINT32	3000
6080h	00h	Max motor speed	R/W	RPDO	UINT32	rpm	UINT32	3000
60C5h	00h	Max acceleration	R/W	RPDO	UINT32	UserUnit/s^2	UINT32	2^{32}-1
60C6h	00h	Max deceleration	R/W	RPDO	UINT32	UserUnit/s^2	UINT32	2^{32}-1
60E0h	00h	Positive torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000
60E1h	00h	Negative torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000

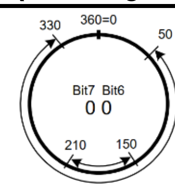
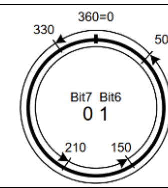
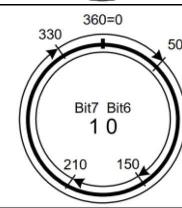
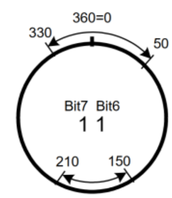
4.4.4 Modulo Positioning

Modulo positioning is only effective in PP mode, which is suitable for applications that require cyclic counting of motor positions. The position of the motor is usually calculated based on the complete mechanical rotation of the load. When the load points in a certain direction, the encoder reading remains unchanged, regardless of how many complete rotations are made. These indicate that the “Position actual value” (object 6064h) is within the range of “Position range limit” (object 607Bh).

“Position range limit” (object 607Bh) indicates the maximum and minimum position range limits, which limits the range of the input value (“Target position”, object 607Ah). If these limits are exceeded or reached, the input value automatically wraps to the other end of range. “Software position limit” (object 607Dh) should be beyond the “Position range limit” (object 607Bh) range.

According to different applications, the types of modulo positioning motion are determined by “Positioning option code” (object 60F2h) (see Table 24). Table 24 also list the schematic diagram of modulo positioning, and it depicts the movements depending on the settings of “Positioning option code” (object 60F2h). In this example, the minimum position range limit is 0° and the maximum position range limit is 360°.

Table 24: Type of Modulo Positioning Option

Bit[7] and Bit[6] of 60F2h	Type of Modulo Positioning	Description	Schematic Diagram of Positioning (Unit: degree)
00	Normal	Normal positioning similar to the linear axis. If “Position range limit” (object 607Bh) is reached or exceeded, the input value (position demand) automatically wraps to the other end of the range.	
01	Only negative direction	Positioning only in the negative direction. If the target position exceeds the actual position, the motion axis does not move in the positive direction, but it moves “Min position limit” (object 607Dh) to the target position.	
10	Only positive direction	Positioning only in the positive direction. If the target position is below actual position, the motion axis will does move in the positive direction, but it moves over “Max position limit” (object 607Dh) to target position.	
11	Shortest way	Positioning with the shortest route to the target position. The position movement distance between two consecutive target positions cannot exceed half of the position range limit. There is a special condition if the difference between the actual value and target position in a 360° system is 180°; in this scenario, the motion axis moves in a positive direction.	

Related Objects

Table 25: Related Objects of Modulo Positioning

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Ah	00h	Target position	R/W	RPDO	INT32	UserUnit	INT32	0
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
607Bh	01h	Min position range limit	R/W	RPDO	UINT32	UserUnit	INT32	-2^{31}
	02h	Max position range limit	R/W	RPDO	UINT32	UserUnit	INT32	2^{31}
60F2h	00h	Positioning option code	R/W	RPDO	UINT16	-	-	0

4.4.5 Protection Settings

The MMS7xxxxBE series all-in-one servo motors are equipped with various protection functions. A protection function action stops the machine, issues an alarm command, and turns off the servo enable function. In the alarm state, the LED red alarm light is always on and the servo cannot be energized.

Before trial operation and debugging, users should enable the necessary protections for the servo motor. The servo motor is equipped with locked rotor protection, over-current protection (OCP), and overload protection by default. Over-speed protection, excessive speed deviation protection, and under-voltage lockout (UVLO) protection are enabled by default for servo motors and cannot be disabled by users.

For a detailed description of fault protections, see Section 7 on page 103.

Related Objects

Table 26: Related Objects of Protection Settings

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	UserUnit	UINT32	182
	06h	Lock speed threshold	R/W	No	UINT16	ms	UINT16	1000
	07h	Lock time window	R/W	No	UINT8	-	0 to 1	0
	08h	Retry enable	R/W	No	UINT16	ms	UINT16	3000
	09h	Retry time	R/W	No	UINT16	V	UINT16	56
	0Ah	DC link limit upper threshold	R/W	No	UINT16	V	UINT16	52
	0Bh	DC link limit lower threshold	RO	TPDO	UINT16	-	-	0
	0Ch	Error status	RW	No	UINT32	rpm	UINT32	3600
	0Dh	Overspeed protection threshold	RW	No	UINT32	rpm	UINT32	1000
	0Eh	Speed error threshold	RW	No	UINT16	ms	UINT16	10
2040h	00h	Temperature	RO	TPDO	INT16	°C	-40 to +125	-
2041h	00h	OTP threshold	R/W	No	INT16	°C	-40 to +125	85
2042h	01h	Overload protection 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

4.4.6 Energy Release Settings

When the motor is decelerating, the energy is transferred from the load side back to the drive side of the servo motor. For power supply systems that are not powered by battery packs, the power supply system usually has a limited sink capacity. The bus voltage tends to increase during deceleration, which poses a risk to the safety of the system. In this scenario, the braking energy must be consumed according to the braking requirements; otherwise, the servo driver is damaged.

Users can monitor the real-time braking resistor load ratio by reading the "Braking resistor load ratio" (200Eh-0Ch) object on page 142. It is recommended to observe the braking resistor load ratio using MotionLAB's multi-axis data sampling interface.

The braking resistor can be built-in or external. When the DC bus voltage rises, the energy can only be consumed by the braking resistor. The MMS7xxxxBE series of all-in-one servo motors have a built-in, low-power braking resistor, and the user can set the operating point of the braking resistor (see Section 7.1 on page 103 for more details).

Table 27 shows the drain resistor specifications.

Table 27: Braking Resistor Specifications

Motor Power	Built-in Braking Resistor Specifications [9]			External Braking Resistor [10] [11]		Capacitor Absorb Energy [11]
	Resistance	Max Power	Handling Power	Allowable Min Value [12]	Allowable Max Power	
50W	25Ω	4W	2W	10Ω	5W	0.1J
100W	25Ω	4W	2W	10Ω	5W	0.1J
200W	25Ω	8W	4W	10Ω	10W	0.3J
400W	25Ω	8W	4W	10Ω	10W	0.3J
750W	18.75Ω	16W	8W	8Ω	18.75W	0.5J

Notes:

9) If the servo motor operates in conditions requiring rapid deceleration or large inertia ratios, the built-in braking resistor may not be able to suppress the DC bus voltage rise and can lead to driver damage. In this scenario, the user should consider adding an external braking resistor.
10) The MMS7xxxxBE supporting accessory — the MMA06-LA50 — is a regeneration clamp that is recommended for DC bus voltage protection. This device prevents DC bus voltage spikes caused by braking energy, when multiple motors are connected in parallel and can support up to 1.6kW of power dissipation.
11) The capacitor-absorbed energy is calculated according to the maximum working voltage of 70V; if the working voltage protection point of the input power supply is below 70V, the capacitor-absorbed energy should be reduced.
12) The allowable minimum value of the external braking resistor is also a recommended value. A value exceeding the allowable minimum reduces the discharge power borne by the external resistor and increases the power burden on the built-in braking resistor.

Braking Resistor Power Calculation

For a motor system, consider the ratio of inertia between the load and the motor itself as *N*, and the rotational inertia of the motor itself as *J*. The braking energy should satisfy the following relationship, calculated with Equation (9):

$$Braking\ Energy = \frac{(N+1)J}{2} \times (Max\ Angular\ Velocity)^2$$

$$= \frac{(N+1)\mathrm{J}}{182}\ (Max\ Motor\ Speed)^2 \qquad (9)$$

The energy that can be absorbed by a DC bus capacitor can be estimated with Equation (10):

$$= \frac{1}{2} Capacitance \times \left((DrainOn\ Threshold\ Voltage)^2 - (Operation\ Voltage)^2\right) \qquad (10)$$

The energy to be dissipated in the braking resistor can be calculated with Equation (11):

$$\textit{Braking resistor absorb energy} = \textit{Braking energy - Capacitor absorbed energy} \tag{11}$$

Figure 27 shows that for a reciprocating motor, it can be assumed that the braking resistor operates for a period of *T*. When calculating the braking resistor power, due to the hysteresis and continuity of heat conduction, the cycle average is used to calculate the braking resistor power by replacing the instantaneous value of the resistor.

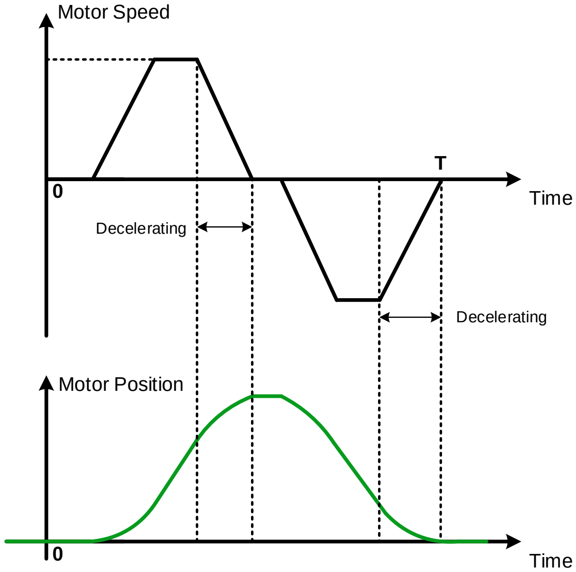


Figure 27: Simple Diagram of the Motor Motion Process

Accordingly, the power on the braking resistor can be estimated with Equation (12):

$$\textit{Braking resistor absorb Power} = \frac{2\times(\textit{Braking energy - Capacitor absorbed energy})}{T} \tag{12}$$

Table 27 on page 52 shows the built-in braking resistor power corresponding to the different motor models. If this power level exceeds the braking resistor power, then there is no need to use an external braking resistor or the MMA06-LA50, which is a regeneration clamp accessory. If this power is below the braking resistor power, then it is necessary to use an external braking resistor or regeneration clamp module. If the calculated power of the external braking resistor exceeds the maximum power of the external braking resistor corresponding to the motor model, it is recommended to use the MMA06-LA50 regeneration clamp.

An example to calculate the braking resistor specifications is below. In this scenario, a user is using the integrated servo motor model MMS76040BE-OB2PKN, which has a nominal moment of inertia of 500 g-cm^2, a built-in braking resistor that can handle 4W of power, and a capacitor that can absorb 0.3J of energy. The motor is set to operate at a maximum speed of 3000rpm, and the load moment of inertia is 9 times the inertia, with a reciprocation cycle of 1s.

Accordingly, the braking energy of the motor is 0.5 x 10 x 500 x 10 - 7 x 30002 / 182 = 12.36J; the power on the braking resistor is 2 x (12.36 - 0.3) / 1 = 24.12W. This power exceeds the sum of the built-in braking resistor’s handling power and the maximum permissible power of the external braking resistor, so in this scenario, it is necessary to access the MMA06-LA50 regeneration clamp.

Figure 28 on page 54 shows the braking resistor selection process.

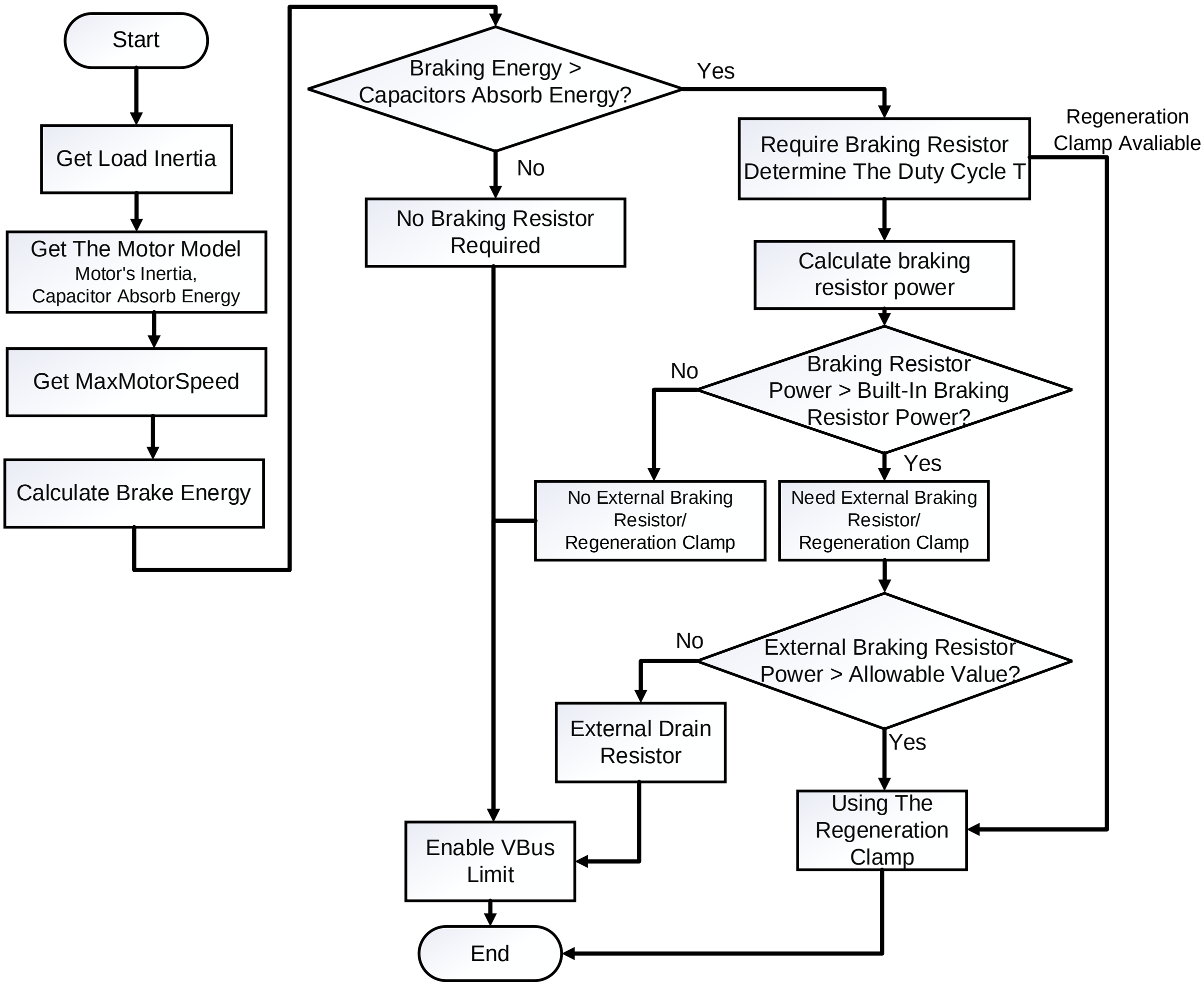


Figure 28: Braking Resistor Selection Process

Related Objects

Table 28: Related Objects of Energy Release Setting

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	01h	Protection enable	R/W	No	UINT8	-		0
	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

4.5 Parameter Writing/Saving

4.5.1 Function Description

To write or save the configured user parameter updates to the servo motor, it is necessary to write and update the configured parameters inside the motor. It is recommended to use the MotionLAB software for the parameter update or save operation, or utilize EtherCAT communication to send a specific function code to the “Special command” (200Dh-00h) object dictionary (see Figure 29 on page 55).

Figure 29: MotionLAB Parameter Writing/Reading UI

When using MotionLAB to execute read/write related operations (as shown in Figure 29), the labeled keys are defined below:

1. Write Settings: Writes the control parameters of the motor according to the current control parameters of the MotionLAB host computer. This command should be sent after a new configuration. Control words, status words, operating modes, and parameters related to trajectory planning do not need this function code to be activated.
2. Read Settings: Reads the current control parameters within the servo motor to the MotionLAB display.
3. Restore Default: Restores all parameters to their factory default values (note that the results of parameter identification are also restored at this point).
4. Save to Motor: Updates the current control parameters from the MotionLAB host computer to the motor's internal NVM.
5. Update: For servo motor motion only, motion-related commands (such as control words, status words, operating modes, and control commands) are written to the servo motor via this button.

Table 29 on page 56 shows the method to perform read and write operations on specific object dictionary "Special command" (200Dh-00h) when using the EtherCAT.

Table 29: Relevant Instruction Code of Parameter Saving

Function	Instruction Code	Description
Write Settings	0xAA5555AA	Write the control parameters according to the value of the register. This command should be sent after a new configuration. Control words, status words, operating modes, and parameters related to trajectory planning do not need this function code to be activated.
Save to Motor	0x65766173	Save all user parameters to the drive's NVM.
Restore Default	0x64616F6C	Restore all parameters to the factory default.
System Reset	0x626F6F74	Reboot the motor controller to simulate a power-down reset for the power supply.
Clear Alarm History	0x11111120	Clear all historical alarm records.
Position Zeroing	0x686F6F6D	Zero out the current position as the reference position origin.

4.5.2 Related Objects

Table 30: Related Objects of Parameter Saving

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Dh	00h	Special command	R/W	No	UINT32	-	-	0

4.5.3 Simple Example

An example of parameter saving is provided below.

Table 31: Example of Parameter Saving

Steps	Index and Sub-Index	Data	Description
1	200Dh-00h	0x65766173	Save all user parameters to the drive's NVM.

4.6 Trial Operation

After the necessary parameter settings have been written and saved to the servo motor, trial operation can begin.

By enabling the servo (Servo On), the servo drive is in a runnable state, but since there is no command input at this time, the servo motor does not rotate and is in an axis-locked state. After inputting commands using the host computer, the servo motor rotates and starts to move.

Trial run the servo motor. On the first run, use the JOG motion mode to run the servo motor at a low speed via the debugging software MotionLAB to confirm whether the servo motor can rotate normally, and whether there is any abnormal vibration or abnormal sound when rotating. Confirm that there is no abnormality related to the position information, speed information, and current information of the motor. In addition, confirm that the servo motor is tracked and in accordance with the set operation mode.

After confirming the above motor operating conditions, adjust the relevant parameters to make the motor work under the expected working conditions. See Section 5 on page 60 for more details.

4.7 Servo Motor Stop

A halt or quick stop may be required during operation. The halt function slows the motor velocity according to the halt option, but the device remains in the operation enable state. The quick stop function slows down the motor velocity and transitions to the switch on disabled state, or the device stays in the quick stop active state according to the quick stop settings.

Table 32 on page 57 shows the halt and stop methods.

Table 32: Comparison of Servo Motor Halt and Stop Methods

Stopping Methods	Stop Mode	Stop Options	Description

Quick Stop	Disable drive	0	Cut off the power supply to the motor windings. The motor stops freely. The emergency stop time is related to the friction condition of the motor load condition.
	Slow down on slow down ramp	1	Decelerate to zero speed at the deceleration rate set for the motor's current operating mode, then disable the drive.
	Slow down on quick stop ramp	2	Decelerate to zero speed at the deceleration rate set for a motor quick stop, then disable the drive.
	Slow down on current limit	3	Decelerate with the set stop current value as the deceleration current. Once the motor has decelerated to zero speed, disable the drive.
	Slow down on voltage limit	4	Use the bus voltage as a limit. The loop outputs the maximum limiting voltage to decelerate. Once the motor has decelerated to zero speed, disable the drive.
	Slow down on slow down ramp and stay in quick stop	5	Decelerate to zero speed at the deceleration rate set for the motor's current operating mode, then keep the quick stop state while the motor is servo on.
	Slow down on quick stop ramp and stay in quick stop	6	Decelerate to zero speed at the deceleration rate set for a motor quick stop, then keep the quick stop state while the motor is servo on.
	Slow down on current limit and stay in quick stop	7	Decelerate with the set stop current value as the deceleration current, and after decelerating to zero speed, disable the drive, then keep the quick stop state while the motor is servo on.
	Slow down on voltage limit and stay in quick stop	8	Use the bus voltage as a limit, the loop outputs the maximum limiting voltage to decelerate. Once the motor has decelerated to zero speed, keep the quick stop state while the motor is servo on.
Halt	Stop freely	0	Motor stops freely and while the motor is servo on.
	Slow down on slow down ramp and stay in halt	1	Decelerate to zero speed at the deceleration rate set for the motor's current operating mode, then keep the halt state while the motor is servo on.
	Slow down on quick stop ramp and stay in halt	2	Decelerate to zero speed at the deceleration rate set for quick stop of the motor, then keep the halt state while the motor is servo on.
	Slow down on current limit and stay in halt	3	Decelerate with the set stop current value as the deceleration current. Once the motor has decelerated to zero speed, disable the drive, then keep the halt state while the motor is servo on.
	Slow down on voltage limit and stay in halt	4	Use the bus voltage as a limit, the loop outputs the maximum limiting voltage to decelerate. Once the motor has decelerated to zero speed, then keep the halt state while the motor is servo on.

4.7.1 Halt Options

If the stop option is set to “disable drive,” the inverter switch turns all the way off and the motor speed is decelerated by mechanical friction.

If the stop option is set to “deceleration ramp,” the motor speed is reduced via “Profile deceleration” (6084h). When the motor speed falls below the braking speed threshold, the motor is held in the current position with Servo On.

If the stop option is set to “emergency stop ramp,” the motor speed is reduced by the “Quick Stop Deceleration” (object 6085h). When the motor speed falls below the braking speed threshold, the motor remains in the current position in the Servo On state.

If the stop option is set to “current limit,” the motor speed is reduced by controlling the motor’s torque current. When the motor speed falls below the braking speed threshold, the motor remains in the current position in the Servo On state.

If the stop option is set to “voltage limit,” the motor speed is reduced by directly controlling the motor’s output voltage current. When the motor speed falls below the braking speed threshold, the motor remains in the current position in the Servo On state.

4.7.2 Quick Stop Options

The quick stop command changes the motor running state to the quick stop enabled state, where the servo motor decelerates to a stop based on the configured quick stop option.

Table 32 on page 57 shows that if the quick stop option is set to 0 through 4, the state changes to the disabled switch on once the motor speed falls below the braking speed threshold.

If the quick stop option is set to 5 through 8, once the motor speed falls below the braking speed threshold, the state remains in the emergency stop state. At the same time, the motor maintains its current position.

4.7.3 Related Objects

Table 33: Related Objects of Stop and Halt

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
6040h	00h	Control word	R/W	RPDO	INT16	-	INT16	1
6041h	00h	Status word	R/W	TPDO	UINT32	INC/s^2	UINT32	3276800
605Ah	00h	Quick stop option code	R/W	No	INT16	-	0 to 8	2
605Dh	00h	Halt option code	R/W	No	INT16	-	0 to 4	1
6085h	00h	Quick stop deceleration	R/W	RPDO	UINT32	INC/s^2	UINT32	3276800

4.7.4 Simple Example

If the motor is working in profile velocity (PV) mode, halt the motor with halt option 1.

Table 34: Example of Halted Motor

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

Section 5. Parameter Tuning

To complete the necessary operational debugging/tuning in the all-in-one servo motor, confirm that the system can run without an issue with a trial run. In addition to a trial operation stage with the user-configured external parameters (such as the electronic gear ratio, protection, limits, external input and output functions), users should confirm that the motor can run with the internal, default configurations (such as filtering, feed-forward, and loop gain parameters). However, the default parameters can only ensure that the servo motor operates normally under most conditions, so these parameters cannot guarantee that the motor can quickly, accurately, and stably track the given operation.

To ensure that the servo motor can respond the control commands quickly and accurately, it is necessary to reasonably adjust the control parameters of the servo motor according to the characteristics of the load, as well as the requirements of the actual working conditions.

5.1 Parameter Identification

5.1.1 Function Description

For simplicity and usability, these servo motors have an integrated parameters identification function. The user only needs a few basic motor parameters (i.e. rated voltage, rated current, rated speed, and pole pairs), which can be obtained by the system automatically while loading the default configuration file and selecting the motor's corresponding model. The all-in-one servo can also recognize other parameters, such as motor phase resistance, phase inductance, torque constant, friction coefficient, and rotational inertia. Based on the parameter identification results, the controller then calculates the appropriate loop parameters to optimize the dynamic response and reduce the system noise.

Meanwhile, it is necessary to identify the servo system's parameters before the tuning these parameters. For example, the servo motor obtains the inertia and friction parameters from parameter identification. It is recommended to execute gain adjustments based on the servo system's parameters.

In addition to completing parameter identification under free rotation, the system provides parameter identification for limited travel to ensure that the program is applicable to systems with limited motion travel, such as a linear actuator. The total number of revolutions allowed by the motor and the number of revolutions used for acceleration and deceleration should be provided. These parameters are not required if free rotation is used.

After a few seconds, the motor and system load parameters are recognized. The loop control parameters are also updated based on the recognition results. Figure 30 shows a block diagram of the parameter identification.

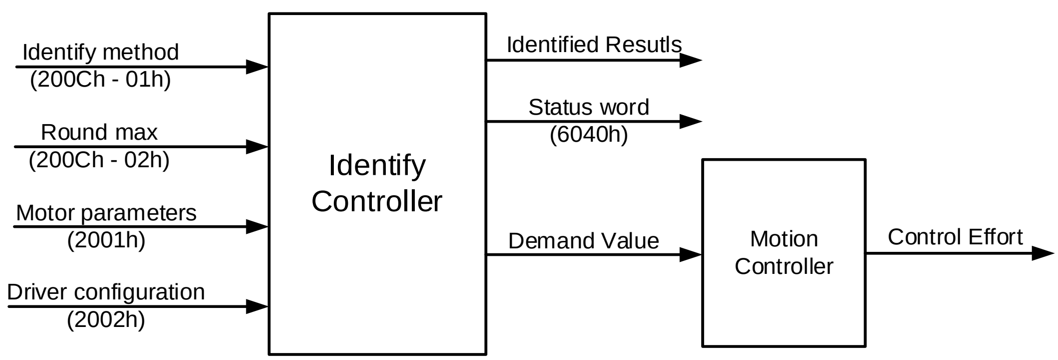


Figure 30: Parameter Identification Block Diagram

It is recommended to connect to the host computer and use MotionLAB debugging software for parameter identification. Based on MotionLAB, the servo motor provides three parameter identification schemes: the free rotation system, the linear limited travel with automatic boundary finding, and the linear limited travel with JOG mode to manual boundary finding.

The free rotation system is suitable for motor parameter identification without travel limitation. The linear limited travel system is suitable for motor parameter identification in the linear system, such as the screw. The motion range of the linear limited travel system can automatically find the boundary, but it is necessary to reach the mechanical limit point. Otherwise, users can use the JOG to find the boundary, and then the motor operates in accordance with the boundary range set by the JOG when the parameter identification is carried out.

5.1.2 Moment of Inertia Identification

It is necessary to identify the parameters of the system, especially the system's rotational inertia, before the gain adjustment. The load moment of inertia is an important parameter for the servo motor and its system. The moment of inertia is closely related to the loop parameter gain, and the gain adjustment is dependent on the correct setting for the moment of inertia. The moment of inertia can be recognized separately by the user (denoted as 1 in Figure 31).

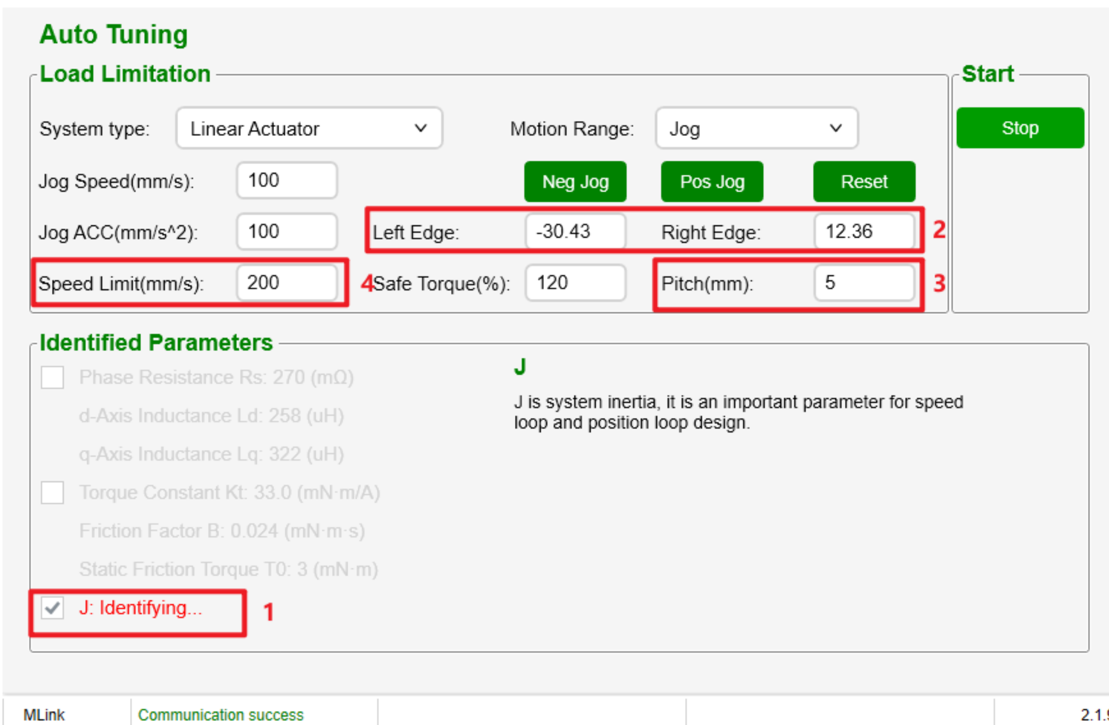


Figure 31: MotionLAB UI for Moment of Inertia Identification

To use the motor's parameter identification/inertia identification function in linear actuator limited mode via MotionLAB, the following conditions must be fulfilled:

- The maximum linear travel must be at least 5 turns (i.e. the maximum travel) in the automatic boundary search mode, or the interval between the left and right boundaries in JOG boundary search mode should be more than 5 turns. If the interval is less than 5 turns, the parameter recognition function automatically reports an error (denoted as 2 in Figure 31).
- The pitch (i.e. the actual distance traveled by the linear mechanical transmission structure for each revolution of the motor) must be filled in correctly according to the actual situation (denoted as 3 in Figure 31).
- The speed limit should between 1200rpm and 3000rpm. The lower speed limit ensures parameter identification accuracy, while the upper speed limit is the motor's rated speed (denoted as 4 in Figure 31).

- The overall load inertia of the actual system must not exceed 100 times the motor itself. Since the parameter identification process performs the motor movement under unknown system conditions, a low loop gain is used. If the actual load inertia ratio is large, this will result in a sluggish motor movement, and the motor will not be able to complete the parameter identification process.
- The load must be stable and must not change drastically.
- During inertia identification, the motor may rapidly accelerate and decelerate if the load inertia is large. To prevent an over-voltage (OV) condition, connect the MMA06-LA50 regeneration clamp module to the motor in advance.

5.1.3 Related Objects

Table 35: Related Objects of Parameter Identification

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation 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
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	$g \times cm^2$	-	0
	0Bh	Identified B	RO	No	UINT32	mNm/rad	-	0
	0Ch	Identified T_F	RO	No	UINT32	mNm	-	0

5.1.4 Use of "Control Word" (6040h) and "Status Word" (6041h)

Table 36: Use of "Control Word" and "Status Word" in Parameter Identification

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		Not used.					
11	Enable auto tuning		1: Enabled 0: Disabled					
10:9	Reserved		Not used.					
8	Halt		Enable halt.					
7	Fault reset		Change from 0 to 1 reset the internal fault status.					
6:4	Reserved		Unused.					
3	Enable operation		Enter operation mode.					
2	Quick stop		Enter quick stop mode.					
1	Enable voltage		No effect; the DC power is always enabled.					
0	Switch on		Enable the power stage switch.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits	**Name**		**Description**					
15	Reserved		Not used.					
14	Auto tuning status		1: Finished 0: Ongoing or not started					
13:12	Reserved		Not used.					
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		Not used.					
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.					

5.2 Gain Tuning

Servo gain related parameters include the speed loop gain, position loop gain, speed loop integration time, filter, and rotational inertia. There is a coupling relationship between the various parameters; when adjusting the servo-related parameters, consider the influence between the various parameters (see Figure 32 on page 64).

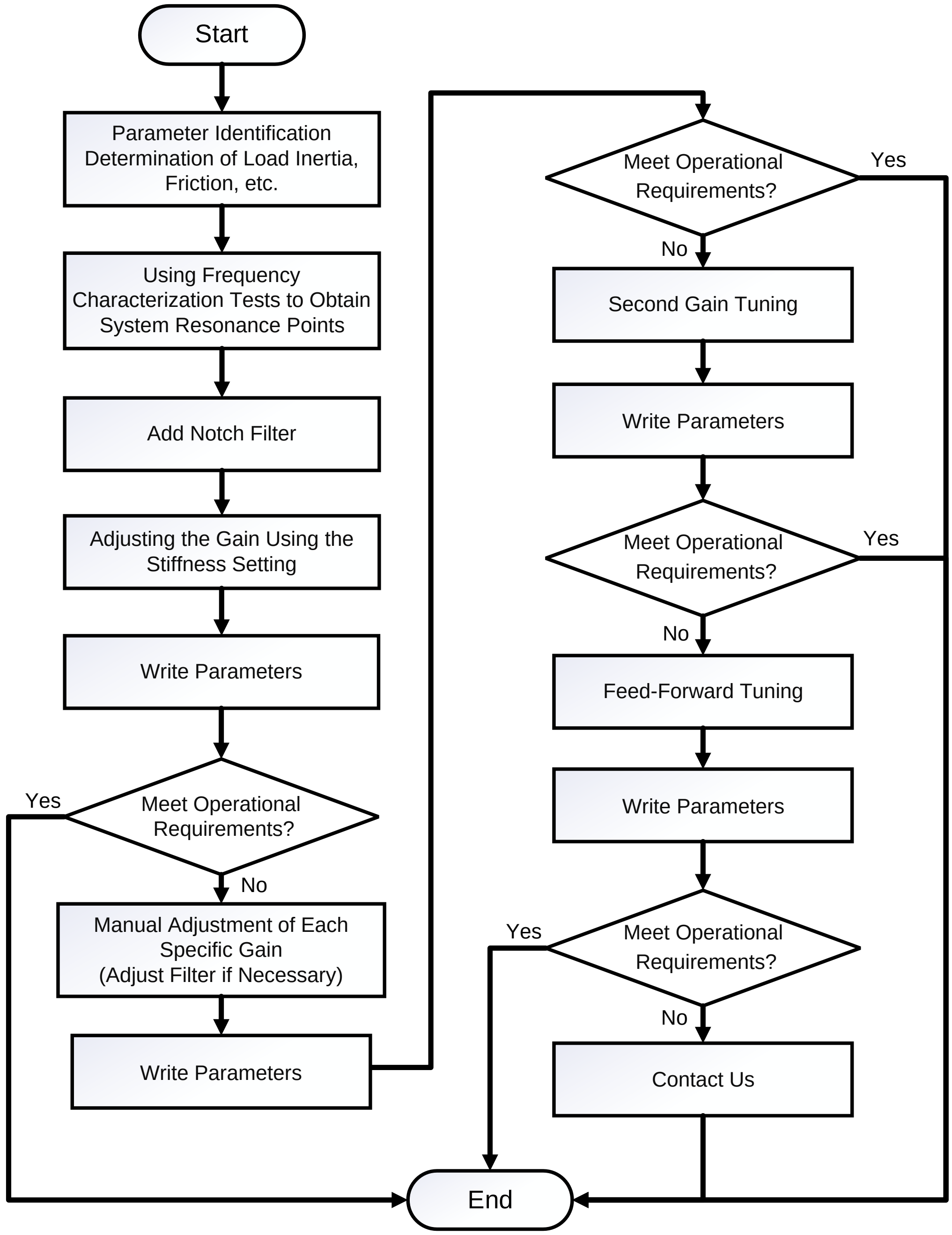


Figure 32: Basic Block Diagram for Parameter Adjustment

In the case of precision motion control, the servo motor parameters must be fully adjusted to maximize the performance of the servo motor to meet the user's needs, such as those related to the dynamic in place time, steady-state error, overshooting, and system stability.

The gain adjustment mainly consists of setting the system inertia and friction, adjusting the loop gain (position loop, speed loop, current loop gain and integration), adjusting the feedback filter parameters (position filter, speed filter), adjusting the feed-forward (speed feed-forward, torque feed-forward), and setting the notch filter (mechanical characterization). Figure 32 shows the general steps of gain adjustment.

It is necessary to manually adjust the position, speed, and current loop gains and other related parameters under the following conditions:

- When the actual working conditions cannot be met, even after the parameters are written in the parameter identification, due to constraints such as the load conditions and control objectives.
- When the user wants to optimize the responsiveness and stability of the servo motors and the loads.

5.2.1 Basic Loop Parameters

The motor uses a three-loop control method. The innermost loop is the current loop, also known as the torque loop. The middle loop is the speed loop, and the outer loop is the position loop. Figure 33 shows the block diagram of the motor control loop.

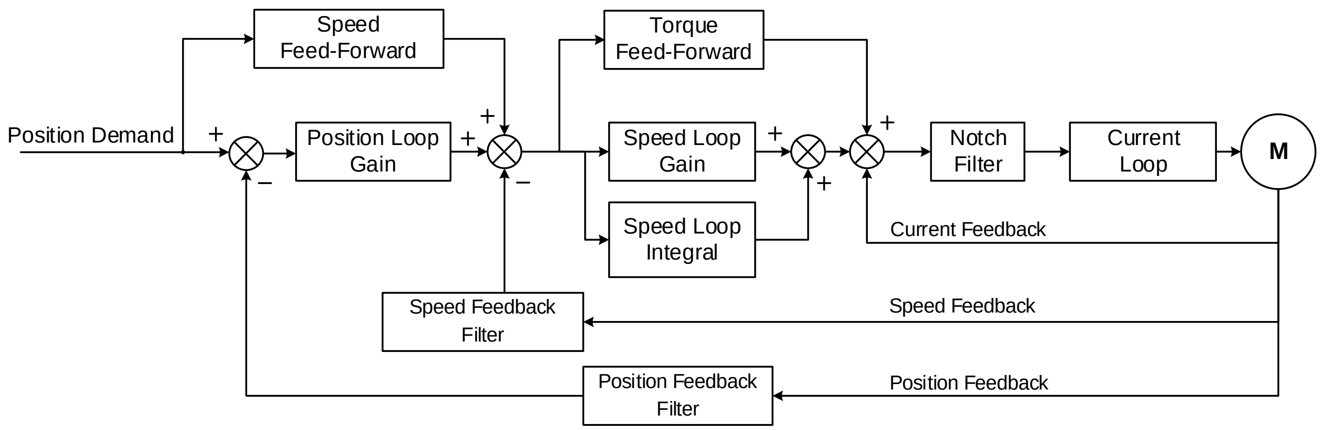


Figure 33: Control Loop Diagram

EZmotion provides an easy-to-use graphical user interface (GUI) to help engineers design and adjust loop parameters. The GUI is available as a downloadable MotionLAB software from the EZmotion website.

To simplify parameterization, the loop parameters are reduced to the loop bandwidth with the motor and load parameters. Optimizing the loop parameters involves a tradeoff: a higher speed and position loop bandwidth improves the dynamic response, but results in higher vibration and noise.

- Current Loop: The current loop is the innermost loop. The motor uses $I_D = 0$ control to control the straight axis current to 0 so that the output torque is proportional to the quadrature axis current (I_Q). The recommended current loop bandwidth uses a default value of 1000Hz, unless special circumstances require optimization.
- Speed Loop: In the speed loop, a proportional integral (PI) regulator controls the motor speed. The input is the speed command, and the output is given by the current loop. The speed loop limits the maximum motor, current and thus the maximum output torque. It is recommended that the speed loop bandwidth be set from 50Hz to 400Hz and the integration time constant from 2Hz to 20Hz. It is recommended that the initial value of the integration time constant be 2Hz and the initial value of the bandwidth be 200Hz.
- Position Loop: The position loop is the outermost loop and is used to control the motor position. The inputs are position commands, and the outputs are given to the speed loop. The position loop uses single proportional (P) control instead of PI control. In the speed loop, an integral link is included to handle the steady-state error. Therefore, introducing an integral link in the position loop raises the system order, increases the phase delay, reduces the phase margin, and may lead to system instability.

If a lower position following error is required, the speed feed-forward function can be enabled. The position loop limits the maximum motor speed in position mode. A loop bandwidth setting of 10Hz to 100Hz is recommended.

To adjust the gain in position control mode while increasing the position loop gain, increase the speed loop gain and ensure that the position loop response is slower than the response of the speed loop; in addition, ensure that the speed loop response is slower than the current loop response. Meet the conditions below for the bandwidths:

- The bandwidth of the current loop should be 2 to 3 times greater than that of the speed loop.
- The bandwidth of the speed loop should be 2 to 5 times greater than that of the position loop.
- The bandwidth of the position feedback filter should be 5 times greater than that of the position loop.
- The bandwidth of the speed feedback filter should be 5 times greater than that of the speed loop.

The trap center frequency of the notch filter should be between 100Hz and 2000Hz.

Table 37 shows the description of basic loop parameter adjustments, which contains the position loop bandwidth, speed loop bandwidth, speed loop integral time constant and second loop gain. The descriptions above provide an idea on how to adjust the loop's basic parameters.

Table 37: Description of Basic Loop Parameter Adjustment

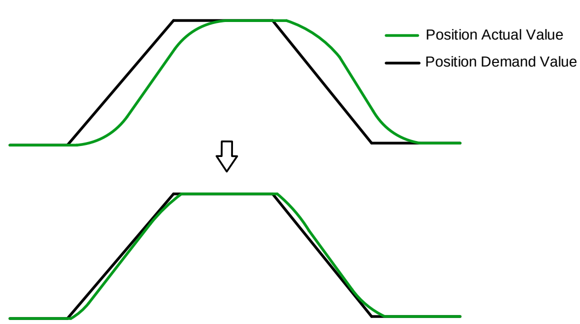
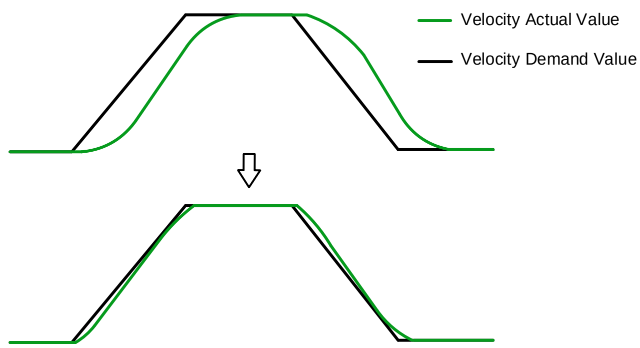
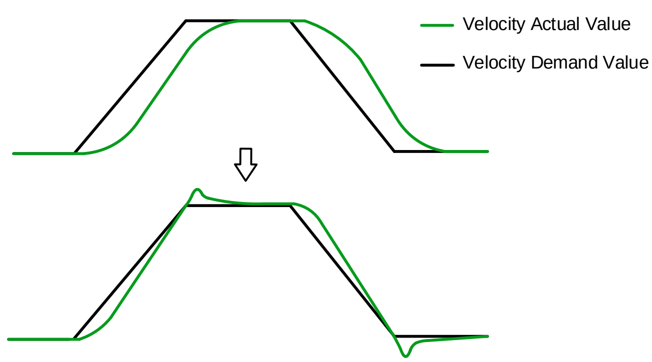
Parameters	EtherCAT Address	Tuning Reasoning
Position loop bandwidth (Second position loop bandwidth) (Unit: Hz)	2005-01h (2005-02h)	1. This value determines the performance of the position loop, such as the position following error and positioning time. 2. Increasing this value can reduce the position following error, shorten the positioning time, improve the performance of the position loop, and improve the anti-interference ability of the motor at zero speed. 3. If the position bandwidth is too high, then mechanical oscillations may occur and be followed by position overshoot. If the bandwidth is too low, increase the system positioning time and affect the following performance. 4. The structure of a single P for the position loop may not be able to meet the demand for accuracy in applications where the positioning accuracy is too high. It may be necessary to appropriately increase the gain of the speed loop and the integration time constant of the speed loop to eliminate the end positioning error.
Position loop bandwidth (Second position loop bandwidth) (Unit: Hz)	2005-01h (2005-02h)	Increase the position loop gain. 

Table 37: Description of Basic Loop Parameter Adjustment *(continued)*

Parameters	EtherCAT Address	Tuning Reasoning
Speed loop bandwidth (Second speed loop bandwidth) (Unit: Hz)	2005-03h (2005-0Ch)	1. Increasing this value speeds up the response of the speed loop and determines the dynamic performance of the speed loop. 2. Increasing this value increases the proportionality, decreases the time-to-place, and improves the performance of the speed loop. 3. If this bandwidth is too large, there may be loop oscillations and noise, as well as overshoot. If this bandwidth is set too low, the speed loop may have poor performance. Increase the speed loop gain. 
Speed loop integration time constant (Second speed loop integration time constant) (Unit: Hz)	2005-04h (2005-0Dh)	1. Increasing this value could eliminate the following error of the speed loop, which in turn reduces the following error of the position in the position control mode. 2. Increasing this value can strengthen the integration effect, amplify the cumulative effect of the error, and reduce the position time. 3. If this time constant is too high, there may be mechanical vibration, especially for long travel conditions. If this constant is too low, the following error may never be eliminated.
Speed loop integration time constant (Second speed loop integration time constant) (Unit: Hz)	2005-04h (2005-0Dh)	Increase the speed loop integration time constant. 

Users can determine whether the first gain adjustment mode (2005h-0Eh) should be manual adjustment or stiffness adjustment according to the actual requirements. If stiffness adjustment is used, Table 38 on page 68 shows stiffness grades corresponding to the gain of position loop and speed loop. Manual adjustment and stiffness adjustment cannot be used at the same time. Users can use the stiffness level to first unify the adjustment parameters after judging whether it meets the requirements, and then determine whether it is necessary to manually fine-tune the gain.

Table 38: Stiffness Rating Scale

Stiffness	Position Loop Bandwidth (Hz)	Speed Loop Bandwidth (Hz)	Speed Loop Integration Time Constant (Hz)
0	0.3	1.5	0.4
1	0.4	2	0.6
2	0.5	2.5	0.7
3	0.6	3	0.8
4	0.7	3.5	1.0
5	0.9	4.5	1.3
6	1.2	6	1.8
7	1.5	7.5	2.3
8	1.8	9	2.7
9	2.2	11	3.2
10	2.8	14	4.0
11	5.1	18	5.1
12	6.3	22	6.4
13	7.7	27	7.6
14	10.0	35	9.9
15	11.4	40	11.4
16	14.3	50	13.3
17	17.1	60	14.5
18	21.4	75	17.7
19	25.7	90	19.9
20	32.9	115	22.7
21	40.0	140	26.5
22	48.6	170	31.8
23	60.0	210	39.8
24	71.4	250	42
25	80.0	280	45.5
26	88.6	310	53.1
27	97.1	340	56
28	105.7	370	63
29	114.3	400	70
30	128.6	450	79
31	142.9	500	88

When adjusting the system gain, there is a tradeoff between system stability, the speed of response, and the steady-state error. Excessive integral action may lead to instability, and excessive proportional action may lead overshooting to occur. Therefore, in practical applications, engineers need to adjust and optimize the parameters according to the actual situation to achieve the best control effect.

Related Objects

Table 39: Basic Loop Parameter Object Dictionary

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	01h	Position loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
	03h	Speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
	04h	Speed loop integral constant	R/W	No	UINT16	0.1Hz	1 to 500	100
	05h	Torque loop bandwidth	R/W	No	UINT16	0.1Hz	2000 to 20000	10000
	06h	Position loop out limit	R/W	No	UINT32	UserUnit/s	UINT32	3276800
	07h	Speed loop out limit	R/W	No	UINT16	‰	UINT16	3000
	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000
	0Eh	First gain adjustment mode	R/W	No	UINT16	-	UINT16	0
	0Fh	First gain stiffness	R/W	No	UINT16	-	0 to 31	13

5.2.2 Gain Switching

The gain switching function is triggered by the internal state of the servo motor and is only effective in the position control mode (including the profile position mode and the cyclic synchronized position (CSP) mode. The gain switching uses “Gain switching type” (2005h-09h) as the enable switch, and the position following error must be less than the set “Gain switching following error threshold” (2005h-0Ah) as the judgment condition. When using gain switching, the following functions are possible:

- When the motor is running from normal operation to positioning completion, the servo motor switches to a lower gain at zero speed to suppress vibration and noise.
- When the motor is running from normal operation to the end positioning state, the servo motor switches to a higher gain to shorten the positioning time.
- When the motor is running from zero speed to positioning, the servo motor switches to a higher gain for better dynamic performance.

Similar to the first gain adjustment, the second gain can also be set to stiffness or manual adjustment via two methods. To smooth and stabilize the loop output when switching between the first gain and the second gain, the gain switching transition time can be set via “Gain switching transition” (2005h-0Bh). It is recommended that the switching time be several ms.

Homing Gain Switching

In some application scenarios, different from high-speed and high dynamic actual operation, users hope to use a lower speed when homing to ensure the accuracy of the operation to homing detection signal (such as homing switch, positive limit switch and negative limit switch, etc.)

Therefore, a set of loop parameters is required to adapt to low-speed operation conditions, which is different from the first and second loop gains, and only takes effect when the homing mode is set and the “Homing gain switch enable” (object 2005h-12h) is configured as 1. It is named as the homing third gain, including position loop bandwidth 3 (object 2005h-13h), speed loop bandwidth 3 (object 2005h-14h) and speed loop integral constant 3 (object 2005h-15h).

It is recommended to use lower position loop bandwidth and higher speed loop bandwidth for better performance in low-speed homing mode. At the same time, it also helps to suppress the low-frequency vibration at the end caused by the load at low speeds.

Related Objects

Table 40: Related Objects of Gain Switching

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	02h	Second position loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
	09h	Gain switching mode	R/W	No	UINT16	-	UINT16	0
	0Ah	Gain switching following error threshold	R/W	No	UINT32	UserUnit	UINT32	0
	0Bh	Gain switching transition time	R/W	No	UINT16	ms	UINT16	1
	0Ch	Second speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
	0Dh	Second speed loop integration factor	R/W	No	UINT16	0.1Hz	1 to 500	100
	10h	Second gain adjustment mode	R/W	No	UINT16	-	UINT16	0
	11h	Second gain stiffness	R/W	No	UINT16	-	0 to 31	13
	12h	Homing gain switch enable	R/W	No	UINT16		0 to 1	0
	13h	Position loop bandwidth 3	R/W	No	UINT16	0.1Hz	1 to 2000	200
	14h	Speed loop bandwidth 3	R/W	No	UINT16	0.1Hz	1 to 5000	1000
	15h	Speed loop integral constant 3	R/W	No	UINT16	0.1Hz	1 to 500	100

5.2.3 Feed-Forward Adjustment

Speed Feed-Forward

Speed feed-forward can be used to minimize the position following error. Figure 34 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 when "Feedforward enable" (2004h-01h), bit[2] is set to 1. If the position reference is changed, the speed reference changes immediately without delaying the position control loop. This makes the position response faster and minimizes errors.

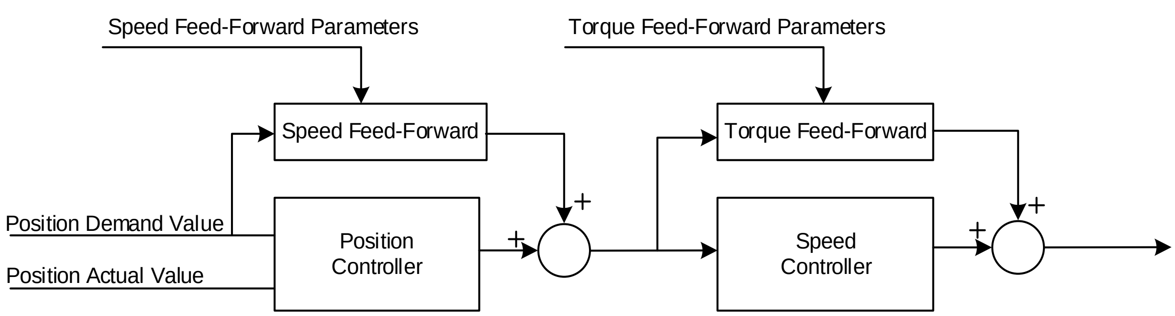


Figure 34: Feed-Forward Block Diagram

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

Figure 34 on page 70 can be disabled by setting "Feed-forward enable" (2004h-01h), bit[2].

Torque Feed-Forward

Torque feed-forward can make the speed loop control response faster (see Figure 34 on page 70). The torque reference to the torque loop is the sum of the feed-forward and the speed loop controller's output when "Feedforward enable" (2004h-01h), bit[1] is set to 1. If the speed reference changes, the torque reference changes immediately without the speed control loop delay. This makes the speed response faster.

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

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

Table 41 shows the reasoning to adjust the parameters related to speed feed-forward and torque feed-forward, and the effect of qualitative testing before and after adjustment for users' reference.

Table 41: Related Parameters for Feed-Forward Adjustment

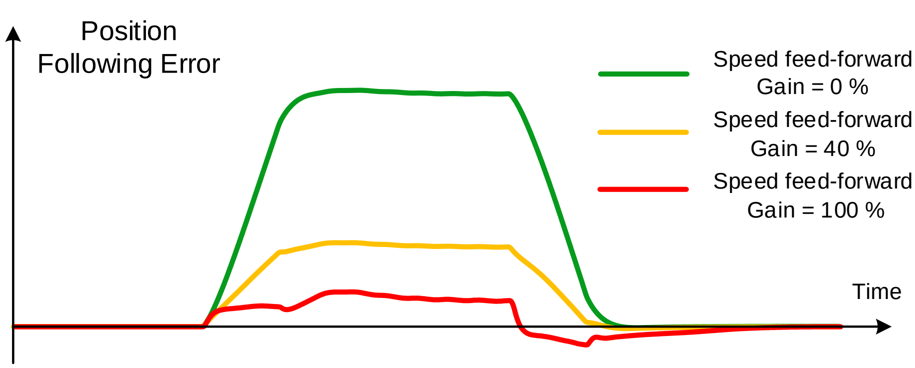
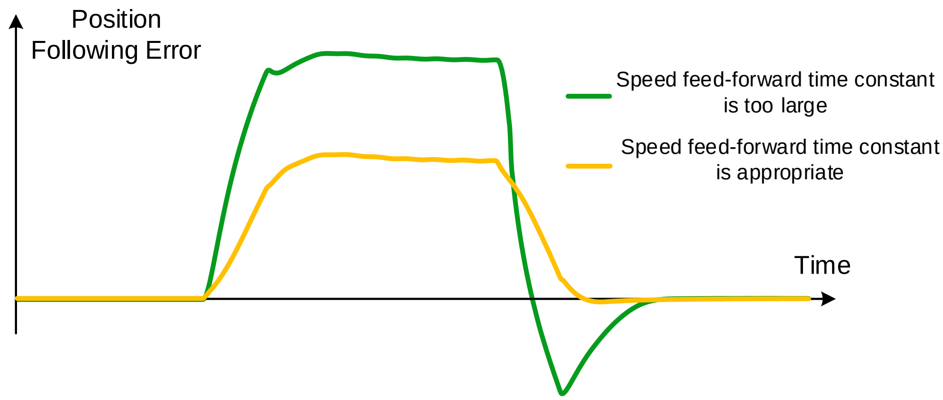
Parameters	EtherCAT Address	Tuning Reasoning
Speed Feedforward Gain (Unit: %)	2004-06h	1. Appropriately increasing this value can improve the dynamic performance of position tracking, reduce the position tracking error, and decrease the positioning time. 2. When the feed-forward gain is too large, there may be position tracking overshoot with speed fluctuations. Modified speed feed-forward gain effect (qualitative test; for reference only, actual condition related). 

Table 41: Related Parameters for Feed-Forward Adjustment *(continued)*

Parameters	EtherCAT Address	Tuning Reasoning
Speed feed-forward time constant (unit: ms)	2004-07h	1. Set the time constant of the filter associated with the speed feed-forward term. 2. Decreasing this value appropriately reduces the position tracking overshoot caused by the high gain of the speed feed-forward link. Modified speed feed-forward gain effect (qualitative test; for reference only, actual condition related). 
Torque Feedforward Gain (Unit: %)	2004-04h	1. Increasing this value in position mode improves torque response and reduces position following error during acceleration and deceleration. 2. Increasing this value in speed mode reduces the speed following error in steady state. Excessive torque feed-forward gain can cause speed tracking overshoot.
Torque feed-forward time constant (unit: ms)	2004-05h	1. Setting the time constant for the low-pass filter associated with the torque feed-forward term. 2. Decreasing this value appropriately reduces the speed tracking overshoot caused by the high gain of the torque feed-forward term.

Decoupling

From the voltage equation of the PMSM, the $-\omega L_Q I_Q$ and $-\omega(L_D I_D + \psi_F)$ parameters (reverse electromotive force from the motor) should be decoupled so that the voltage equation is linear.

Note that the decoupling function depends on the exact motor parameters L_D, L_Q and permanent magnet chain ψ_F. U_D and U_Q can be calculated with Equation (13) and Equation (14) respectively:

$$U_D = RI_D + L_D \frac{dI_D}{dt} - \omega L_Q I_Q \tag{13}$$

$$U_Q = RI_Q + L_Q \frac{dI_Q}{dt} - \omega\left(L_D I_D + \psi_F\right) \tag{14}$$

in which U_{DQ}, I_{DQ} and L_{DQ} are the motor stator voltage, current, and inductance in DQ-axis, respectively. R is the stator resistance, ω is the electrical angular speed, and ψ_F is the amplitude of permanent magnet (PM) flux.

The decoupling gain object (2004h-02h) and speed decoupling time constant object (2004h-03h) can be set to obtain a filtered decoupling value. The decoupling function can be disabled by setting “Feed-forward enable” (2004h-01h), bit[0] Figure 35 on page 73 shows the decoupling block diagram.

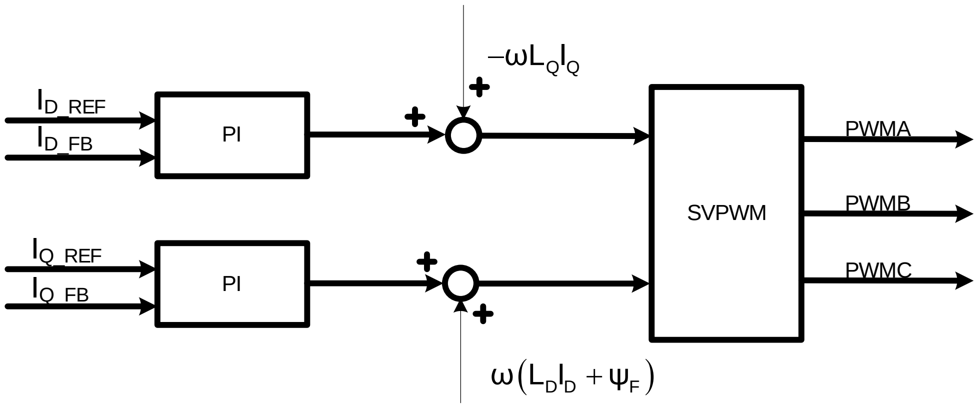


Figure 35: Decoupling Block Diagram

Related Objects

Table 42: Related Objects of Feedforward Adjustment

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	01h	Feed-forward enable	R/W	No	UINT8	-	UINT8	0
	02h	Decoupling gain	R/W	No	UINT8	%	0 to 200	100
	03h	Decoupling time constant	R/W	No	UINT16	0.1ms	UINT16	0
	04h	Torque feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	05h	Torque feed-forward time constant	R/W	No	UINT16	0.1ms	UINT16	0
	06h	Speed feed-forward gain	RW	No	UINT8	%	0 to 200	100
	07h	Speed feed-forward time constant	RW	No	UINT16	0.1ms	UINT16	0

5.2.4 Filters

Position Feedback Filter

Since noise from the position angle sensor can cause system vibration and noise, it is recommended that a position feedback filter be used to minimize the noise. It is often recommended that the bandwidth of the position filter be set to more than 5 times the bandwidth of the position loop to minimize the phase delay introduced by the filter.

Speed Feedback Filter

The speed feedback signal is obtained by the difference of the position feedback signal, the same noise that may cause vibration in the system. The speed filter 1 bandwidth and speed filter 2 bandwidth should be set below the noise frequency. Typically, the recommended filter bandwidth settings are 5 to 10 times the speed loop bandwidth.

There are two optional sources of speed feedback: speed filter 1 (Speed feedback source, object 2003h-05h is set to 0) and speed filter 2 (object 2003h-05h is set to 1). Speed filter 1 has better dynamic performance than speed filter 2, this feature let speed filter 1 is more suitable for high-precision servo control. However, high dynamic response means poorer noise resistance ability. The actual use process should be adjusted and selected according to the working conditions.

Related Objects

Table 43: Related Objects of Filters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	05h	Speed feedback source	R/W	No	UINT8	-	0 to 1	0
2007h	01h	Position filter bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	2000
	02h	Speed filter 1 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000
	05h	Speed filter2 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000

5.2.5 Frequency Characteristics

Users must work with MotionLAB to analyze the frequency characteristics of the individual control loops of the servo system, which contains the amplitude-frequency characteristics and the phase-frequency characteristics. Users can refer to the results of the bandwidth test to analyze whether the loop gain meets the requirements after the gain of the system is adjusted, or determine the mechanical resonance point of the system with reference to the frequency characteristic test result.

1. Select the loop to be tested (closed loop speed, closed loop position).
2. Set the injected signal amplitude, sampling time ,and filter window.
3. Click “Start” to carry out test.
4. The test is completed.

If the user is measuring the closed-loop frequency characteristics, the amplitude bandwidth and phase bandwidth are displayed on the frequency characteristic curve after the test is completed (see Figure 36). Is the user is measuring the open-loop frequency characteristics, the cutoff frequency, phase margin, traversal frequency, and amplitude margin are displayed on the frequency characteristic curve after the test is completed.

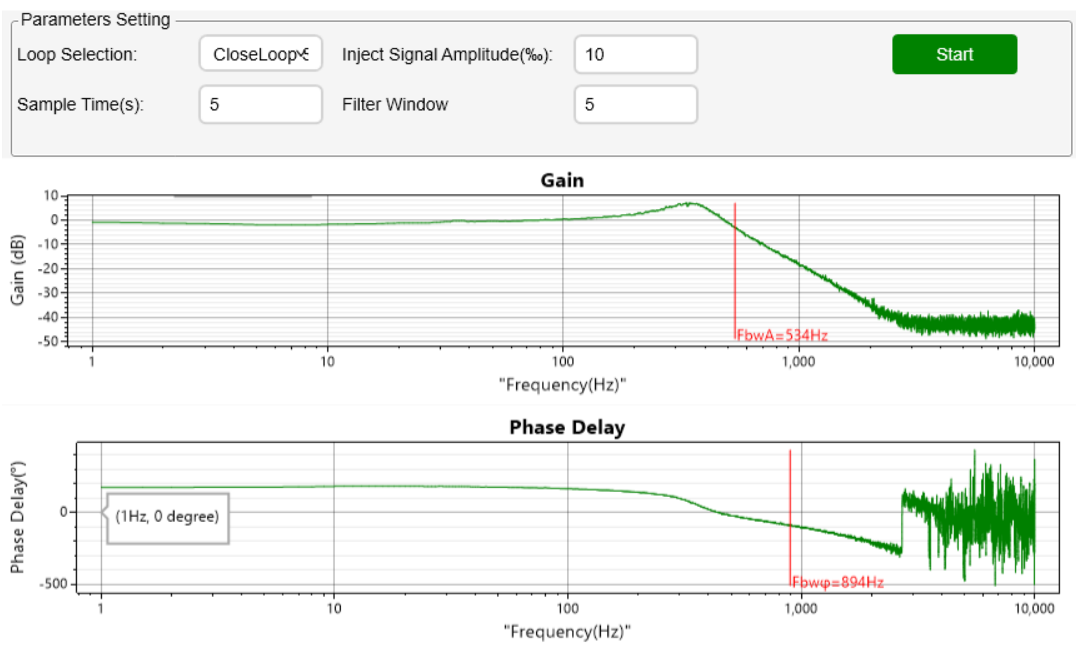


Figure 36: Frequency Characteristic UI (Closed Loop Speed)

If the injected signal has too low of an amplitude, this may lead to inaccurate test results; meanwhile, an amplitude that is too large can result in vibration and noise, making the loop output saturated. It is recommended that users start with a low injected signal amplitude. The sampling time sets the length of the test between 1s and 5s. A longer sampling time provides more accurate the measurement results. The filter window sets the degree of waveform smoothing between 1 and 32. A larger filter window results in a higher the degree of waveform smoothing.

5.3 Resonance Suppression

5.3.1 Mechanical Characterization

Mechanical Resonance

When a system involves flexible connection (e.g. elastic couplings, polymer rods, synchronous belts, or gearbox), the system's elasticity causes energy to be stored and released as torque, which is transmitted from one shaft to another. This behavior is similar to how an LC oscillating circuit functions within an electrical system, which leads to specific resonance points within the system.

If some frequency components in the torque are equal to the system's resonant frequency, the system may vibrate and rattle. This can make it impossible to increase the loop gain and simultaneously reduce the system's control performance. In this scenario, it is necessary to obtain the system's mechanical resonance point by using the servo motor's mechanical characterization function, and then to suppress the resonance using the notch filter suppression.

Figure 37 shows the frequency characteristics at resonance for a common two-inertia system. In Figure 37, f_1 is the anti-resonance point frequency, and f_R is the resonance point frequency. The anti-resonance point and resonance point generally appear in pairs, and the resonance point frequency exceeds the anti-resonance point frequency. For multi-inertia systems with multiple non-rigid connecting links, there may be multiple pairs of anti-resonance and resonance points, and their frequency characteristics are more complex.

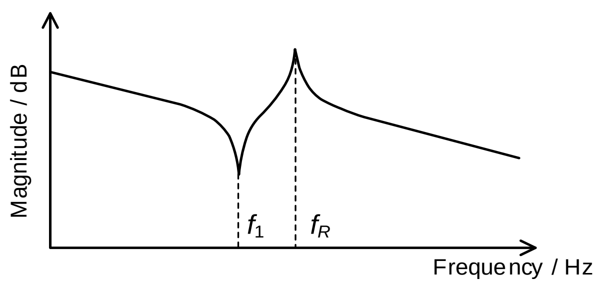


Figure 37: Frequency Characteristics during Vibration

Mechanical Characterization

The MMS7xxxxBE Series EtherCAT all-in-one servo motor has a mechanical characterization function. Users can determine the system's frequency characteristics by selecting torque-speed mode in MotionLAB's frequency characteristic UI. The frequency characteristic test automatically finds the resonance points of the servo system and displays up to four resonance points within 50Hz to 10000Hz.

To test the mechanical characteristics of a system using the torque-speed mode, follow the steps below:

1. Loop selection selects the torque speed (see Figure 41 on page 79).
2. Set the injected signal amplitude, sampling time, and filter window.
   a. <u>Injected Signal Amplitude</u>: Determines the amplitude of the disturbance injected into the system. If the amplitude is too low, there may be inaccurate test results; if the amplitude is too large, there

may be vibrations and noise, which saturates the loop output. It is recommended that the user starts with a smaller amplitude of the injected signal.

b. Sampling Time: Sets the duration of the test, which ranges between 1s and 5s. The longer the sampling time, the more accurate the measurement result.

c. Filter Window: Sets the degree of waveform smoothing, which ranges between 1 and 32. The larger the value, the higher the degree of waveform smoothing.

3. Click "Start" to perform the test.

4. The test is completed and the result should be displayed on the MotionLAB interface, which automatically identifies the resonant frequency point (f_R) (see Figure 41a on page 79).

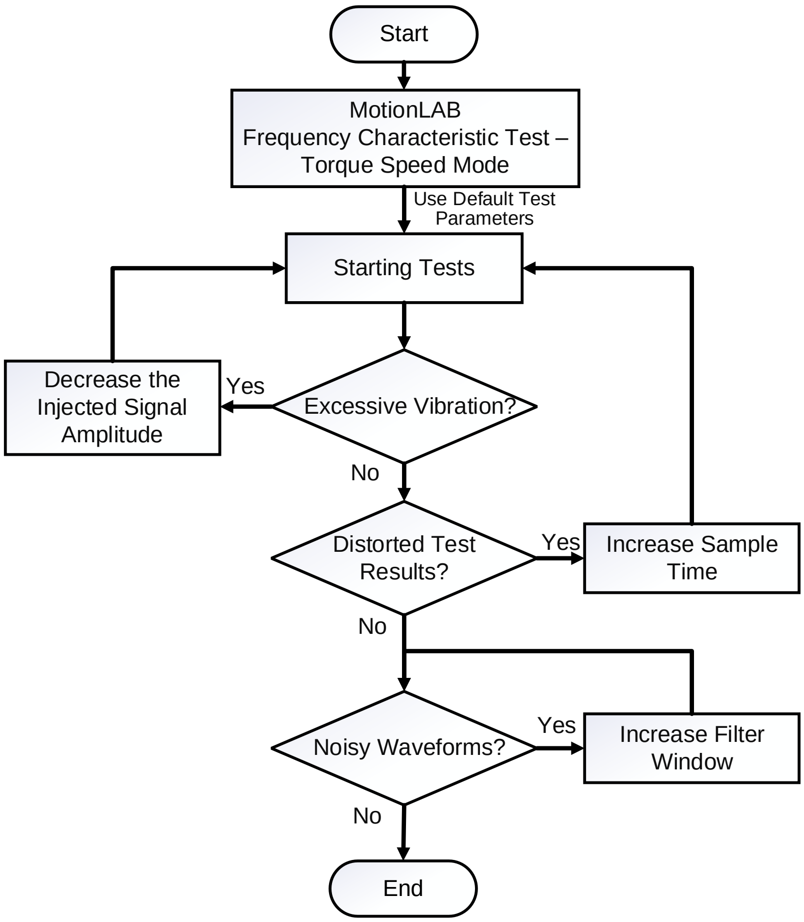


Figure 38: Mechanical Characteristics Flowchart

5.3.2 Notch Filters

If there are resonant frequency points in the servo system that are left untreated, there may be mechanical resonance in the system or even system instability. After obtaining the system's mechanical characteristics, the notch filter is used to filter out the resonant frequency components to prevent the system's mechanical resonance.

The notch filter is a band-stop filter with a narrower stopband and deeper notch depth. Figure 39b on page 77 shows its frequency characteristic, where f_C is the resonant center frequency, f_B is the bandwidth frequency, and h_D is the notch depth. The notch center frequency should be the same as the resonance point in the mechanical characteristics of the system (see Figure 39a on page 77).

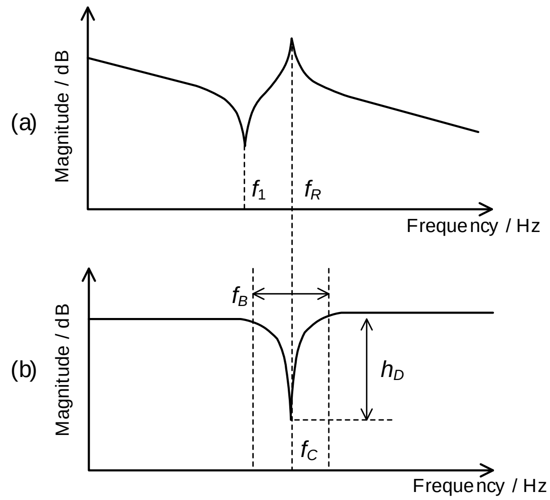


Figure 39: Frequency Characteristics of Notch Filters

Figure 40 shows the configuration screen when users configure the notch filters via MotionLAB. Under the "Frequency Features" tab, choose the torque speed and notch setting. It is recommended to first use the RPM speed mode of the MotionLAB interface to obtain the mechanical characteristics of the servo system. The notch filter selections are described below.

Notch Filter Enable: Enables the notch filter (check the box for enable the filter).

Notch Filter Center Frequency: Sets the center frequency of resonance. The default value is 400Hz.

Notch Filter Bandwidth: Sets the frequency bandwidth where the amplitude attenuation is -3dB. The default value is 100Hz.

Notch Filter Depth: Sets the amplitude attenuation rate at the notch filter center frequency. The default value is -20dB (i.e. the amplitude attenuation is 0.1 times that of the original).

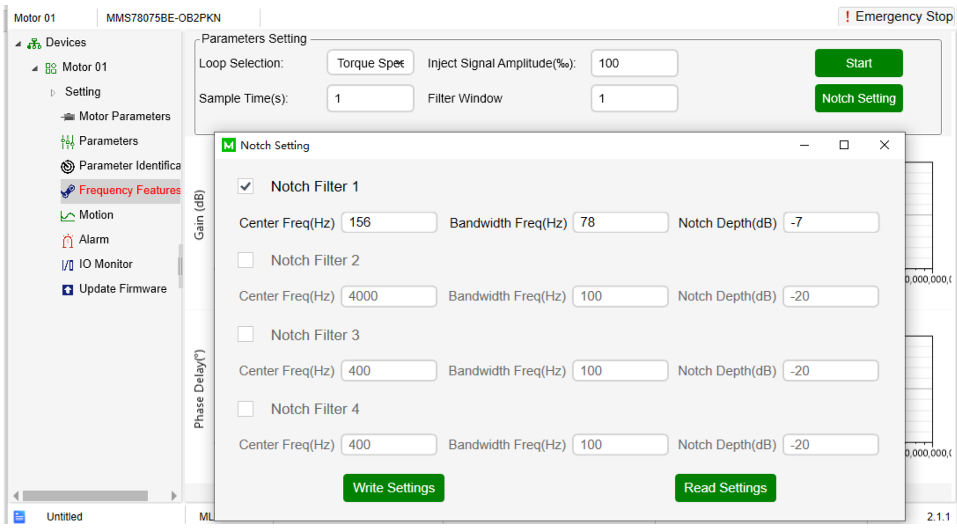


Figure 40: Setting the Notch Filter via MotionLAB

In actual notch filter operations, a1, a2, b1 and b2 (object 2008h) participate in calculations, rather than as mentioned earlier f_C, f_B and h_D. The notch filter parameters (a1, a2, b1 and b2; object 2008h) can be calculated with Equation (15), Equation (16), Equation (17), and Equation (18), respectively.

$$a1 = \left((2\pi \times f_C \times t_S)^2 + 10^{(h_D/20)} \times 2\pi \times f_B \times t_S - 2\right) \times 10000 + 32768 \tag{15}$$

$$a2 = \left(1 - 10^{h_D/20} \times 2\pi \times f_B \times t_S\right) \times 10000 + 32768 \tag{16}$$

$$b1 = \left((2\pi \times f_C \times t_S)^2 + 2\pi \times f_B \times t_S - 2\right) \times 10000 + 32768 \tag{17}$$

$$b2 = (1 - 2\pi \times f_B \times t_S) \times 10000 + 32768 \tag{18}$$

If users configure the notch filter using EtherCAT communication, they should write object 2008h, which means they should select the appropriate resonance center frequency (in Hz), bandwidth frequency (in Hz), and notch depth (in dB), and then calculate a1, a2, b1, and b2 (object 2008h) by Equation (15) to (18).

So it is recommended that users to use MotionLAB software to configure the notch filter, as the software can automatically perform mechanical characterization and calculate the parameters of notch filters and set proper notch filters. Section 5.3.3 provides an example of suppressing mechanical vibration using the frequency characteristic function.

5.3.3 How to Use the Resonance Suppression and Notch Filters by MotionLAB

The following is an example of suppressing mechanical vibration using the frequency characteristic function (see Figure 41 and Figure 42 on page 79).

- Figure 41a on page 79 shows when the mechanical resonance points of the system are tested in torque-speed mode. The test waveform shows that there are two mechanical resonance points in the system, which are automatically labeled as fr1 = 561Hz and fr2 = 2038Hz.
- Figure 41 and Figure 42 on page 79 shows the MotionLAB interface. Click the “Notch Setting” button to access the notch settings window, which displays the configured notch filter parameters corresponding to all the measured resonance points automatically. The users can modify the parameters of each notch.
  - To add a new set of notch filter, check the enable box of a notch filter that is not active, then configure the parameters.
  - To delete a group of filters, uncheck the enable box in front of that filter.
  - Click “Read Settings” to read the current configuration of the notch filter parameters inside the motor.
  - Click the “Write Settings” button to write the configured filter parameters to the motor.
- Figure 41b on page 79 shows that the set-up is complete. The frequency test is rerun, which shows that the resonant frequency point has been eliminated.

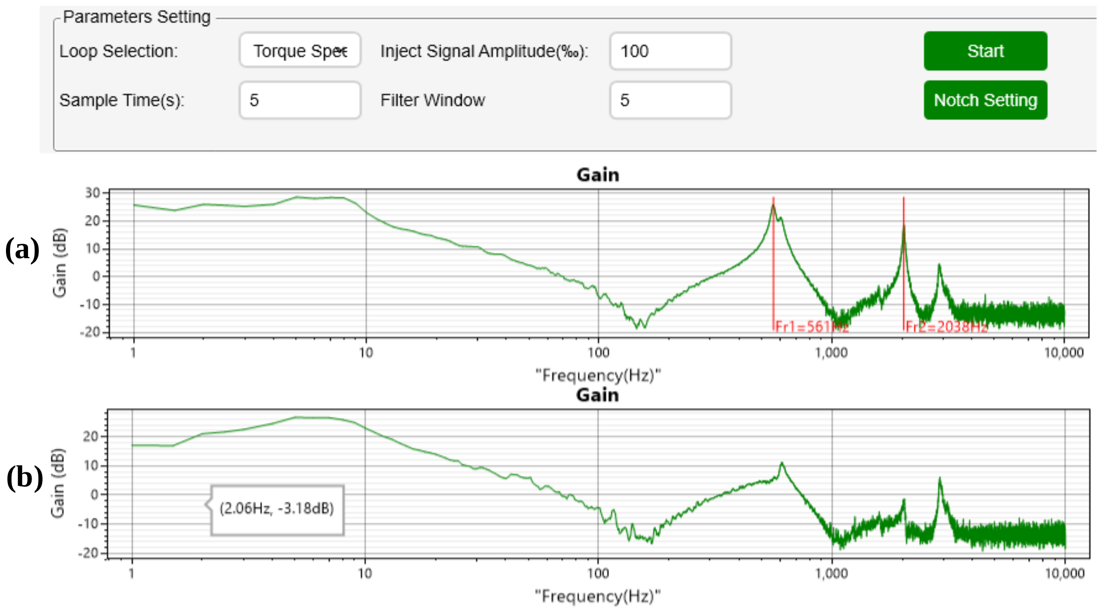


Figure 41: Mechanical Characteristic Test and Notch by using MotionLAB

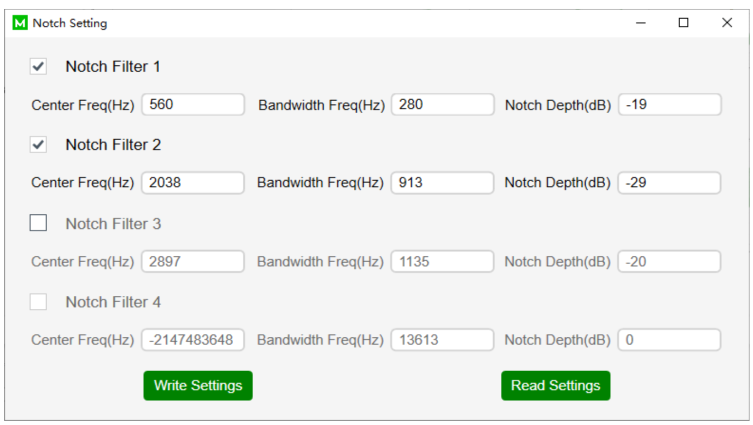


Figure 42: Notch Filter Settings via the MotionLAB

Section 6. Operational Mode

6.1 State Machine

6.1.1 Function Description

The all-in-one motor uses a finite state machine to manage the motor controller's state transitions. The state changes according to the current state, control word or local signals, and fault signals. Figure 43 shows the finite state automation diagram.

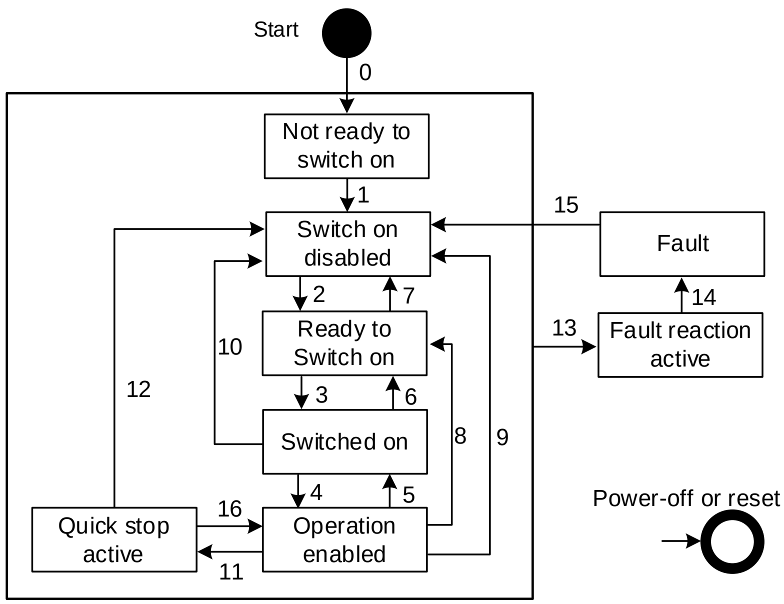


Figure 43: Finite State Automation

Table 44 shows the transition event and actions.

Table 44: Transition Events and Actions

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

Table 45 on page 81 shows the relationship between events and "Control word" (6040h).

Table 45: Command Coding

Command	Bits of "Control Word" (6040h)					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 (13)
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:

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

After start-up, the state transition function to switch on is disabled. Writing 0x0006 to "Control word" (6040h) (the shutdown command) causes the state to advance to the "ready to switch on" state. Then writing 0x000F to "Control word" (6040h) (the switch on + enable operation) causes the state to advance to the "enable operation" state, and the motor operates according to the set operation mode.

If the motor is in a fault state and there are no additional errors, then a rising edge on "Control word" (6040h), bit[7] returns the system to the switch on disabled state.

6.1.2 Related Objects

Table 46: Related Objects of State Machine

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

6.2 Profile Position Mode

6.2.1 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 44 shows the overall structure for this mode.

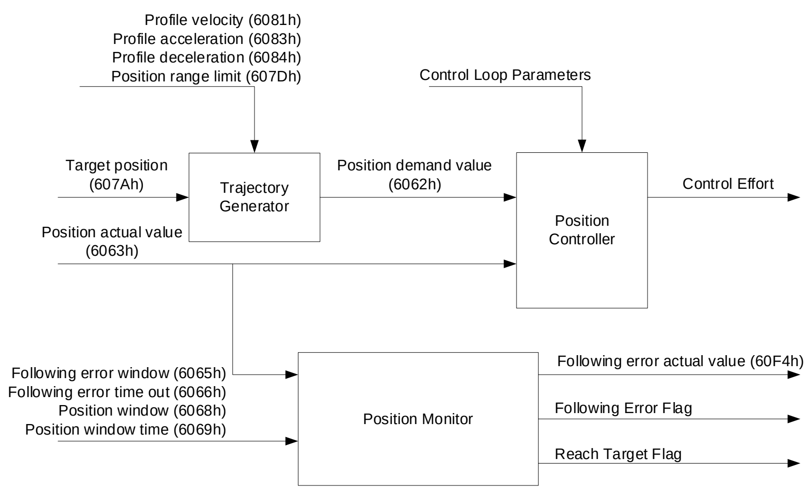


Figure 44: Profile Position Mode Block Diagram

The driver module uses a trapezoidal profile, with the acceleration and deceleration constant between two set points (see Figure 45).

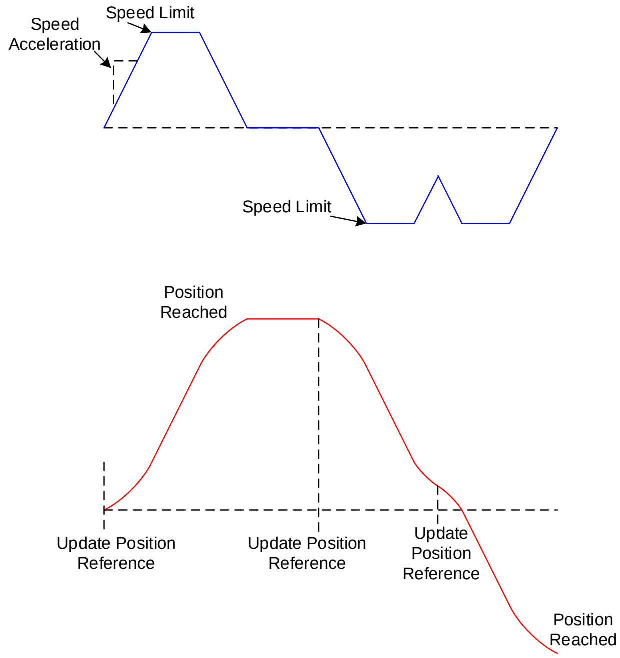


Figure 45: Profile Position Trajectory Generator

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

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

6.2.2 Related Objects

Table 47: Related Objects of Profile Position Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6062h	00h	Position demand value	RO	TPDO	INT32	UserUnit	INT32	-
6063h	00h	Position actual internal value	RO	TPDO	INT32	INC	INT32	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
6065h	00h	Following error window	R/W	RPDO	UINT32	UserUnit	UINT32	182
6066h	00h	Following error time out	R/W	RPDO	UINT32	ms	UINT32	10
6067h	00h	Position window	R/W	RPDO	UINT32	UserUnit	UINT32	182
6068h	00h	Position window time	R/W	RPDO	UINT16	ms	UINT32	10
607Ah	00h	Target position	R/W	RPDO	INT32	UserUnit	INT32	0
607Dh	01h	Min position limit	R/W	RPDO	INT32	UserUnit	INT32	-2^{31}
	02h	Max position limit	R/W	RPDO	INT32	UserUnit	INT32	$2^{31} – 1$
6081h	00h	Profile velocity	R/W	RPDO	UINT32	UserUnit /s	UINT32	655360
6083h	00h	Profile acceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	3276800

6.2.3 Use of “Control Word” (6040h) and “Status Word” (6041h)

Table 48: Use of “Control Word” and “Status Word” in PP Mode

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	Not used.
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	Not used.
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	Not used.
13	Set point acknowledge	1: A new set point is allowed 0: The previous set point still in process
12	Following error	1: The position following error is too large 0: The position following error is within the set range
11	Internal limit active	If position limit is reached, this is set.
10	Target reached	0: Target not reached (if Halt equals 0); axis deceleration (if Halt equals 1) 1: Target reached (if Halt equals 0); velocity axis is 0 (if Halt equals 1)
9	Remote	If set, the parameters may be modified by communication. This bit is always 1.
8	Reserved	Not used.
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.

6.2.4 Simple Example

Move the motor to position 10 revolutions and 0 degrees, then move the motor to 20 revolutions and 0 degrees in profile position (PP) mode.

Table 49: Example of Using PP Mode

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

6.3 Homing Mode

6.3.1 Function Description

Homing mode (HM) 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 46).

MMS7xxxxBE series servo motor provides the feature of using the third gain parameters in homing mode. For more information, please see Section 5.2.2 in page 69.

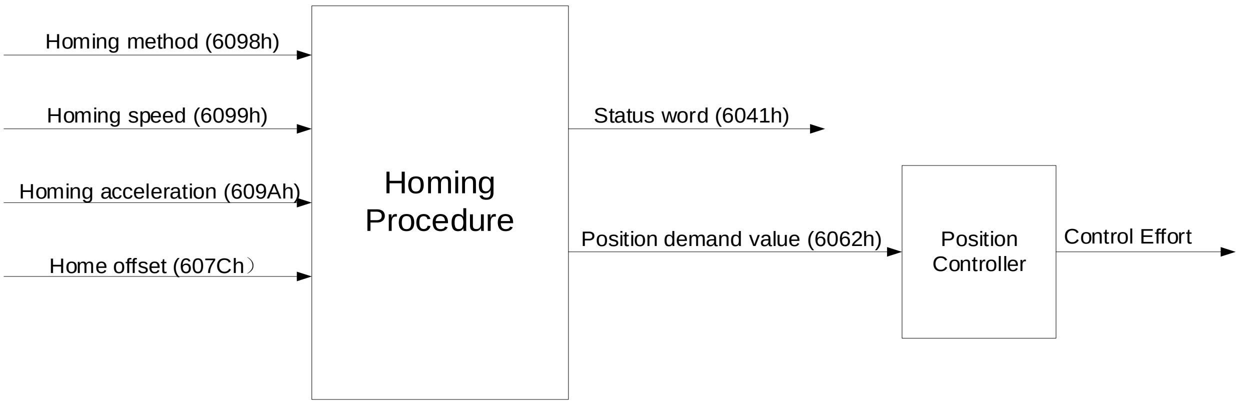


Figure 46: Homing Mode Block Diagram

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 50 shows the description and diagram for each method.

Users can set the homing error window in MotionLAB. When the total homing time exceeds the homing time out then Status Word, bit[13] (Homing_error) is set.

Table 50: Homing Methods

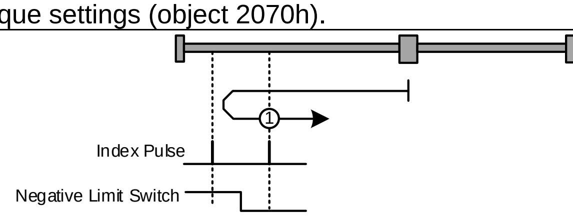
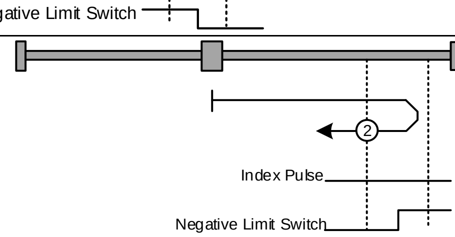
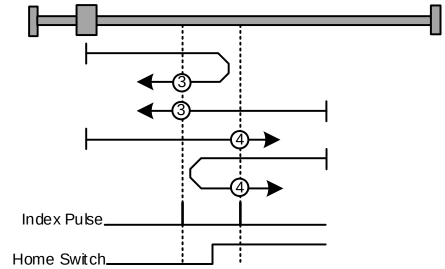
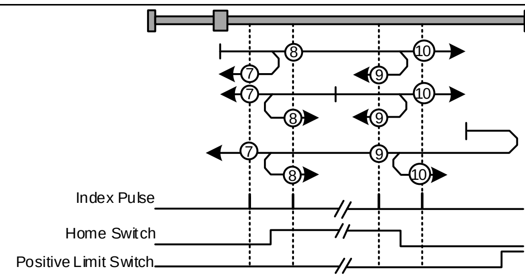
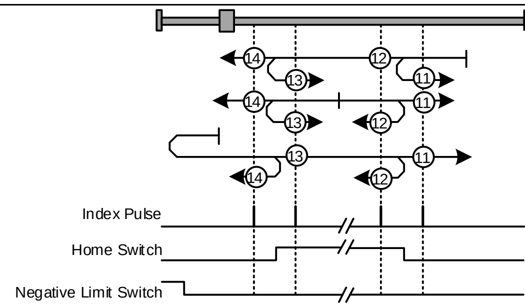
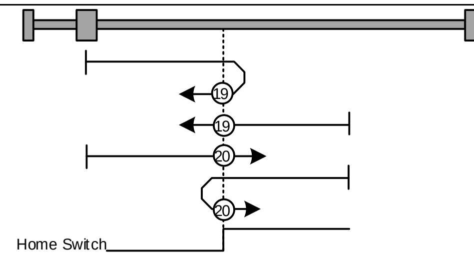
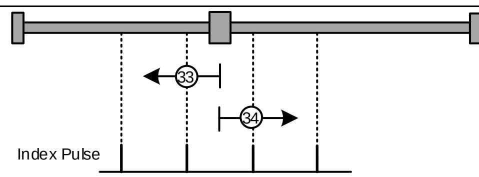
Method	Description	Diagram
-3	Homing clockwise with limited torque.	These two methods allow for homing without a limit switch or home switch. The motor goes in one direction until it reaches the mechanical range limit. The motor output torque is limited with the homing torque settings (object 2070h).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

Table 50: Homing Methods *(continued)*

Method	Description	Diagram
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.	

6.3.2 Related Objects

Table 51: Related Objects of Homing Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
2070h	02h	Homing stall time	R/W	No	UINT16	ms	UINT16	500
2070h	03h	Homing time out	R/W	No	UINT16	s	UINT16	100
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
607Ch	00h	Home offset	R/W	RPDO	INT32	UserUnit	INT32	0
6098h	00h	Homing method	R/W	RPDO	INT8	-	-3 to +35	1
6099h	01h	Homing speed switch	R/W	RPDO	UINT32	UserUnit /s	UINT32	655360
	02h	Homing speed zero	R/W	RPDO	UINT32	UserUnit /s	UINT32	65536
609Ah	00h	Homing acceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	0

6.3.3 Use of “Control Word” (6040h) and “Status Word” (6041h)

Table 52: Use of “Control Word” and “Status Word” in HM

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	Not used.
8	Halt	Enable halt.
7	Fault reset	Change from 0 to 1 to reset the internal fault status.
6:5	Reserved	Not used.
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	Not used.
13	Homing error	1: A homing error has occurred 0: No homing error has occurred
12	Homing attained	1: Homing is complete 0: Homing has not started (or in progress)
11	Internal limit active	1: Internal limit is reached 0: Internal limit not reached
10	Target reached	If the set point is reached, this bit is set.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Not used.
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.

6.3.4 Simple Example

For this example, homing the motor is accomplished using the homing method 1 (see Table 53).

Table 53: Example of Using Homing Mode

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

6.4 Profile Velocity Mode

6.4.1 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 the status word (see Figure 47).

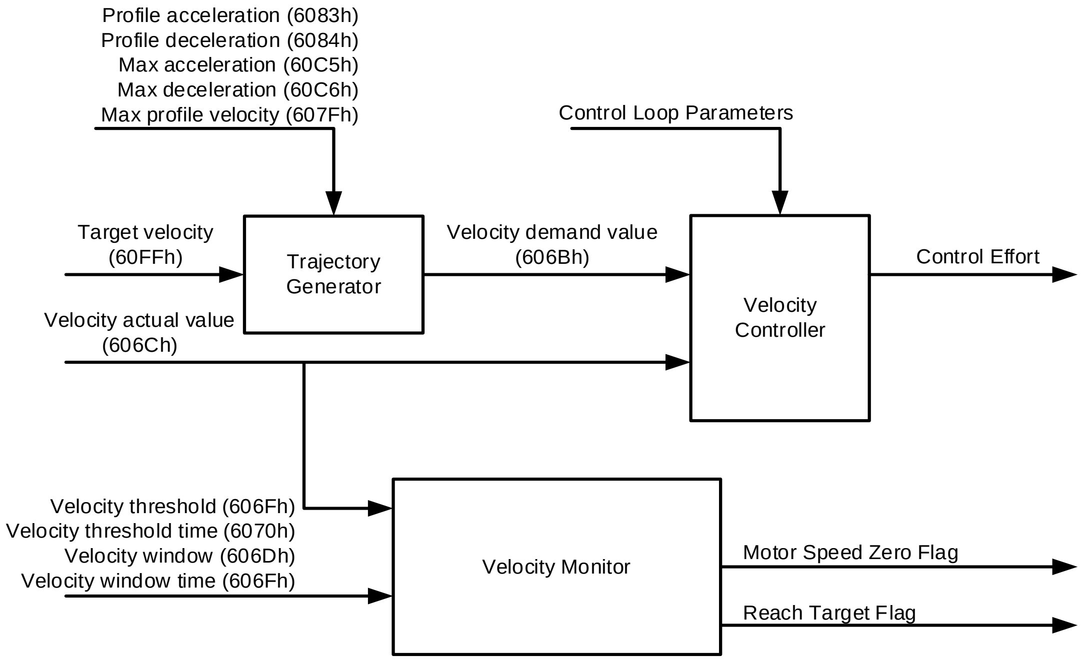


Figure 47: Profile Velocity Mode Diagram

A trapezoidal profile is supported (see Figure 48). If the actual velocity is below the target velocity after a new speed command is sent to the controller, the motor speed decreases. Otherwise, the motor speed increases.

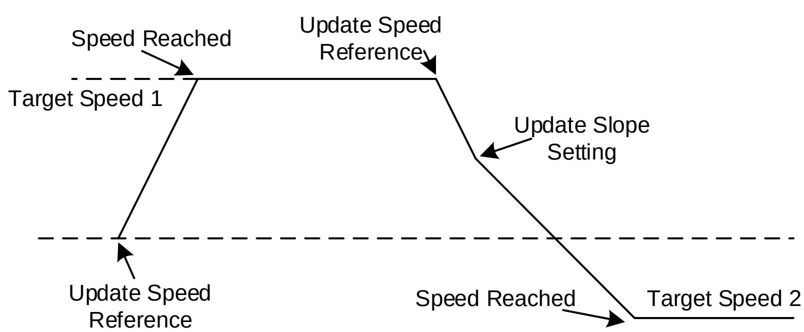


Figure 48: Trapezoidal Speed Profile

6.4.2 Related Objects

Table 54: Related Objects of Profile Velocity Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
606Bh	00h	Velocity demand value	RO	TPDO	INT32	UserUnit /s	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit /s	INT32	-
606Dh	00h	Velocity window	R/W	RPDO	UINT16	UserUnit /s	UINT16	65536
606Eh	00h	Velocity window time	R/W	RPDO	UINT16	ms	UINT16	10
606Fh	00h	Velocity threshold	R/W	RPDO	UINT16	UserUnit /s	UINT16	65536
6070h	00h	Velocity threshold time	R/W	RPDO	UINT16	ms	UINT16	10
6083h	00h	Profile acceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	3276800
6084h	00h	Profile deceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	3276800
60C5h	00h	Max acceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	2^{32} - 1
60C6h	00h	Max deceleration	R/W	RPDO	UINT32	UserUnit /s^2	UINT32	2^{32} - 1
60FFh	00h	Target velocity	R/W	RPDO	IN32	UserUnit /s	INT32	0

6.4.3 Use of “Control Word” (6040h) and “Status Word” (6041h)

Table 55: Use of “Control Word” and “Status Word” in PV Mode

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	Not used.					
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	Not used.
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	Not used.
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.

6.4.4 Simple Example

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

Table 56: Example of Using 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.

6.5 Profile Torque Mode

6.5.1 Function Description

The 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 49 shows the profile torque mode block diagram. The trajectory generator calculates the torque demand value according to the profile parameter, then sends the value to the torque controller block. The torque controller performs closed-loop torque control according to the torque's demand value and torque's actual value.

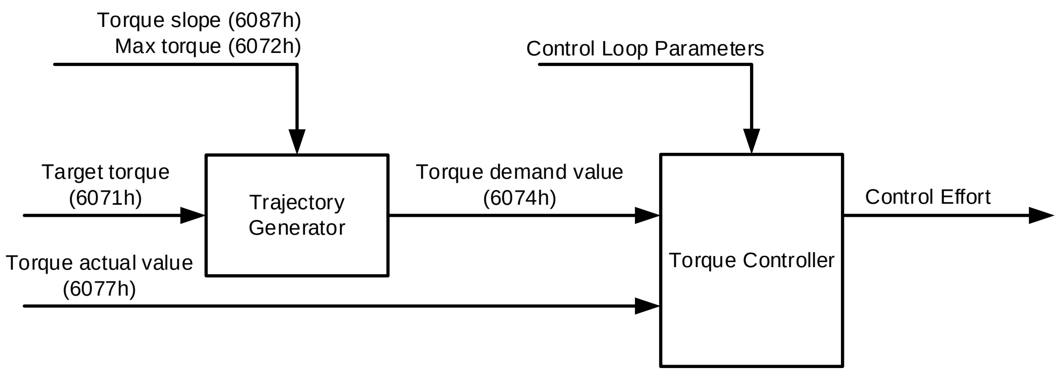


Figure 49: Profile Torque Mode Functional Block

6.5.2 Related Objects

Table 57: Related Objects of Profile Torque Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	RW	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation 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	RPDO	UINT16	‰	0 to 3000	3000
6073h	00h	Max current	R/W	RPDO	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	RPDO	UINT32	‰/s	UINT32	3000
6088h	00h	Torque profile type	R/W	RPDO	INT16	-	0	0

6.5.3 Related Objects Use of "Control Word" (6040h) and "Status Word" (6041h)

Table 58: Use of "Control Word" and "Status Word" in PT Mode

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	Not used.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:4		Reserved	Not used.					
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	Not used.					
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	Not used.					
7		Warning	0: No warning 1: Warning					
6		Switch on disabled	If set, the driver is in switch on disabled state.					
5		Quick stop	1: Quick stop is able to perform 0: Quick stop is performing (or is unable to perform)					
4		Voltage enabled	Always 1. A high voltage is applied to the drive.					
3		Fault	If a fault occurs, this bit is set.					
2		Operation enabled	Operation enabled mode is entered.					
1		Switch on	The driver switch is on.					
0		Ready to switch on	The driver is ready to switch.					

6.5.4 Simple Example

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

Table 59: Example of Using PT Mode

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

6.6 Cyclic Synchronous Position Mode

6.6.1 Function Description

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

Figure 50 shows the controller block diagram.

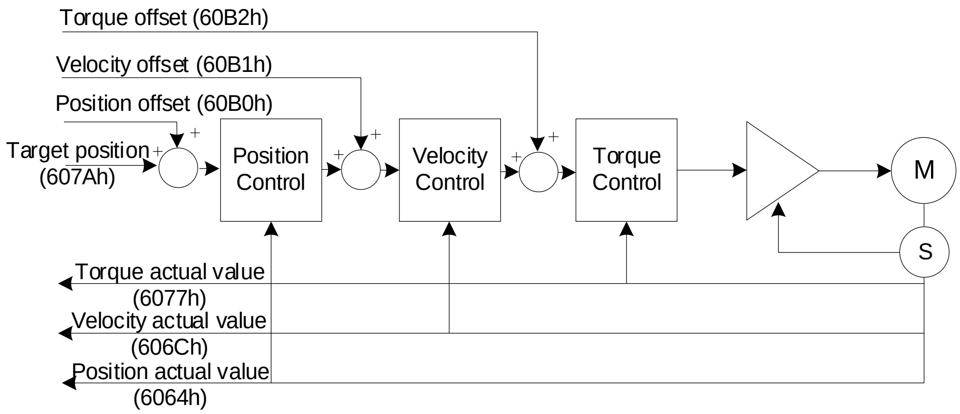


Figure 50: Cyclic Synchronous Position Mode Block Diagram

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.

6.6.2 Related Objects

Table 60: Use of “Control Word” and “Status Word” in CSP Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
6065h	00h	Following error window	R/W	RPDO	UINT32	UserUnit	UINT32	182
6066h	00h	Following error time out	R/W	RPDO	UINT32	ms	UINT32	10
607Ah	00h	Target position	R/W	RPDO	INT32	UserUnit	INT32	0
607Dh	01h	Min position limit	R/W	RPDO	INT32	UserUnit	INT32	-2^{31}
	02h	Max position limit	R/W	RPDO	INT32	UserUnit	INT32	$2^{31} - 1$
60B0h	00h	Position offset	R/W	RPDO	INT32	UserUnit	INT32	0
60B1h	00h	Velocity offset	R/W	RPDO	INT32	UserUnit /s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
60C2h	01h	Interpolation time period value	R/W	No	UINT8	-	1 to 255	1
	02h	Interpolation time index	R/W	No	INT8	-	-4 to -3	-3
60F4h	00h	Following error actual value	RO	TPDO	INT32	INC	INT32	-

6.6.3 Use of "Control Word" (6040h) and "Status Word" (6041h)

Table 61: Use of "Control Word" and "Status Word" in CSP Mode

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	Not used.
8	Halt	Enable halt.
7	Fault reset	Change from 0 to 1 reset the internal fault status.
6:4	Reserved	Not used.
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	Not used.
13	Following error	1: No following error 0: Following error
12	Target accepted	1: Target position is used as the input to position control loop 0: Target position ignored
11	Internal limit active	If position limit is reached, this bit is set.
10	Target reached	Reserved in cyclic synchronous mode.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Not used.
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.

6.7 Cyclic Synchronous Velocity Mode

6.7.1 Function Description

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

Figure 51 shows the controller block diagram.

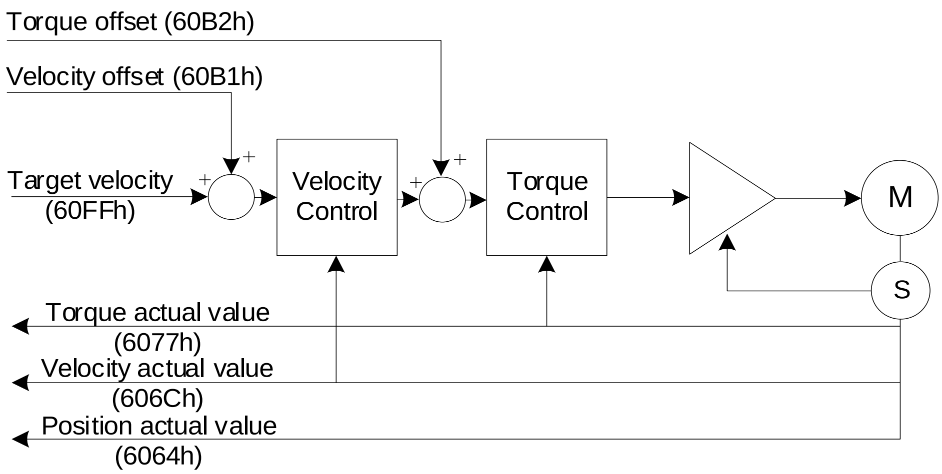


Figure 51: Cyclic Synchronous Velocity Mode Block Diagram

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

6.7.2 Related Objects

Table 62: Related Objects in Cyclic Synchronous Velocity Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit /s	INT32	-
60B1h	00h	Velocity offset	R/W	RPDO	INT32	UserUnit /s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
60FFh	00h	Target velocity	R/W	RPDO	IN32	UserUnit /s	INT32	0

6.7.3 Use of “Control Word” (6040h) and “Status Word” (6041h)

Table 63: Use of “Control Word” and “Status Word” in CSV Mode

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	Not used.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 to reset the internal fault status.					
6:4		Reserved	Not used.					
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	Not used.					
12		Target accepted	1: Target position is used as input to position control loop 0: Target position ignored					
11		Internal limit active	If the position limit is reached, this bit is set.					
10		Reserved	Not used.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Not used.					
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.					

6.8 Cyclic Synchronous Torque Mode

6.8.1 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 additive torque value can be provided by the motion controller to allow for a second source of torque. Figure 52 on page 98 shows the block diagram.

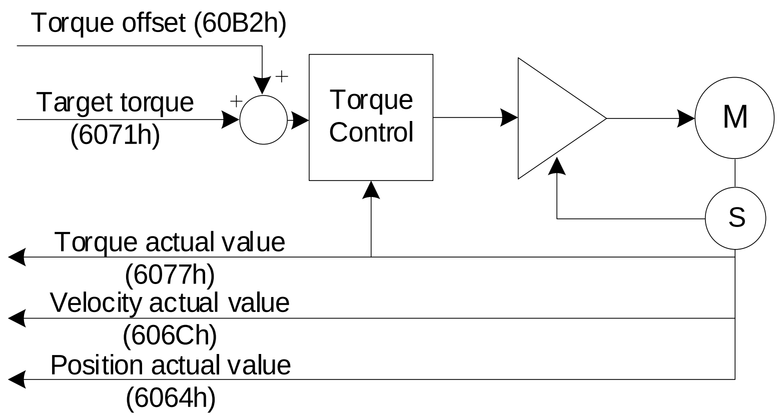


Figure 52: Cyclic Synchronous Torque Mode Block Diagram

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

To ensure safe operation in this mode, the motor speed is limited via "Torque loop speed limit" (2005h-08h).

6.8.2 Related Objects

Table 64: Related Objects in Cyclic Synchronous Torque Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit /s	INT32	-
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	0

6.8.3 Use of "Control Word" (6040h) and "Status Word" (6041h)

Table 65: Use of "Control Word" and "Status Word" in CST Mode

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	Not used.
8	Halt	Enable halt.
7	Fault reset	Change from 0 to 1 reset the internal fault status.
6:4	Reserved	Not used.
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	Not used.
12	Target accepted	1: Target position is used as input for position control loop 0: Target position ignored
11	Internal limit active	If position limit is reached, this bit is set.
10	Reserved	Not used.
9	Remote	If set, parameters may be modified by communication.
8	Reserved	Not used.
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.

6.9 Impedance Control Mode

6.9.1 Function Description

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

To achieve impedance control, the driver module implements an impedance controller (see Figure 53). The control loop parameters (K_P, K_I, and K_D) are mapped to RPDO, so they can be updated in real time. Changing different loop parameters can obtain different mechanical impedances that allow the robot to complete different tasks. This provides more flexibility for the robot's joint control.

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

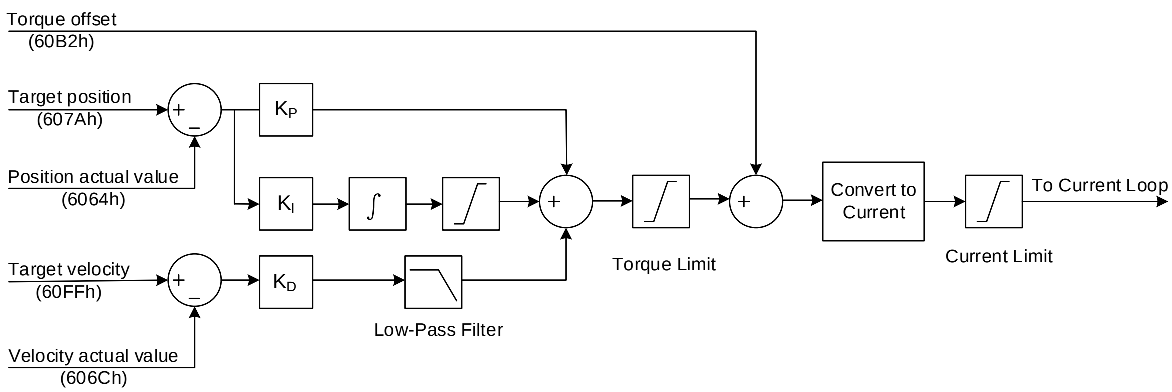


Figure 53: Impedance Controller Block Diagram

6.9.2 Related Objects

Table 66: Related Objects in Impedance Control Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	01h	K_P	R/W	No	REAL32	-	-	0
	02h	K_I	R/W	No	REAL32	-	-	0
	03h	K_D	R/W	No	REAL32	-	-	0
	04h	Filter cutoff frequency	R/W	No	REAL32	Hz	-	1000
	05h	Joint torque limit	R/W	No	REAL32	Nm	-	0
	06h	Motor current limit	R/W	RPDO	REAL32	A	-	0
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit /s	INT32	-
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0

6.9.3 Use of "Control Word" (6040h) and "Status Word" (6041h)

Table 67: Use of "Control Word" and "Status Word" in Impedance Control Mode

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	Not used.					
8		Halt	Enable halt.					
7		Fault reset	Change from 0 to 1 reset the internal fault status.					
6:4		Reserved	Not used.					
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	Not used.					
12		Target accepted	1: Target position shall be used as input to position control loop 0: Target position ignored					
11		Internal limit active	If position limit is reached, this bit is set.					
10		Reserved	Not used.					
9		Remote	If set, parameters may be modified by communication.					
8		Reserved	Not used.					
7		Warning	0: No warning 1: Warning					

6.10 Touch Probe

6.10.1 Function Description

Touch probe refers to the external input signal as a trigger, the input trigger when the position of the locking function. For traditional control, the motor's I/O interface is connected to the sensor. If the related event triggers this signal, the host computer obtains the trigger signal coming event through I/O status monitoring, and then query the current position to the servo motor after receiving the event.

This all-in-one servo motor supports 2-channel probes, which can lock the rising edge and falling edge position information of each signal, totaling 4 position values.

6.10.2 Related Objects

Table 68: Touch Probe Related Objects

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B8h	00h	Touch probe function	R/W	RPDO	UINT16	-	UINT16	0
60B9h	00h	Touch probe status	RO	TPDO	UINT16	-	UINT16	0
60BAh	00h	Touch probe 1 rising edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BBh	00h	Touch probe 1 falling edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BCh	00h	Touch probe 2 rising edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BDh	00h	Touch probe 2 falling edge position value	RO	TPDO	INT32	UserUnit	INT32	0

6.10.3 Simple Example

Table 69 shows an example of continuous latching of position information with the rising edge of probe 1.

Table 69: Example of Using Touch Probe Function

Steps	Index and Sub-Index	Data	Description
1	2030h-01h	0x04	Set the DI function to probe 1.
2	60B8h-00h	0x0013	Bit[0]: Enable probe 1 Bit[1]: Set probe 1 trigger mode to continuous trigger Bit[4]: Enable upper and lower edge latch for probe 1

After the setting is completed, read the probe status (60B9h-00h). In this example, read whether bit[1] of this register is set to 1 to determine whether the locking of the rising edge position of probe 1 has completed. If the locking of the position information on the rising edge of probe 1 has been completed, the position information can be obtained by reading the register of the position value of the rising edge of probe 1 (60BAh-00h). Figure 54 shows the process timing diagram.

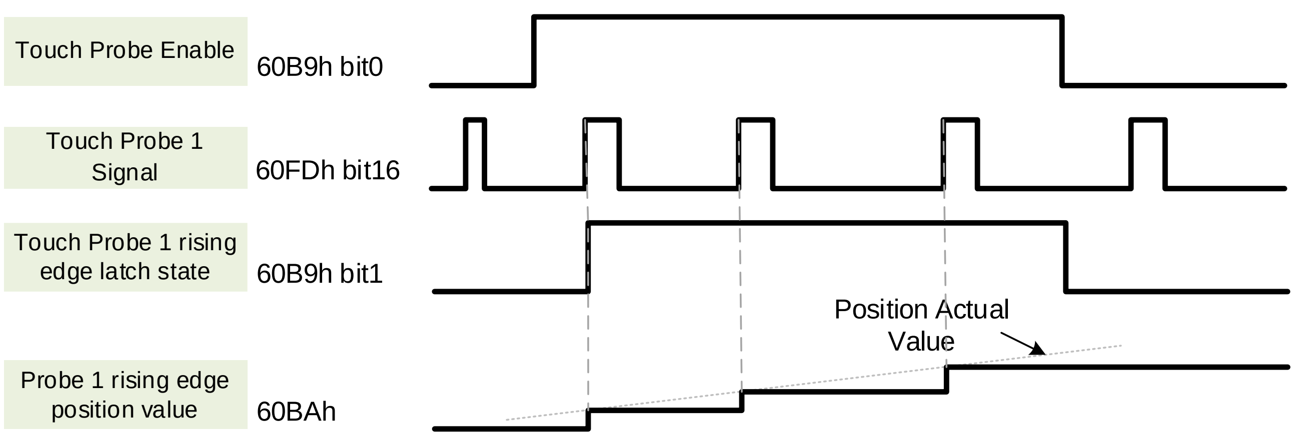


Figure 54: Touch Probe 1 Rising Edge Continuous Latch Timing Chart

Section 7. Faults and Protection

The motor offers extensive protection against accidental faults and damage to external components. The type of fault can be determined according to the value of "Error status" (200Bh-0Bh). When a fault occurs, the ALARM signal outputs high and the fault indication LED lights up red.

7.1 Fault Protection Instructions

Table 70: Summary of Fault Protection

Fault Protection Type	Error Status (200Bh-0Bh)	Error Code (603Fh)	Description
Over Current Protection	0001h	2300h	Over-current protection (OCP) usually occurs when a device on the PCB is damaged or short-circuited. The motor turns off the power switch to avoid further damage to the system. If any phase current exceeds the OCP threshold (200Bh-02h), OCP is triggered and the error state OCP bit (200Bh-0Bh) is set to 1. The controller then enters the fault state.
Under-Voltage Lockout (UVLO) Protection	0002h	3220h	If under-voltage lockout (UVLO) protection is enabled, the error status UVLO bit (200Bh-0Bh) is set to 1 and the controller enters a fault state when the DC bus voltage falls below the UVLO threshold (200Bh-03h). UVLO protection can be disabled by setting the protection enable (UVLO_EN) bit (200Bh-01h) to 0.
Rotor-Lock Protection	0004h	7121h	If the motor does not reach the target position or target speed, and the motor displacement is below the lock position threshold (200Bh-04h) and the output current exceeds the rated current during the lock time window (200Bh-06h), lock protection is triggered, the error status LOCK bit (200Bh-0Bh) is set to 1, and the controller enters into the fault state. The lock protection function can be disabled by setting the protection enable (LOCK_EN) bit (200Bh-01h) to zero.
Power Stage Fault (PSFT) Protection	0008h	5400h	If the internal power stage pre-driver device sends a fault signal, Power Stage Fault (PSFT) is triggered, the error status PSFT bit (200Bh-0Bh) is set to 1, and the controller enters a fault state. If a power stage fault is detected, the controller shuts down the power stage to avoid further damage to the system.
Overload Protection	0010h	3230h	To avoid damage to the mechanical system and the motor, if the output torque exceeds the overload protection threshold (2042h-02h) and the duration exceeds the overload time window (2042h-03h), overload protection is triggered, the error status OVERLOAD bit (200Bh-0Bh) is set to 1, and the controller turns off the power switch. Overload protection can be disabled by setting the overload enable bit (2042h-01h) to 0.
Position over Limit Protection	0020h	-	If the motor moves to the mechanical limit, the system prompts the position over limit, the error status (POS_LIMIT) bit (200Bh-0Bh) is set to 1, and the controller enters the fault state.
Position Sensor Error	0040h	-	If an abnormality occurs while reading the sensor feedback or the encoder is disconnected, the position sensor error protection is triggered and the error status (SENSOR_ERR) bit (200Bh-0Bh) is set to 1.

Table 70: Summary of Fault Protection *(continued)*

Fault Protection Type	Error Status (200Bh-0Bh)	Error Code (603Fh)	Description
Internal Memory Error	0080h	-	If an internal parameter storage or loading exception occurs, the internal storage exception protection is triggered and the error status (MEM_ERR) bit (200Bh-0Bh) is set to 1.
Over Temperature Protection (OTP)	0100h	4210h	If the temperature reaches (OTP threshold -20°C), the system pre-announces an over-temperature warning and the bit (6041h-00h) of the status word is set to 1. The controller does not shut down the power stage, allowing the user to respond. If over-temperature protection (OTP) is enabled, when the temperature exceeds the OTP threshold (2041h-00h), OTP is triggered, the error status OTP bit (200Bh-0Bh) is set to 1, and the servo controller enters a fault state. The OTP function can be disabled by setting the protection enable (OTP_EN) bit to 0 in “Protection enable” (200Bh-01h).
DC Link Voltage Limit Protection	0200h	3210h	The DC bus voltage is automatically detected inside the motor. If the DC bus voltage exceeds the upper limit threshold (200Bh-09h), then VDCCON starts working. If the DC bus voltage falls below the DC bus limit lower threshold (200Bh-0Ah), then VDCCON stops operating. This limits the voltage at which energy is returned to the DC bus from the motor. This function can be disabled by setting the protection enable VIN_LIMIT_EN to zero. If the DC bus voltage is detected to exceed (upper threshold + 1)V, over-voltage protection is triggered, the error status OVP bit (200Bh-0Bh) is set to 1, and the controller enters the fault state.
Over Speed Protection	0400h	8400h	If the motor speed exceeds the set overspeed protection threshold (200Bh-0Ch), overspeed protection is triggered, the error status (OVER_SPEED) bit (200Bh-0Bh) is set to 1, and the controller enters the fault state.
Over Speed Error Protection	0800h	8401h	If the difference between the motor’s internal commanded speed and the actual speed (speed error) exceeds the speed error threshold (200Bh-0Dh) and continues to exceed the speed error time window (200Bh-0Eh), the speed deviation overrun protection is triggered, the error status (SPEED_ERROR_LMT) bit (200Bh-0Bh) is set to 1, and the controller enters a fault state.
EtherCAT Communication Protection	1000h	7500h	If the all-in-one servo motor is in the “servo on” state and the EtherCAT communication between the MainDevice and the SubDevice servo motor is disconnected during normal communication, EtherCAT communication protection is triggered, the error status (ECAT_WATCHDOG_ERR) bit (200Bh-0Bh) is set to 1, and the controller enters the fault state.

7.2 Fault Reaction Mode

Users can set the fault reaction mode in the 605Eh object. When a fault is reported, the servo motor enters the fault reaction active state and stops the motor according to the set fault reaction option code (605Eh), and automatically switches to the fault state. Table 71 on page 105 shows the stopping actions corresponding to different fault stopping options.

Certain severe faults have a fixed fault reaction stop mode that disables drive and prohibits other means of slowing down the motor to shut down. See Section 7.3 on page 105 for more details.

Table 71: Fault Reaction Options Code

Stopping Methods	Stop Mode	Stop Options	Description
Fault Reaction Stop	Disable drive	0	Cut off the power supply to the motor windings. The motor stops freely, and the emergency stop time is related to the friction condition of the motor load condition.
	Slow down on slow down ramp	1	Decelerate to zero speed at the deceleration rate set for the motor's current operating mode, and then disable the drive.
	Slow down on quick stop ramp	2	Decelerate to zero speed at the deceleration rate set for the quick stop of the motor, and then disable the drive.
	Slow down on current limit	3	Decelerate with the set stop current value as the deceleration current. After decelerating to zero speed, disable the drive.
	Slow down on voltage limit	4	Use the bus voltage as a limit. The loop outputs the maximum limiting voltage to decelerate. After decelerating to zero speed, disable the drive.

7.3 Countermeasures against Faults

Table 72 shows the possible causes and corresponding countermeasures when the fault occurs. Over-current protection (OCP), power stage fault (PSFT) protection, position sensor error protection, over-temperature protection (OTP), over-speed protection, and over-speed error protection is fixed and cannot be disabled. When these fixed protections have been triggered, the motor will shuts down immediately and the set fault reaction mode (605Eh) does not take effect.

Table 72: Causes and Countermeasures of Faults

Fault Protection Type	Fault Reaction Mode	Causes	Countermeasures
Over Current Protection	Fixed, disable drive	• Hardware failure • Abnormal parameter settings	• Re-energize the start-up and observe whether the phenomenon recurs • The current protection threshold should exceed 1.2 times the peak motor operating current
Under-Voltage Lockout (UVLO) Protection	Configurable	• Input power supply voltage is too low, or the power supply capacity is insufficient and the power supply voltage has dipped too much	• Check the input power supply voltage • Verify that the power supply power meets the application requirements
Rotor-Lock Protection	Configurable	• Mechanical structure jammed • Movement to end of mechanism	• Check the mechanical structure for proper functioning • Check that the motor is not moving to the end of the mechanism
Power Stage Fault (PSFT) Protection	Fixed, disable drive	• Hardware fault • Too low of an input DC voltage	• Check that the input DC supply voltage and the servo motor is normal

Table 72: Causes and Countermeasures of Faults *(continued)*

Fault Protection Type	Fault Reaction Mode	Causes	Countermeasures
Overload Protection	Configurable	• Excessive load for a long time • Unreasonable parameter settings	• Check the mechanical structure to ensure that there is no excessive load for a long period of time • The overload protection time may be too short for the motor output load
Position over Limit Protection	Configurable	• Movement to mechanical limit • Abnormal limit switch connection	• Check that the motor is not moving to a mechanical limit • Check if the limit switch is connected properly
Position Sensor Error Protection	Fixed, disable drive	• Loss of encoder signal	• Rotate the motor and observe whether the feedback encoder position changes
Internal Memory Error Protection	Configurable	• Parameter storage or reading error	• Re-energize
Over Temperature Protection (OTP)	Fixed, disable drive	• Driver's temperature is too high • Over-temperature protection threshold set too low	• Check whether the motor has been overloaded for a long time • Check whether the over-temperature protection threshold is set too low
DC Link Voltage Limit Protection	Configurable	• Input power supply voltage is too high • The braking resistor does not operate when the motor is in a regenerative braking mode	• Check the input power supply voltage • Check whether the DC voltage clamp function is enabled • Check whether the braking resistor operates normally
Over Speed Protection	Configurable	• Command speed is too high • The overspeed protection threshold is set too low • The gain setting is not reasonable and the speed is overshooting	• Decrease command speed • Increase the overspeed protection detection threshold • Adjust the appropriate gain
Over Speed Error Protection	Configurable	• The motor rotor is locked • Gain setting is not reasonable • Too heavy a load, too much rotational inertia, no identification of system inertia	• Check the movement of the mechanical structure • Adjust the appropriate gain • Determine if the system load is reasonable
EtherCAT Communication Protection	Configurable	• EtherCAT communication is interrupted • EtherCAT communication is disturbed	• Check whether the communication cable is reliably connected • Check the operating status of the EtherCAT MainDevice

7.4 Clear Error

To clear the error and restart the motor from the faulted state without shutting it down, send a fault reset command to the controller (rising edge of "Control word" (6040h), bit[7]). If there are no faults, the controller enters the switch on disabled state. a switch on and enable operation command is sent to re-enable the motor.

7.5 Related Objects

Table 73: Related Objects in Fault Protection

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	01h	Protection enable	R/W	No	UINT8	-	-	0
	02h	OCP threshold	R/W	No	UINT16	A	UINT16	20
	03h	UVLO voltage threshold	R/W	No	UINT16	V	8 to 30	12
	04h	Lock position threshold	R/W	No	UINT32	UserUnit	UINT32	182
	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
	0Ch	Over speed threshold	RW	No	UINT32	rpm	UINT32	3600
	0Dh	Speed error threshold	RW	No	UINT32	rpm	UINT32	1000
	0Eh	Speed error time window	RW	No	UINT16	ms	UINT16	10
2040h	00h	Temperature	RO	TPDO	INT16	°C	-40 to +125	-
2041h	00h	OTP threshold	R/W	No	INT16	°C	-40 to +125	85
2042h	01h	Overload protection 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
605Eh	00h	Fault Reaction Option Code	R/W	No	INT16	-	0 to 4	0

Section 8. Objective Dictionary

8.1 1000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1600h		**RPDO Mapping 1**						
	00h	Number of mapped objects	RO	No	UINT8	-	-	05h
	01h	RPDO mapping object 1	R/W	No	UINT32	-	-	60400010h
	02h	RPDO mapping object 2	R/W	No	UINT32	-	-	60600008h
	03h	RPDO mapping object 3	R/W	No	UINT32	-	-	607A0020h
	04h	RPDO mapping object 4	R/W	No	UINT32	-	-	60B80010h
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	60FE0120h
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	0
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	0
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	0
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping objects 12	R/W	No	UINT32	-	-	0
1601h		**RPDO Mapping 2**						
	00h	Number of mapped objects	RO	No	UINT8	-	-	06h
	01h	RPDO Mapping object 1	R/W	No	UINT32	-	-	60400010h
	02h	RPDO Mapping object 2	R/W	No	UINT32	-	-	60600008h
	03h	RPDO Mapping object 3	R/W	No	UINT32	-	-	607A0020h
	04h	RPDO Mapping object 4	R/W	No	UINT32	-	-	60FF0020h
	05h	RPDO Mapping object 5	R/W	No	UINT32	-	-	60B80010h
	06h	RPDO Mapping object 6	R/W	No	UINT32	-	-	60FE0120h
	07h	RPDO Mapping object 7	R/W	No	UINT32	-	-	0
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	0

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping objects 12	R/W	No	UINT32	-	-	0
1602h	**RPDO Mapping 3**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	07h
	01h	RPDO mapping object 1	R/W	No	UINT32	-	-	60400010h
	02h	RPDO mapping object 2	R/W	No	UINT32	-	-	60600008h
	03h	RPDO mapping object 3	R/W	No	UINT32	-	-	607A0020h
	04h	RPDO mapping object 4	R/W	No	UINT32	-	-	60FF0020h
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	60710010h
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	60B80010h
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	60FE0120h
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	0
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping objects 12	R/W	No	UINT32	-	-	0
1603h	**RPDO Mapping 4**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	02h
	01h	RPDO mapping object 1	R/W	No	UINT32	-	-	60400010h
	02h	RPDO mapping object 2	R/W	No	UINT32	-	-	607A0020h
	03h	RPDO mapping object 3	R/W	No	UINT32	-	-	0
	04h	RPDO mapping object 4	R/W	No	UINT32	-	-	0
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	0

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	0
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	0
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	0
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping objects 12	R/W	No	UINT32	-	-	0
1A00h	**TPDO Mapping 1**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	08h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	603F0010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60410010h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60610008h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	60640020h
	05h	TPDO mapping object 5	R/W	No	UINT32	-	-	60B90010h
	06h	TPDO mapping object 6	R/W	No	UINT32	-	-	60BA0020h
	07h	TPDO mapping object 7	R/W	No	UINT32	-	-	60BC0020h
	08h	TPDO mapping object 8	R/W	No	UINT32	-	-	60FD0020h
	09h	TPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	TPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	TPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping objects 12	R/W	No	UINT32	-	-	0
1A01h	**TPDO Mapping 2**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	09h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	603F0010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60410010h

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60610008h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	60640020h
	05h	TPDO mapping object 5	R/W	No	UINT32	-	-	606C0020h
	06h	TPDO mapping object 6	R/W	No	UINT32	-	-	60B90010h
	07h	TPDO mapping object 7	R/W	No	UINT32	-	-	60BA0020h
	08h	TPDO mapping object 8	R/W	No	UINT32	-	-	60BC0020h
	09h	TPDO mapping object 9	R/W	No	UINT32	-	-	60FD0020h
	0Ah	TPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	TPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping objects 12	R/W	No	UINT32	-	-	0
1A02h	**TPDO Mapping 3**							
	00h	Number of mapped objects	RO	No	UINT8	-	-	0Ah
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	603F0010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60410010h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60610008h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	60640020h
	05h	TPDO mapping object 5	R/W	No	UINT32	-	-	606C0020h
	06h	TPDO mapping object 6	R/W	No	UINT32	-	-	60770010h
	07h	TPDO mapping object 7	R/W	No	UINT32	-	-	60B90010h
	08h	TPDO mapping object 8	R/W	No	UINT32	-	-	60BA0020h
	09h	TPDO mapping object 9	R/W	No	UINT32	-	-	60BC0020h
	0Ah	TPDO mapping object 10	R/W	No	UINT32	-	-	60FD0020h
	0Bh	TPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping objects 12	R/W	No	UINT32	-	-	0
1A03h	**TPDO Mapping 4**							

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	00h	Number of mapped objects	RO	No	UINT8	-	-	03h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	603F0010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60410010h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60640020h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	0
	05h	TPDO mapping object 5	R/W	No	UINT32	-	-	0
	06h	TPDO mapping object 6	R/W	No	UINT32	-	-	0
	07h	TPDO mapping object 7	R/W	No	UINT32	-	-	0
	08h	TPDO mapping object 8	R/W	No	UINT32	-	-	0
	09h	TPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	TPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	TPDO mapping objects 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping objects 12	R/W	No	UINT32	-	-	0
1C12h	**Syncmanager 2 Assigned Object**							
	00h	Maximum sub-index	R/W	No	UINT16	-	-	1
	01h	RPDO assignment mapping group number	R/W	No	UINT16	-	-	1603h
1C13h	**Syncmanager 3 Assigned Object**							
	00h	Maximum sub-index	R/W	No	UINT16	-	-	1
	01h	TPDO assignment mapping group number	R/W	No	UINT16	-	-	1A03h

8.2 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	-	-	-
	04h	Software version	RO	No	UINT16	-	-	-
	05h	Hardware version	RO	No	UINT16	-	-	-
2001h		**Motor Parameters**						
	00h	Max sub-index	RO	No	UINT8	-	11	11
	01h	Phase resistance	R/W	No	UINT32	mΩ	UINT32	-
	02h	D-axis inductance	R/W	No	UINT32	µH	UINT32	-
	03h	Q-axis inductance	R/W	No	UINT32	µH	UINT32	-
	04h	Pole pairs	R/W	No	UINT8	-	1 to 255	-
	05h	Torque constant	R/W	No	UINT32	mNm/A	UINT32	-
	06h	Inertia	R/W	No	UINT32	g x cm^2	UINT32	-
	07h	Rated voltage	R/W	No	UINT32	mV	UINT32	-
	08h	Rated current	R/W	No	UINT32	mA	UINT32	-
	09h	Rated speed	R/W	No	UINT32	rpm	UINT32	-
	0Ah	Friction coefficient	R/W	No	UINT16	µNm x s	UINT16	0
	0Bh	Static friction torque	R/W	No	UINT16	mNm	UINT16	0
2002h		**Driver Configuration**						
	00h	Max sub-index	RO	No	UINT8	-	10	10
	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
2003h		**Position Sensor Configuration**						
	00h	Max sub-index	RO	No	UINT8	-	7	7
	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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	06h	Speed feedback source	R/W	No	UINT8	-	0 to 2	2
	07h	Position feedback source	R/W	No	UINT8	-	0 to 2	0
2004h	**Feed-Forward Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	7	7
	01h	Feed-forward enable	R/W	No	UINT8	-	UINT8	0
	02h	Decoupling gain	R/W	No	UINT8	%	0 to 200	100
	03h	Decoupling time constant	R/W	No	UINT16	0.1ms	UINT16	0
	04h	Torque feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	05h	Torque feed-forward time constant	R/W	No	UINT16	0.1ms	UINT16	0
	06h	Speed feed-forward gain	R/W	No	UINT8	%	0 to 200	100
	07h	Speed feed-forward time constant	R/W	No	UINT16	0.1ms	UINT16	0
2005h	**Loop Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	17	17
	01h	Position loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
	02h	Second position loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
	03h	Speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
	04h	Speed loop integral constant	R/W	No	UINT16	0.1Hz	1 to 500	100
	05h	Torque loop bandwidth	R/W	No	UINT16	0.1Hz	2000 to 20000	10000
	06h	Position loop out limit	R/W	No	UINT32	UserUnit/s	UINT32	3276800
	07h	Speed loop out limit	R/W	No	UINT16	‰	UINT16	3000
	08h	Torque loop speed limit	R/W	No	UINT32	rpm	UINT32	3000
	09h	Gain switching type	R/W	No	UINT16	-	UINT16	0
	0Ah	Gain switching following error threshold	R/W	No	UINT32	UserUnit	UINT32	0
	0Bh	Gain-switching transition time	R/W	No	UINT16	ms	UINT16	1
	0Ch	Second speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
	0Dh	Second speed loop integration factor	R/W	No	UINT16	0.1Hz	1 to 500	100
	0Eh	First gain adjustment mode	R/W	No	UINT16	-	UINT16	0
	0Fh	First gain stiffness	R/W	No	UINT16	-	0 to 31	13

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	10h	Second gain adjustment mode	R/W	No	UINT16	-	UINT16	0
	11h	Second gain stiffness	R/W	No	UINT16	-	0 to 31	13
	12h	Homing gain switch enable	R/W	No	UINT16		0 to 1	0
	13h	Position loop bandwidth 3	R/W	No	UINT16	0.1Hz	1 to 2000	200
	14h	Speed loop bandwidth 3	R/W	No	UINT16	0.1Hz	1 to 5000	1000
	15h	Speed loop integral constant 3	R/W	No	UINT16	0.1Hz	1 to 500	100
2007h	**Filter Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	5
	01h	Position filter bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	2000
	02h	Speed filter1 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000
	03h	Reserved	-	-	-	-	-	-
	04h	Reserved	-	-	-	-	-	-
	05h	Speed filter2 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000
2008h	**Notch Filter Parameters**							
	00h	Max sub-index	RO	No	UINT8	-	-	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
	0Ah	Notch3_a1	R/W	No	UINT16	LSB	UINT16	0
	0Bh	Notch3_a2	R/W	No	UINT16	LSB	UINT16	0
	0Ch	Notch3_b1	R/W	No	UINT16	LSB	UINT16	0
	0Dh	Notch3_b2	R/W	No	UINT16	LSB	UINT16	0
	0Eh	Notch4_a1	R/W	No	UINT16	LSB	UINT16	0
	0Fh	Notch4_a2	R/W	No	UINT16	LSB	UINT16	0
	10h	Notch4_b1	R/W	No	UINT16	LSB	UINT16	0
	11h	Notch4_b2	R/W	No	UINT16	LSB	UINT16	0
200Bh	**Protection Parameter**							
	00h	Max sub-index	RO	No	UINT8	-	14	14
	01h	Protection enable	R/W	No	UINT8	-	-	0
	02h	OCP threshold	R/W	No	UINT16	A	UINT16	20
	03h	UVLO voltage threshold	R/W	No	UINT16	V	8 to 30	12

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	04h	Lock position threshold	R/W	No	UINT32	UserUnit	UINT32	182
	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
	0Ch	Over speed threshold	RW	No	UINT32	rpm	UINT32	3600
	0Dh	Speed error threshold	RW	No	UINT32	rpm	UINT32	1000
	0Eh	Speed error time window	RW	No	UINT16	ms	UINT16	10
200Ch	**Parameter Identification**							
200Ch	00h	Max sub-index	RO	No	UINT8	-	12	12
200Ch	01h	Identify method	RW	No	UINT8	-	0 to 1	0
200Ch	02h	Round max	R/W	No	UINT16	round	3 to 65535	50
200Ch	03h	Round acceleration	R/W	No	UINT16	round	1 to 65535	10
200Ch	04h	Round J	R/W	No	UINT16	round	1 to 65535	10
200Ch	05h	Identification status	RO	No	UINT8	-	0 to 16	0
200Ch	06h	Identified R_S	RO	No	UINT32	mΩ	-	0
200Ch	07h	Identified L_D	RO	No	UINT32	µH	-	0
200Ch	08h	Identified L_Q	RO	No	UINT32	µH	-	0
200Ch	09h	Identified K_T	RO	No	UINT32	mNm/A	-	0
200Ch	0Ah	Identified J	RO	No	UINT32	g x cm^2	-	0
200Ch	0Bh	Identified B	RO	No	UINT32	mNm x s	-	0
200Ch	0Ch	Identified T_F	RO	No	UINT32	mNm	-	0
200Dh	00h	Special command	RW	No	UINT32	-	-	0
200Eh	**Servo Internal Information**							
200Eh	00h	Max sub-index	RO	No	UINT8	-	12	12
200Eh	01h	I_D	RO	TPDO	INT16	mA	INT16	0
200Eh	02h	I_Q	RO	TPDO	INT16	mA	INT16	0
200Eh	03h	U_D	RO	TPDO	INT16	mV	INT16	0
200Eh	04h	U_Q	RO	TPDO	INT16	mV	INT16	0
200Eh	05h	Torque	RO	TPDO	INT16	mNm	INT16	0
200Eh	06h	Sensor position	RO	TPDO	UINT16	INC	UINT16	0
200Eh	07h	Filtered position	RO	TPDO	UINT16	INC	UINT16	0
200Eh	08h	Reserved	-	-	-	-	-	-
200Eh	09h	Filtered speed	RO	TPDO	INT32	INC/s	INT32	0
200Eh	0Ah	Reserved	-	-	-	-	-	-
200Eh	0Bh	Average load ratio	RO	No	UINT16	0.1%	UINT16	0

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	0Ch	Braking resistor load ratio	RO	No	UINT16	1%	UINT16	0
200Fh	00h	Encoder PPR	R/W	No	UINT32	INC/r	UINT32	16384
2030h	**I/O Function**							
	00h	Max sub-index	RO	No	UINT8		8	8
	01h	DI1 function	R/W	No	UINT8	-	0 to 4	0
	02h	DI2 function	R/W	No	UINT8	-	0 to 4	0
	03h	DI3 function	R/W	No	UINT8	-	0 to 4	0
	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
	05h	DO1 function	R/W	No	UINT8	-	0 to 1	0
	06h	DO2 function	R/W	No	UINT8	-	0 to 1	0
	07h	Reserved	-	-	-	-	-	-
	08h	Reserved	-	-	-	-	-	-
2031h	**I/O Control**							
	00h	Max sub-index	RO	No	UINT8	-	-	0
	01h	IO polarity	R/W	No	UINT16	-	-	0
	02h	IO simulation enable	R/W	No	UINT16	-	-	0
	03h	IO simulation value	R/W	No	UINT16	-	-	-
2040h	00h	Temperature	RO	TPDO	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 protection 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 Sense Divider**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Voltage lower divider	R/W	No	UINT16	kΩ	1 to 65535	10
	02h	Voltage upper divider	R/W	No	UINT16	kΩ	1 to 65535	402
2070h	**Homing Torque Settings**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
	02h	Homing stall time	R/W	No	UINT16	ms	UINT16	500
	03h	Homing time out	R/W	No	UINT16	s	UINT16	500
2080h	**Impedance Control Mode Parameters**							
	01h	Kp	R/W	RPDO	REAL32	-	-	0
	02h	Ki	R/W	RPDO	REAL32	-	-	0
	03h	Kd	R/W	RPDO	REAL32	-	-	0
	04h	Filter cutoff frequency	R/W	RPDO	REAL32	-	-	0
	05h	Joint torque limit	R/W	RPDO	REAL32	-	-	0

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	06h	Motor current limit	R/W	RPDO	REAL32	-	-	0
2105h	00h	MLink slave address	R/W	No	UINT8	-	UINT8	1
2106h	00h	MLink baudrate	R/W	No	UINT32	bps	UINT32	2500000
2107h	00h	MLink parity check method	R/W	No	UINT8	bps	UINT8	2
2109h	00h	Explicit ID	R/W	No	UINT16	-	UINT16	5
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

8.3 6000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
603Fh	00h	Error code	RO	TPDO	UINT16	-	UINT16	0
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
605Ah	00h	Quick stop option	R/W	No	INT16	-	0 to 8	2
605Bh	00h	Shutdown option	R/W	No	INT16	-	0 to 1	2
605Ch	00h	Disable operation option	R/W	No	INT16	-	0 to 1	2
605Dh	00h	Halt option	R/W	No	INT16	-	0 to 4	1
605Eh	00h	Fault reaction option	R/W	No	INT16	-	0 to 4	1
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-4 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-4 to +10	-
6062h	00h	Position demand value	RO	TPDO	INT32	UserUnit	INT32	-
6063h	00h	Position actual internal value	RO	TPDO	INT32	INC	INT32	-
6064h	00h	Position actual value	RO	TPDO	INT32	UserUnit	INT32	-
6065h	00h	Following error window	R/W	RPDO	UINT32	UserUnit	UINT32	182
6066h	00h	Following error time out	R/W	RPDO	UINT32	ms	UINT32	10
6067h	00h	Position window	R/W	RPDO	UINT32	UserUnit	UINT32	182
6068h	00h	Position window time	R/W	RPDO	UINT16	ms	UINT16	10
606Bh	00h	Velocity demand value	RO	TPDO	INT32	UserUnit/s	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit/s	INT32	-
606Dh	00h	Velocity window	R/W	RPDO	UINT16	UserUnit/s	UINT16	32768
606Eh	00h	Velocity window time	R/W	RPDO	UINT16	ms	UINT16	10
606Fh	00h	Velocity threshold	R/W	RPDO	UINT16	UserUnit/s	UINT16	32768
6070h	00h	Velocity threshold time	R/W	RPDO	UINT16	ms	UINT16	10
6071h	00h	Target torque	R/W	RPDO	INT16	‰	-3000 to +3000	0
6072h	00h	Max torque	R/W	RPDO	UINT16	‰	0 to 3000	3000
6073h	00h	Max current	R/W	RPDO	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	RPDO	INT32	UserUnit	INT32	0
607Bh	**Position Range Limit**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Min position range limit	R/W	RPDO	UINT32	UserUnit	INT32	-2^{31}
	02h	Max position range limit	R/W	RPDO	UINT32	UserUnit	INT32	2^{31}
607Ch	00h	Home offset	R/W	RPDO	INT32	UserUnit	INT32	0
607Dh	**Software Position Limit**							

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Min position limit	R/W	RPDO	INT32	UserUnit	INT32	-2^{31}
	02h	Max position limit	R/W	RPDO	INT32	UserUnit	INT32	$2^{31}-1$
607Eh	00h	Polarity	R/W	No	UINT8	-	0 to 1	0
607Fh	00h	Max profile velocity	R/W	RPDO	UINT32	UserUnit/s	UINT32	3276800
6080h	00h	Max motor speed	R/W	RPDO	UINT32	rpm	UINT32	3000
6081h	00h	Profile velocity	R/W	RPDO	UINT32	UserUnit/s	UINT32	655360
6083h	00h	Profile acceleration	R/W	RPDO	UINT32	UserUnit/s^2	UINT32	3276800
6084h	00h	Profile deceleration	R/W	RPDO	UINT32	UserUnit/s^2	UINT32	3276800
6085h	00h	Quick stop deceleration	R/W	RPDO	UINT32	UserUnit/s	UINT32	3276800
6086h	00h	Motion profile type	R/W	RPDO	INT16	-	0	0
6087h	00h	Torque slope	R/W	RPDO	UINT32	‰/s	UINT32	3000
608Fh	**Position Encoder Resolution**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Encoder increments	R/W	No	UINT32	INC	UINT32	65536
	02h	Motor revolutions	R/W	No	UINT32	REV	UINT32	1
6090h	**Velocity Encoder Resolution**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Encoder increments per second	R/W	No	UINT32	INC/s	UINT32	65536
	02h	Motor revolutions per second	R/W	No	UINT32	REV/s	UINT32	1
6091h	**Gear Ratio**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Motor shaft revolutions	R/W	No	UINT32	REV	UINT32	1
	02h	Drive shaft revolutions	R/W	No	UINT32	REV	UINT32	1
6092h	**Feed Constant**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Feed	R/W	No	UINT32	UserUnit	UINT32	65536
	02h	Drive shaft revolutions	R/W	No	UINT32	REV	UINT32	1
6098h	00h	Homing method	R/W	No	INT8	-	0 to 35	0
6099h	**Homing Speed**							
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Homing speed switch	R/W	RPDO	UINT32	UserUnit/s	UINT32	655360
	02h	Homing speed zero	R/W	RPDO	UINT32	UserUnit/s	UINT32	65536
609Ah	00h	Homing acceleration	R/W	RPDO	UINT32	UserUnit/s^2	UINT32	0
60B0h	00h	Position offset	R/W	RPDO	INT32	UserUnit	INT32	0
60B1h	00h	Velocity offset	R/W	RPDO	INT32	UserUnit/s	INT32	0
60B2h	00h	Torque offset	R/W	RPDO	INT16	‰	INT16	0
60B8h	00h	Touch probe function	R/W	RPDO	UINT16	-	UINT16	0
60B9h	00h	Touch probe status	RO	TPDO	UINT16	-	UINT16	0

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60BAh	00h	Touch probe 1 rising edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BBh	00h	Touch probe 1 falling edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BCh	00h	Touch probe 2 rising edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60BDh	00h	Touch probe 2 falling edge position value	RO	TPDO	INT32	UserUnit	INT32	0
60C2h		**Interpolation Cycle Time**						
	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	RPDO	UINT32	UserUnit/s 2	UINT32	2^{32}-1
60C6h	00h	Max deceleration	R/W	RPDO	UINT32	UserUnit/s 2	UINT32	2^{32}-1
60E0h	00h	Positive torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000
60E1h	00h	Negative torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000
60F2h	00h	Positioning option code	R/W	RPDO	UINT16	-	-	0
60F4h	00h	Following error actual value	RO	TPDO	INT32	UserUnit	INT32	-
60FCh	00h	Position demand internal value	RO	TPDO	INT32	UserUnit	INT32	0
60FDh	00h	Digital inputs	RO	TPDO	UINT32	-	UINT32	-
60FEh		**Digital Outputs**						
	00h	Max sub-index	RO	No	UINT8	-	2	2
	01h	Physical outputs	R/W	TPDO	UINT32	-	UINT32	-
	02h	Bit mask	R/W	TPDO	UINT32	-	UINT32	-
60FFh	00h	Target velocity	R/W	RPDO	INT32	UserUnit/s	INT32	0
6502h	00h	Supported drive modes	RO	No	UINT32	-	-	0x03ED

Section 9. Object Details

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

2001h: Motor Parameters

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

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	04h	Pole pairs	R/W	No	UINT8	-	UINT8	-
Bits		Name	Description					
7:0		Pole pairs	Sets the motor pole pairs. This parameter is vital to make the motor spin. Setting the motor pole pairs to the wrong value may 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	-
Bits		Name	Description					
31:0		Torque constant	Sets the motor torque constant, which represents the amount of motor output torque per ampere of current. The current unit is Arms (the rooted mean square current in Ampere).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	06h	Inertia	R/W	No	UINT32	g x cm^2	UINT32	-
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	-
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	-
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	-
Bits		**Name**	**Description**					
31:0		Rated speed	The motor-rated speed is in rpm.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	0Ah	Friction coefficient	R/W	No	UINT16	µNm x s	UINT16	0
Bits		**Name**	**Description**					
15:0		Friction coefficient	Sets the system friction coefficient (unit: µNm x s) for the friction compensation of the speed filter AccuFilter, which can be obtained automatically using the parameter recognition function.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2001h	0Bh	Static friction torque	R/W	No	UINT16	mNm	UINT16	0
Bits		**Name**	**Description**					
15:0		Static friction torque	Sets the system static friction torque (unit: mNm) for the friction compensation of the speed filter AccuFilter, which can be obtained automatically using the parameter recognition function.					

2002h: Driver Configuration

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

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

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

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	08h	Command type	R/W	No	UINT8	-	-	0
Bits		**Name**	**Description**					
7:0		Command type	Reserved, default bus command.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2002h	09h	Driver type	R/W	No	UINT8	-	-	0
Bits		**Name**	**Description**					
7:0		Driver type	Reserved, default GLx and GHx signaling drivers.					

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.					

2003h: Position Sensor Configuration

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	01h	Sensor bias	R/W	No	UINT32	INC	0 to 65535	0
Bits		**Name**	**Description**					
31:0		Sensor bias	Sets the theta bias between the rotor electrical angle and the angle sensed via the angular sensor. The sensor bias and sensor direction are vital parameters to make the motor spin, and the rotor alignment procedure determines these values automatically. Does not have to be set manually. See Section 4.3 on page 45 for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	02h	Sensor direction	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:1		Reserved	Not used.					
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	Not used.					
0		INL enable	0: Disable INL calibration. 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	0
Bits		**Name**	**Description**					
7:2		Reserved	Not used.					
1:0		Speed feedback source	0: Use the speed after the low-pass filter (speed filter 1) as the feedback source 1: Use the speed after the AccuFilter (speed filter 2) as the feedback source Others: Reserved					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2003h	07h	Position feedback source	R/W	No	UINT8	-	0 to 2	0
Bits		**Name**	**Description**					
7:2		Reserved	Not used.					
1:0		Position feedback source	0: Use the absolute encoder bits data as the feedback source 1: Reserved. Do not use this setting 2: Use the virtual position signal 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	Not used.					
2		Speed feed-forward enable	If set, the speed feed-forward function is enabled.					
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 time constant	R/W	No	UINT16	0.1ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Decoupling 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	In position or speed control mode, the torque feed-forward signal is multiplied by this gain factor to add to the torque command. Increasing this parameter reduces the speed-following error during dynamic response. See Section 5.2.3 on page 70 for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	05h	Torque feed-forward time constant	R/W	No	UINT16	0.1ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Torque feed-forward 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	In position control mode, the velocity feed-forward signal is multiplied by this gain coefficient and added to the velocity command. Increasing this parameter reduces the position tracking error during dynamic response. See Section 5.2.3 on page 70 for more details.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2004h	07h	Speed feed-forward time constant	R/W	No	UINT16	0.1ms	UINT16	0
Bits		**Name**	**Description**					
15:0		Speed feed-forward time constant	Determines the rising time constant of the torque feed-forward value to avoid speed reference step.					

2005h: Loop Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	01h	Position loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
Bits		**Name**	**Description**					
15:0		Position loop bandwidth	Sets the position loop bandwidth (in Hz). This is the outermost loop for three-loop control. A reasonable range is between 10Hz and 100Hz; this value should be 3 times smaller than the speed loop bandwidth (2005h-03h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	02h	Second position loop Bandwidth	R/W	No	UINT16	0.1Hz	1 to 2000	200
Bits		**Name**	**Description**					
15:0		Second position loop Bandwidth	Sets the second gain of the position loop. See Section 5.2.1 on page 65 for more details on gain switching.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	03h	Speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
Bits		**Name**	**Description**					
15:0		Speed loop bandwidth	Sets the speed loop bandwidth (in Hz). A reasonable range is 50Hz to 400Hz. This value should be 5 to 10 times larger than the position loop bandwidth (2005h-01h), and 3 times smaller than the torque loop bandwidth (2005h-05h).					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	04h	Speed loop integral constant	R/W	No	UINT16	0.1Hz	1 to 500	100
Bits		**Name**	**Description**					
15:0		Speed loop integral constant	Sets the speed loop integral constant. A reasonable range is 2Hz to 20Hz. A larger values results in a faster response, but creates a larger overshoot during speed transitions.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	05h	Torque loop bandwidth	R/W	No	UINT16	0.1Hz	2000 - 20000	10000
Bits		**Name**	**Description**					
15:0		Torque loop bandwidth	Set the torque loop bandwidth to a reasonable range between 1kHz and 2kHz. This value should be 5 to 10 times larger than the speed loop bandwidth (2005h-03h). The larger the setting value, the faster the torque response, but setting this value too high can cause loop oscillation.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	06h	Position loop output limit	R/W	No	UINT32	rpm	UINT32	3000
Bits		**Name**	**Description**					
31:0		Position loop output limit	Limits the output of the position loop to limit the motor speed and prevent damage or loop saturation.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	07h	Speed loop output limit	R/W	No	UINT16	%	UINT16	15
Bits		**Name**	**Description**					
15:0		Speed loop output limit	Limits the output of the speed controller, 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 for the motor to operate in torque mode to prevent the motor from rotating too fast.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	09h	Gain switching type	R/W	No	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:0		Gain switching type	0: No switching 1: When the position following error is below the gain switching threshold, switch to the second gain Others: Reserved					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Ah	Gain switching following error threshold	R/W	No	UINT32	UserUnit	UINT32	0
Bits		**Name**	**Description**					
31:0		Gain switching following error threshold	In position mode, the position loop and speed loop switch to the second gain when the following error of position is below this set value.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Bh	Gain switching transition	R/W	No	UINT16	ms	UINT16	1
Bits		**Name**	**Description**					
15:0		Gain switching transition	Sets the time required to transition from the first gain parameter to the second gain parameter after the gain switching condition is satisfied. Increasing this parameter reduces the shock caused by the gain parameter change.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Ch	Second speed loop bandwidth	R/W	No	UINT16	0.1Hz	1 to 5000	2000
Bits		**Name**	**Description**					
15:0		Second speed loop bandwidth	Sets the second set of speed loop bandwidth parameters. See Section 5.2.2 on page 69 for more details on gain switching.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Dh	Second speed loop integral constant	R/W	No	UINT16	0.1Hz	1 to 500	100
Bits		**Name**	**Description**					
15:0		Second speed loop integral constant	Sets the second set of speed loop integral parameters. See Section 5.2.2 on page 69 for more details on gain switching.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Eh	First gain adjustment mode	R/W	No	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:0		First gain adjustment mode	0: Manual adjustment of loop parameters 1: Adjust the loop parameters according to the stiffness class Other: Reserved					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	0Fh	First gain stiffness	R/W	No	UINT16	-	0 to 31	13
Bits		**Name**	**Description**					
15:0		First gain stiffness	Sets the stiffness level of the servo system. The higher the stiffness level, the larger the bandwidth of the position loop and speed loop, and the faster the system response. If the stiffness level is too high, this can result in oscillation.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	10h	Second gain adjustment mode	R/W	No	UINT16	-	UINT16	0

Bits	Name	Description
15:0	Second gain adjustment mode	0: Manual adjustment of loop parameters 1: Adjust the loop parameters according to the stiffness class Other: Reserved

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	11h	Second gain stiffness	R/W	No	UINT16	-	0 to 31	13

Bits	Name	Description
15:0	Second gain stiffness	Sets the servo system's stiffness level. The higher the stiffness level, the larger the bandwidth of the position loop and speed loop, and the faster the system response. If the stiffness level is too high, this can result in oscillation.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	12h	Homing gain switch enable	R/W	No	UINT16	-	0 to 1	0

Bits	Name	Description
15:0	Homing gain switch enable	0: No switching 1: When "Modes of operation" (object 6060h) is set to homing, switch to the third gain parameters Others: Reserved

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	13h	Position loop bandwidth 3	R/W	No	UINT16	-	0 to 1	0

Bits	Name	Description
15:0	Position loop bandwidth 3	Sets the third gain of the position loop. See Section 5.2.1 on page 65 for more details on gain switching.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	14h	Speed loop bandwidth 3	R/W	No	UINT16	-	0 to 1	0

Bits	Name	Description
15:0	Speed loop bandwidth 3	Sets the third set of speed loop bandwidth parameters. See Section 5.2.2 on page x for more details on gain switching.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2005h	15h	Speed loop integral constant 3	R/W	No	UINT16	-	0 to 1	0
Bits		**Name**	**Description**					
15:0		Speed loop integral constant 3	Sets the third gain of speed loop integral parameters. See Section 5.2.2 on page 69 for more details on gain switching.					

2007h: Filter Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	01h	Position filter bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	2000
Bits		**Name**	**Description**					
15:0		Position filter bandwidth	To minimize the phase delay caused by the filter, set this value to be 10 times larger than the position loop bandwidth.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2007h	02h	Speed filter1 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000
Bits		**Name**	**Description**					
15:0		Speed filter1 bandwidth	Setting this parameter adjusts the bandwidth of the low-pass filter when low-pass filter is selected for the speed feedback source (2003h-06h is set to 0). 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 filter2 bandwidth	R/W	No	UINT16	0.1Hz	1000 to 20000	10000
Bits		**Name**	**Description**					
15:0		Speed filter2 bandwidth	Setting this parameter adjusts the bandwidth of the AccuFilter when AccuFilter is selected for the speed feedback source (2003h-06h is set to 1). 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**					
15:4		Reserved	Not used.					
3		Notch4 enable	Enables notch filter 4.					
2		Notch3 enable	Enables notch filter 3.					
1		Notch2 enable	Enables notch filter 2.					
0		Notch1 enable	Enables notch filter 1.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	02h	Notch1_a1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch1_a1	Sets the *a1* parameter for notch filter 1. See Section 5.3.2 on page 76 for the formula to calculate the notch filter parameters.					

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 the *a2* parameter for notch filter 1.					

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

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 the *b2* parameter for notch filter 1.					

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 the *a1* parameter for notch filter 2.					

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 the *a2* parameter for notch filter 2.					

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 the *b1* parameter for notch filter 2.					

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 the *b2* parameter for notch filter 2.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Ah	Notch3_a1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch3_a1	Sets the *a1* parameter for notch filter 3.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Bh	Notch3_a2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch3_a2	Sets the *a2* parameter for notch filter 3.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Ch	Notch3_b1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch3_b1	Sets the *b1* parameter for notch filter 3.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Dh	Notch3_b2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch3_b2	Sets the *b2* parameter for notch filter 3.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Eh	Notch4_a1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch4_a1	Sets the *a1* parameter for notch filter 4.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	0Fh	Notch4_a2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch4_a2	Sets the *a2* parameter for notch filter 4.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	10h	Notch4_b1	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch4_b1	Sets the *b1* parameter for notch filter 4.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2008h	11h	Notch4_b2	R/W	No	UINT16	LSB	UINT16	0
Bits		**Name**	**Description**					
15:0		Notch4_b2	Sets the *b2* parameter for notch filter 4.					

200Bh: Protection Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	01h	Protection enable	R/W	No	UINT8	-	UINT8	0
Bits		**Name**	**Description**					
7:5		Reserved	Not used.					
4		OTP_EN	0: Disable over-temperature protection (OTP) 1: Enable OTP					
3		VIN_LIMIT_EN	0: Disable the DC link voltage limit 1: Enable the DC link voltage limit					
2		LOCK_EN	0: Disable locked-rotor protection 1: Enable locked-rotor protection					
1		UVLO_EN	0: Disable under-voltage lockout (UVLO) 1: Enable UVLO					
0		OCP_EN	0: Disable over-current protection (OCP) 1: Enable OCP					

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	04h	Lock position threshold	R/W	No	UINT32	UserUnit	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 locked-rotor 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	If the motor does not reach the target position or target speed, and the motor displacement is less than the blocking protection position threshold and the output current exceeds the rated current within this set time, blocking protection is triggered.					

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	Not used.					
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 the protection retry function 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 bus voltage exceeds this set value by more than 1V, over-voltage protection is triggered and the motor stops running. When the DC voltage clamp bits function is enabled, and the DC bus voltage reaches this setting value, the discharge load ratio reaches 100%.					

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Bh	Error status	RO	TPDO	UINT16	-	-	0
Bits		**Name**	**Description**					
15:13		Reserved	Not used.					
12		ECAT_WATCHDOG_ERR	0: EtherCAT communication error protection has not been triggered 1: EtherCAT communication error protection has been triggered					
11		SPEED_ERROR_LMT	0: Excessive speed error protection has not been triggered 1: Excessive speed error speed error protection has been triggered					
10		OVER_SPEED	0: No overspeed protection has been triggered 1: Over-speed protection has been triggered					
9		OVP	0: Over-voltage protection (OVP) has not been triggered 1: OVP has been triggered					
8		OTP	0: Over-temperature protection (OTP) has not been triggered 1: OTP has been triggered					
7		MEM_ERR	0: Internal memory working normally 1: Internal memory working abnormally					
6		SENSOR_ERR	0: The position sensor is working normally 1: The position sensor is not working normally					
5		POS_LIMIT	0: The position is in the allowed range 1: The position is out of range					
4		OVERLOAD	0: Overload protection has not been triggered 1: Overload protection has been triggered					
3		VIN_LIMIT	0: VIN_LIMIT protection has not been triggered 1: VIN_LIMIT protection has been triggered					
2		LOCK	0: Lock protection has not been triggered 1: Lock protection has been triggered					
1		UVLO	0: Under-voltage lockout (UVLO) protection has not been triggered 1: UVLO protection has been triggered					
0		OCP	0: Over-current protection (OCP) has not been triggered 1: OCP has been triggered					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Ch	Overspeed threshold	R/W	No	UINT32	rpm	UINT32	3600
Bits		**Name**	**Description**					
31:0		Overspeed threshold	If the motor speed exceeds this value, overspeed protection is triggered.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Dh	Speed error threshold	R/W	No	UINT32	rpm	UINT32	1000
Bits		**Name**	**Description**					
31:0		Speed error threshold	If the difference between the commanded speed and the actual speed inside the motor (speed error) exceeds this value and continues to exceed the speed error time window (200Bh-0Eh via the object dictionary), the speed error protection is triggered.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Bh	0Eh	Speed error time window	R/W	No	UINT16	ms	UINT16	10
Bits		**Name**	**Description**					
15:0		Speed error time window	See the object dictionary 200Bh-0Dh section above for more details.					

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	Not used.					
0		Identify method	Sets the method for auto-tuning. 0: Range unlimited method 1: Range-limited method					

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

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Ch	05h	Identification status	RO	No	UINT8	-	-	0
Bits		**Name**	**Description**					
7:0		Identification status	Indicates the current identification status. 0: Idle 1: Preparation 2: Identifying phase resistor 3: Ready for identify inductor 4: Identifying d-axis inductor 5: Identifying q-axis inductor 6: Find theta bias 7: Identifying torque constant (range unlimited) 8: Identifying inertia (range unlimited) 9: Identifying inertia the second time (range unlimited) 10: Identify torque constant (range limited) 11: Identifying inertia (range unlimited) 12: Identify complete 13: Homing 14: Identify acceleration design 15: Identify error handling 16: Identify error 17: Waiting 18: JOG homing					

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

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

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

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

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

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

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

200Dh: Special Command

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Dh	00h	Special command	R/W	No	UINT32	-	UINT32	0
Bits		**Name**	**Description**					
15:0		Special command	Send the function code to this object. See Section 4.5 on page 54 for more details.					

200Eh: Servo Internal Information

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

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

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	05h	Estimated torque	RO	TPDO	INT16	mNm	INT16	0
Bits		**Name**	**Description**					
15:0		Estimated 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 can be calculated with the following Equation: 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	Shows the filtered angle sensor data, which is also used as the feedback for position loop control.					

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.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	0Bh	Average load ratio	RO	No	UINT16	0.1%	UINT16	0
Bits		**Name**	**Description**					
15:0		Average load ratio	Shows the motor's average load ratio during operation.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
200Eh	0Ch	Braking resistor load ratio	RO	No	UINT16	1%	UINT16	0
Bits		**Name**	**Description**					
15:0		Braking resistor load ratio	Indicates the load ratio of the internal braking resistor when the motor is in the status of regen brake.					

2030h: I/O Functions

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	01h	DI1 function	R/W	No	UINT8	-	0 to 4	0
Bits		**Name**	**Description**					
7:0		DI1 function	Selects the function for DI1. 0: Not used 1: Negative limit switch 2: Positive limit switch 3: Home switch 4: Touch probe 1					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	02h	DI2 function	R/W	No	UINT8	-	0 to 4	0
Bits		**Name**	**Description**					
7:0		DI2 function	Selects the function for DI2. 0: Not used 1: Negative limit switch 2: Positive limit switch 3: Home switch 4: Touch probe 2					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	03h	DI3 function	R/W	No	UINT8	-	0 to 4	0
Bits		**Name**	**Description**					
7:0		DI3 function	Selects the function for DI3. 0: Not used 1: Negative limit switch 2: Positive limit switch 3: Home switch 4: Alarm reset					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	04h	DI4 function	R/W	No	UINT8	-	0 to 3	0
Bits		**Name**	**Description**					
7:0		DI4 function	Selects the DI4 function. Only models with DI4 are supported. 0: Not used 1: Negative limit switch 2: Positive limit switch 3: Home switch					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	05h	DO1 function	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:0		DO1 function	Selects the DO1 function. 0: Target reached 1: Alarm					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2030h	06h	DO2 function	R/W	No	UINT8	-	0 to 1	0
Bits		**Name**	**Description**					
7:0		DO2 function	Selects the DO2 function. 0: Target reached 1: Alarm					

2031h: I/O Control

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2031h	01h	IO polarity	R/W	No	UINT16	-	-	0
Bits		**Name**	**Description**					
15:10		Reserved	Not used.					
9		DO2 Polarity	0: Normally closed 1: Normally open					
8		DO1 Polarity	0: Normally closed 1: Normally open					
4:7		Reserved	Not used.					
3		DI4 Polarity	0: Normally closed 1: Normally open					
2		DI3 Polarity	0: Normally closed 1: Normally open					
1		DI2 Polarity	0: Normally closed 1: Normally open					
0		DI1 Polarity	0: Normally closed 1: Normally open					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2031h	02h	IO simulation enable	R/W	No	UINT16	-	-	0
Bits		**Name**	**Description**					
15:10		Reserved	Not used.					
9		DO2 Simulation Enable	0: Disable the DO2 simulation function 1: Enable the DO2 simulation function					
8		DO1 Simulation Enable	0: Disable the DO1 simulation function 1: Enable the DO1 simulation function					
4:7		Reserved	Not used.					
3		DI4 Simulation Enable	0: Disable the DI4 simulation function 1: Enable the DI4 simulation function					
2		DI3 Simulation Enable	0: Disable the DI3 simulation function 1: Enable the DI3 simulation function					
1		DI2 Simulation Enable	0: Disable the DI42 simulation function 1: Enable the DI2 simulation function					
0		DI1 Simulation Enable	0: Disable the DI1 simulation function 1: Enable the DI1 simulation function					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2031h	03h	IO simulation value	R/W	No	UINT16	-	-	0
Bits		**Name**	**Description**					
15:10		Reserved	Not used.					
9		DO2 Simulation Value	When DO2 emulation is enabled, the DO2 output value is equal to this emulation value.					
8		DO1 Simulation Value	When DO1 emulation is enabled, the DO1 output value is equal to the emulated value.					
4:7		Reserved	Not used.					
3		DI4 Simulation Value	When DI4 emulation is enabled, the DI4 input value is equal to this emulation value.					
2		DI3 Simulation Value	When DI3 emulation is enabled, the DI3 input value is equal to the emulation value.					
1		DI2 Simulation Value	When DI2 emulation is enabled, the DI2 input value is equal to the emulation value.					
0		DI1 Simulation Value	When DI1 emulation is enabled, the DI1 input value is equal to the emulation value.					

2040h: Temperature

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2040h	00h	Temperature	RO	TPDO	INT16	°C	-71 to+400	-
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/protection point.

2042h: Overload Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	01h	Overload protection enable	R/W	No	UINT8	-	-	0

Bits	Name	Description
15:1	Reserved	Not used.
0	OVERLOAD_EN	0: Disable overload protection 1: Enable overload protection

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	02h	Overload current threshold	R/W	No	UINT16	‰	0 to 3000	3000

Bits	Name	Description
15:0	Overload current threshold	Sets the overload protection current threshold, which is given in thousandths of the motor rated current.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2042h	03h	Overload time window	R/W	No	UINT16	ms	UINT16	1000

Bits	Name	Description
15:0	Overload time window	Overload protection is triggered if the controller detects that the motor current exceeds the overload current threshold for longer than the overload time window. Setting the time window to longer than 1 second allows the motor current to exceed the overload current threshold for a short period of 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	Voltage lower divider	R/W	No	UINT16	kΩ	1 to 65535	10

Bits	Name	Description
15:0	Voltage 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	Voltage upper divider	R/W	No	UINT16	kΩ	1 to 65535	402
Bits		**Name**	**Description**					
15:0		Voltage upper divider	Sets the voltage divider used for the DC-link voltage-sense upper resistor.					

2070h: Homing Torque Settings

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2070h	01h	Homing torque	R/W	No	UIN16	‰	UINT16	500
Bits		**Name**	**Description**					
15:0		Homing torque	Sets the maximum motor output torque limit during torque limited homing method (object 6098h-00h equals -3 or -2). The homing torque should be set 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 stall time	R/W	No	UINT16	ms	UINT16	500
Bits		**Name**	**Description**					
15:0		Homing stall time	If the motor stalls for a period of time (the homing stall 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	Homing time out	R/W	No	UINT16	s	UINT16	100
Bits		**Name**	**Description**					
15:0		Homing time out	If the homing total time exceeds this setting, a homing error is triggered and “Status word” (6041h), bit[13] is set.					

2080h: Impedance Controller Parameters

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

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	03h	Kd	R/W	RPDO	REAL32	-	-	0

Bits	Name	Description
31:0	Kd	Sets the differential gain for the impedance controller.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	04h	Filter cutoff frequency	R/W	No	REAL32	Hz	-	1000

Bits	Name	Description
31:0	Filter cutoff frequency	Sets the filter cutoff frequency of the low-pass filter in the impedance controller. Choose an appropriate filter bandwidth according to the test results. A higher filter bandwidth introduces more speed feedback noise.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	05h	Joint torque limit	R/W	No	REAL32	Nm	-	0

Bits	Name	Description
31:0	Joint torque limit	Sets the output torque limit of the impedance controller. This prevents the motor from outputting too much torque, which may damage the mechanical parts or the environment.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2080h	06h	Motor current limit	R/W	RPDO	REAL32	A	-	0

Bits	Name	Description
31:0	Motor current limit	Sets the current limit of the impedance controller. This prevents the motor from outputting excessive torque that could damage mechanical parts or the environment.

2105h: MLink Slave Address

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2105h	00h	MLink slave address	R/W	No	UINT8	-	UINT8	1

Bits	Name	Description
7:0	MLink slave address	Sets the MLink communication address for the current device.

2106h: MLink Bitrate

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2106h	00h	MLink baudrate	R/W	No	UINT32	bps	UINT32	2500000

Bits	Name	Description
31:0	MLink baudrate	Sets the MLink communication baud rate for the current device.

2107h: MLink Parity Check

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2107h	00h	MLink parity check	R/W	No	UINT8	bps	UINT8	2

Bits	Name	Description
7:0	MLink parity check	Sets the parity of the data frame. 0: No parity 1: Odd parity 2: Even parity

2109h: Explicit ID

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2109h	00h	Explicit ID	R/W	No	UINT16	-	UINT16	5

Bits	Name	Description
15:0	Explicit ID	The “Explicit ID” (object 2109h) can be used optionally for unique addressing .The users can change the address of the SubDevice by modifying the device identification value. When users set the “Explicit ID”, the value should be set uniquely within a network configuration. And the value = 0 is invalid, the length of the value should be 2 bytes.

603Fh: Error Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
603Fh	00h	Error code	RO	TPDO	UINT16	-	UINT16	0

Bits	Name	Description
15:0	Error code	Indicates the fault and error type. See Section 7.1 on page 103 to find more details about the relationship between the error code and error type

6040h: Control Word

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

Bits	Name	Description
15:11	Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on Section 6 starting on page 80.
10	Reserved	Not used.
9	Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on Section 6 starting on page 80.
8	Halt	Enable halt.
7	Fault reset	Change from 0 to 1 to reset the internal fault status.
6:4	Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on Section 6 starting on page 80.
3	Enable operation	Enter operation mode.
2	Quick stop	Enter quick stop mode.
1	Enable voltage	No effect, the DC power is always enabled.
0	Switch on	Enable the power stage switch.

6041h: Status Word

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

Bits	Name	Description
15:14	Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on Section on Section 6 starting on page 80.
13:12	Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on Section on Section 6 starting on page 80.
11	Internal limit active	If position limit is reached, this bit is set.
10	Operation mode specific	For more details, see the Use of “Control World” and “Status Word” sections on Section 6 starting on page 80.
9	Remote	If set, parameters may be modified by communication.
8	Manufacture specific	For more details, see the Use of “Control World” and “Status Word” sections on Section 6 starting on page 80.
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 being performed (or is unable to perform)
4	Voltage enabled	Always set to 1. A high voltage is applied to the drive.
3	Fault	If a fault occurs, this bit is set.
2	Operation enabled	Indicates if operation enabled mode is active.
1	Switch on	Indicates if the driver switch is on.
0	Ready to switch on	Indicates that the driver’s power switch is ready to be switched on.

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	-	0 to 8	2

Bits	Name	Description
15:0	Quick stop option code	Sets the action when the quick stop function is executed. 0: Shut down the drive, free stop, and keep free running 1: Deceleration to zero speed at profile deceleration (6084h), and then disable the drive 2: Deceleration to zero speed at quick stop deceleration speed (6085h), and then disable the drive 3: Deceleration to zero speed with current limitation, and then disable the drive 4: Deceleration to zero speed by DC bus voltage limitation, and then disable the drive 5: Deceleration by profile deceleration (6084h), maintain position lock status 6: Deceleration at quick stop deceleration (6085h), maintain position lock status 7: Deceleration with current limitation, position locking status 8: Deceleration with DC bus voltage limitation, hold position lock status

605Bh: Shutdown Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Bh	00h	Shutdown option code	R/W	No	INT16	-	0 to 1	0

Bits	Name	Description
15:0	Shutdown option code	Sets the action from Operation enable to Ready to switch on when the Shutdown command is received: 0: Shut down the driver 1: Decelerate and stop at the profile deceleration (6084h) to shut down the driver

605Ch: Disable Operation Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Ch	00h	Disable operation option code	R/W	No	INT16	-	0 to 1	0

Bits	Name	Description
15:0	Disable operation option code	Sets the action from operation enable to switched on when the disable operation command is received. 0: Shut down the drive 1: Decelerate and stop at the profile deceleration (6084h) to shut down the drive

605Dh: Halt Option

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Dh	00h	Halt option	R/W	No	INT16	-	0 to 4	1

Bits	Name	Description
15:0	Halt option	Sets the action when the pause function is executed. 0: Stops freely and stay in halt 1: Decelerate at contour deceleration and stay in halt 2: Deceleration at fast stop deceleration and stay in halt 3: Deceleration with current limit and stay in halt 4: Deceleration with DC bus voltage limitation and stay in halt

605Eh: Fault Reaction Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
605Eh	00h	Fault reaction option code	R/W	No	INT16	-	0-4	0

Bits	Name	Description
15:0	Fault reaction option code	Sets the action when the quick stop function is executed. 0: Shut down the drive, free stop, and keep free running. 1: Deceleration to zero speed at profile deceleration (6084h), and then disable the drive 2: Deceleration to zero speed at quick stop deceleration speed (6085h), and then disable the drive 3: Deceleration to zero speed with current limitation, and then disable the drive 4: Deceleration to zero speed by DC bus voltage limitation, and then disable the drive

6060h: Modes of Operation

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	0 to +10	0

Bits	Name	Description
7:0	Modes of operation	Selects the operation mode. -128 to -1: Manufacture test mode 0: No mode 1: Profile position mode (PP) 3: Profile velocity mode (PV) 4: Profile torque mode (PT) 6: Homing mode (HOME) 7: Interpolation mode (IP) 8: Cyclic synchronous position mode (CSP) 9: Cyclic synchronous velocity mode (CSV) 10: Cyclic synchronous torque mode (CST) 2 ,5 ,11 to17: Reserved

6061h: Modes of Operation Display

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	0 to +10	-

Bits	Name	Description
7:0	Modes of operation display	Selects the modes of operation. -128 to -1: Manufacture test mode 0: No mode 1: Profile position mode (PP) 3: Profile velocity mode (PV) 4: Profile torque mode (PT) 6: Homing mode (HOME) 7: Interpolation mode (IP) 8: Cyclic synchronous position mode (CSP) 9: Cyclic synchronous velocity mode (CSV) 10: Cyclic synchronous torque mode (CST) 2 ,5 ,11 to17: Reserved

6062h: Position Demand Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6062h	00h	Position demand value	RO	TPDO	INT32	UserUnit	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 (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	UserUnit	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	RPDO	UINT32	UserUnit	UINT32	182
Bits		**Name**	**Description**					
31:0		Following error window	Sets the threshold for an excessive position error. When the difference between the position command (6062h) and the actual value of the position (6064h) exceeds this set value, and the time reaches the following error excessive detection time (6066h), the system reports a position deviation excessive fault, the “Status word” (6041h), bit[13] is set to 1, and the motor continues to run.					

6066h: Following Error Timeout

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6066h	00h	Following error time out	R/W	RPDO	UINT32	UserUnit	UINT32	10
Bits		**Name**	**Description**					
15:0		Following error time out	Sets the detection time for excessive position error. When the difference between the position command (6062h) and the actual value of the position (6064h) exceeds the window for excessive following error (6065h) and the time reaches this set value, the system reports a fault of excessive position deviation, then “Status word” (6041h), bit[13] is set to 1 and the motor continues to run.					

6067h: Position Window

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6067h	00h	Position window	R/W	RPDO	UINT32	UserUnit	UINT32	182
Bits		**Name**	**Description**					
31:0		Position window	Sets the judgment threshold for position arrival. When the difference between the position command (6062h) and the actual value of the position (6064h) is below this set value and the time reaches the time of the arrival bits judgment window (6068h), then “Status word” (6041h), bit[10] is set to 1 in contour position mode.					

6068h: Position Window Time

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6068h	00h	Position window time	R/W	RPDO	UINT16	ms	UINT32	10
Bits		**Name**	**Description**					
15:0		Position window time	Sets the time of the judgment window for position arrival. When the difference between the position command (6062h) and the actual set value (6064h) is below the in-place judgment bits set window (6067h) and the time reaches this set value, then “Status word” (6041h), bit[10] is set to 1 in contour position mode.					

606Bh: Velocity Demand Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Bh	00h	Velocity demand value	RO	TPDO	INT32	UserUnit/s	INT32	-
Bits		**Name**	**Description**					
31:0		Velocity demand value	Reflects the real-time velocity command value (unit: INC/s), which is the output value of the velocity control trajectory generator.					

606Ch: Velocity Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Ch	00h	Velocity actual value	RO	TPDO	INT32	UserUnit/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	RPDO	UINT16	UserUnit/s	UINT16	65536
Bits		**Name**	**Description**					
15:0		Velocity window	Sets the velocity arrival judgment threshold. When the difference between the speed command (606Bh) and the actual value of the speed (606Ch) is below this set value and the time reaches the speed the bits judgment window time (606Eh), then “Status Word” (6041h), bit[10] is set to 1 in profile speed mode.					

606Eh: Velocity Window Time

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Eh	00h	Velocity window time	R/W	RPDO	UINT16	ms	UINT16	10
Bits		**Name**	**Description**					
15:0		Velocity window time	Sets the velocity in place judgment window time. When the difference between the speed command (606Bh) and the actual value of the speed (606Ch) is below the speed-in-place judgment speed window (606Dh) and the time reaches this setting, then “Status Word” (6041h), bit[10] is set to 1 in contour speed mode.					

606Fh: Velocity Threshold

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
606Fh	00h	Velocity threshold	R/W	RPDO	UINT16	UserUnit/s	UINT16	65536
Bits		**Name**	**Description**					
15:0		Velocity threshold	Sets the velocity threshold, which measures whether the motor is stationary. See the Velocity threshold time (6070h) section on page 155 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	RPDO	UINT16	ms	UINT16	10
Bits		**Name**	**Description**					
15:0		Velocity threshold time	Sets the window time to judge whether the motor is in the zero speed state. When the actual value of the speed (606Ch) is below the zero speed judgment speed window (606Fh) and the time reaches this setting, then “Status Word” (6041h), bit[12] is set to 1 in profile speed mode to indicate that the motor has stopped.					

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	RPDO	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
15:0		Max torque	Sets the maximum allowable torque in the motor (in thousandths of the rated torque).					

6073h: Max Current

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6073h	00h	Max current	R/W	RPDO	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
15:0		Max current	Sets the maximum allowed torque-creating current in the motor (in thousandths of the rated torque).					

6074h: Torque Demand Value

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

6077h: Torque Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6077h	00h	Torque actual value	RO	TPDO	INT16	‰	-3000 to +3000	-

Bits	Name	Description
15:0	Torque actual value	Reflects the actual value of the real-time torque feedback (in thousandths of the rated torque) and is the feedback input to the torque control loop.

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 current).

6079h: DC Link Voltage

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6078h	00h	DC link voltage	RO	TPDO	UINT32	mV	UINT32	-

Bits	Name	Description
31:0	DC link voltage	Reflects the actual DC bus voltage (in mV).

607Ah: Target Position

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Ah	00h	Target position	R/W	RPDO	INT32	UserUnit	INT32	0

Bits	Name	Description
31:0	Target position	Sets the position that the motor should move to in profile position mode. The target position is interpreted as absolute or relative, depending on the absolute/relative flag in "Control word" (6040h). In CST mode, the target position is interpreted as an absolute value.

607Bh: Position Range Limit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Bh	01h	Min position range limit	R/W	RPDO	INT32	UserUnit	INT32	-2^{31}

Bits	Name	Description
31:0	Min position range limit	Indicates the minimum position range limits and determines the lower limit of the input value. If the minimum position limit is reached or exceeded, the input value automatically wraps to the other end of the range (minimum position limit).

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Bh	02h	Max position range limit	R/W	RPDO	INT32	UserUnit	INT32	2^{31} to 1
Bits		**Name**	**Description**					
31:0		Max position range limit	Indicates the maximum position range limit and determines the upper limit of the input value. If the maximum position limit is reached or exceeded, the input value automatically wraps to the other end of the range (minimum position limit).					

607Ch: Home Offset

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Ch	00h	Home offset	R/W	RPDO	INT32	UserUnit	INT32	0
Bits		**Name**	**Description**					
31:0		Home offset	Indicates the difference between the zero position for the application and machine home position (found during homing). Once homing is complete, the zero position is offset from the home position by adding the home offset to the home position. All of the subsequent, absolute moves are taken relative to this new zero position. 					

607Dh: Software Position Limit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Dh	01h	Min position limit	R/W	RPDO	INT32	UserUnit	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	RPDO	INT32	UserUnit	INT32	2^{31} to 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	-	0 to 1	0

Bits	Name	Description
7	Position polarity	Indicates whether the demanded position value should be multiplied by 1 or -1. This flag has no influence on homing mode. This bit is used for profile position (PP) mode, cyclic synchronized position (CSP) mode, and homing mode (HM). 0: Multiply by 1 1: Multiply by -1
6	Velocity polarity	Used for PV mode CSP mode, and HM. 0: Multiply by 1 1: Multiply by -1
5:0	Reserved	Not used.

607Fh: Max Profile Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
607Fh	00h	Max profile velocity	R/W	RPDO	UINT32	UserUnit/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 velocity mode and torque mode.

6080h: Max Motor Speed

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6080h	00h	Max motor speed	R/W	RPDO	UINT32	UserUnit/s	UINT32	3000

Bits	Name	Description
31:0	Max motor speed	Limits the maximum speed loop reference for speed control mode. It takes effect in both profile velocity (PV) and cyclic synchronized velocity (CSV) mode.

6081h: Profile Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6081h	00h	Profile velocity	R/W	RPDO	UINT32	UserUnit/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	RPDO	UINT32	UserUnit/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	RPDO	UINT32	UserUnit/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	RPDO	UINT32	UserUnit/s^2	UINT32	3276800
Bits		**Name**	**Description**					
31:0		Quick stop deceleration	Set the deceleration ramp during a halt or quick stop period.					

6086h: Motion Profile Type

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6086h	00h	Motion profile type	R/W	RPDO	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	RPDO	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	RPDO	INT16	-	0	0
Bits		**Name**	**Description**					
15:0		Torque profile type	0: Linear ramp profile Others: Reserved					

608Fh: Position Encoder Revolution

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
608Fh	01h	Position encoder increments	R/W	No	UINT32	INC	UINT32	65536
Bits		**Name**	**Description**					
31:0		Position encoder increments	Sets the increment for the motor encoder corresponding to *n* rotations of the motor. Fixed, do not rewrite.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
608Fh	02h	Motor revolutions	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Motor revolutions	Sets the position encoder revolution. Fixed, do not rewrite. Position Encoder Resolution (INC/r) $= \frac{\text{Encoder Increments (608Fh-01h)}}{\text{Motor Revolutions (608Fh-02h)}}$					

6090h: Velocity Encoder Revolution

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6090h	01h	Position encoder increments per second	R/W	No	UINT32	INC/s	UINT32	65536
Bits		**Name**	**Description**					
31:0		Position encoder increments per second	Sets the increment of the motor velocity encoder corresponding to *n* rotations of the motor. Fixed, do not rewrite.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6090h	02h	Motor revolutions per second	R/W	No	UINT32	REV/s	UINT32	1
Bits		**Name**	**Description**					
31:0		Motor revolutions per second	Sets the position encoder revolution. Fixed, do not rewrite. Velocity Encoder Resolution (INC/r^2) $= \frac{\text{Encoder Increments per second (6090h-01h)}}{\text{Motor Revolutions per second (6090h-02h)}}$					

6091h: Gear Ratio

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6091h	01h	Motor shaft revolutions	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Motor shaft revolutions	Sets a user-specified proportional relationship between the load axis displacement and motor axis displacement.					

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6091h	02h	Shaft revolutions	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Shaft revolutions	Sets a user-specified proportional relationship between the load axis displacement and motor axis displacement. Gear Ratio $= \frac{\text{Motor Shaft Revolutions (6091h-01h)}}{\text{Driving Shaft Revolutions (6091h-02h)}}$					

6092h: Feed Constant

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6092h	01h	Feed	R/W	No	UINT32	UserUnit	UINT32	65536

Bits	Name	Description
31:0	Feed	Sets the position unit feed for each load axis revolution.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6092h	02h	Driving shaft revolutions	R/W	No	UINT32	REV	UINT32	1

Bits	Name	Description
31:0	Driving shaft revolutions	Sets the position unit feed for each load axis revolution. *Feed Constant* (User_Unit/r) $= \frac{\text{Feed (6092h-01h)}}{\text{Driving Shaft Revolutions (6092h-02h)}}$

6098h: Homing Method

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6098h	00h	Homing method	R/W	RPDO	INT8	-	0 - 35	1

Bits	Name	Description
7:0	Homing method	-3: Homing clockwise with limited torque -2: Homing counterclockwise with limited torque -1: Reserved 0: No homing operation required 1~35: Methods 1 to 35 (see the Section 6.3 on page 84 for more details)

6099h: Homing Speeds

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6099h	01h	Homing speed switch	R/W	RPDO	UINT32	UserUnit/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	RPDO	UINT32	UserUnit/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	RPDO	UINT32	UserUnit/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	UserUnit/s^2	INT32	0
Bits		**Name**	**Description**					
31:0		Position offset	Set the offset in cyclic synchronized position (CSP) mode. After the offset, the final target position can be calculated with the following equation: Final Target Position = Target Position (607Ah) + Position Offset (60B0h)					

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	Sets the velocity command offset in cyclic synchronized velocity (CSV) mode. After the offset, the final target velocity can be calculated with the following equation: Final Target Velocity = Target Velocity (60FFh) + Velocity Offset (60B1h)					

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	Sets the torque command offset in cyclic synchronized torque (CST) mode. After the offset, the final target torque can be calculated with the following equation: Final Target Torque = Target Torque (6071h) + Torque Offset (60B2h)					

60B8h: Touch Probe Function

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B8h	00h	Touch probe function	R/W	RPDO	UINT16	-	UINT16	0

Bits	Name	Description
15:14	Reserved	Not used.
13	Touch probe 2 falling edge enable	0: Touch probe 2 falling edge not latched 1: Touch probe 2 falling edge latch
12	Touch probe 2 rising edge enable	0: Touch probe 2 rising edge not latched 1: Touch probe 2 rising edge latch
11:10	Reserved	Not used.
9	Touch probe 2 trigger mode	0: Touch probe 2 single trigger 1: Touch probe 2 continuous trigger
8	Touch probe 2 enable	0: Touch probe 2 disabled 1: Enable touch probe 2
7:6	Reserved	Not used.
5	Touch probe 1 falling edge enable	0: No latch on falling edge of touch probe 1 1: Touch probe 1 falling edge latch
4	Touch probe 1 rising edge enable	0: Touch probe 1 rising edge not latched 1: Touch probe 1 rising edge latch
3:2	Reserved	Not used.
1	Touch probe 1 trigger mode	0: Touch probe 1 single trigger 1: Touch probe 1 continuous trigger
0	Touch probe 1 enable	0: Touch probe 1 disabled 1: Enable touch probe 1

60B9h: Touch Probe Status

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60B9h	00h	Touch probe status	RO	TPDO	UINT16	-	UINT16	0

Bits	Name	Description
15:11	Reserved	Not used.
10	Touch probe 2 falling edge latch state	0: Probe 2 falling edge latch not completed 1: Probe 2 falling edge latch completed
9	Touch probe 2 rising edge latch state	0: Probe 2 rising edge latch not completed 1: Probe 2 rising edge latch completed
8	Touch probe 2 enable	0: Probe 2 not enabled 1: Probe 2 is enabled
7: 3	Reserved	Not used.
2	Touch probe 1 falling edge latch state	0: Probe 1 falling edge latch not completed 1: Probe 1 falling edge latch completed
1	Touch probe 1 rising edge latch state	0: Probe 1 rising edge latch not completed 1: Probe 1 rising edge latch completed
0	Touch probe 1 enable	0: Probe 1 not enabled 1: Probe 1 is enabled

60BAh: Touch Probe 1 Rising Edge Position Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60BAh	00h	Touch probe 1 rising edge value	RO	TPDO	INT32	UserUnit	INT32	0
Bits		**Name**	**Description**					
31:0		Touch probe 1 rising edge value	Shows the position feedback latch value of the motor at the moment of the rising edge of probe 1's signal.					

60BBh: Touch Probe 1 Falling Edge Position Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60BBh	00h	Touch probe 1 falling edge value	RO	TPDO	INT32	UserUnit	INT32	0
Bits		**Name**	**Description**					
31:0		Touch probe 1 falling edge value	Shows the position feedback latch value of the motor at the moment of the falling edge of the probe 1's signal.					

60BCh: Touch Probe 2 Rising Edge Position Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60BAh	00h	Touch probe 2 rising edge value	RO	TPDO	INT32	UserUnit	INT32	0
Bits		**Name**	**Description**					
31:0		Touch probe 2 rising edge value	Shows the position feedback latch value of the motor at the moment of the rising edge of probe 2's signal.					

60BDh: Touch Probe 2 Falling Edge Position Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60BBh	00h	Touch probe 2 falling edge value	RO	TPDO	INT32	UserUnit	INT32	0
Bits		**Name**	**Description**					
31:0		Touch probe 2 falling edge value	Shows the position feedback latch value of the motor at the moment of the falling edge of probe 2's signal.					

60C2h: Interpolation Time Period

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

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60C2h	02h	Interpolation time index	R/W	No	INT8	-	-4 to -3	-3
Bits		**Name**	**Description**					
7:0		Interpolation time index	See 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	RPDO	UINT32	UserUnit/s^2	UINT32	2^{32} to 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	RPDO	UINT32	UserUnit/s^2	UINT32	2^{32} to 1
Bits		**Name**	**Description**					
31:0		Max deceleration	Sets the maximum deceleration to prevent damage and limit the maximum deceleration to an acceptable value.					

60E0h: Positive Torque Limit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60E0h	00h	Positive torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
31:0		Positive torque limit	Indicates the configured maximum positive torque in the motor. The value shall be given per thousand of rated torque.					

60E1h: Negative Torque Limit

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60E1h	00h	Negative torque limit	R/W	RPDO	UINT16	‰	0 to 3000	3000
Bits		**Name**	**Description**					
31:0		Negative torque limit	Indicates the configured maximum negative torque in the motor. The value shall be given per thousand of rated torque.					

60F2h: Positioning Option Code

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60F2h	00h	Positioning option code	R/W	RPDO	UINT16	-	-	0

Bits	Name	Description
15:8	Reserved	Not used.
7:6	Positioning option code	Displays the motion mode in modulo positioning. 00: Normal 01: Positioning only in negative direction 10: Positioning only in positive direction 11: Positioning only in shortest way
5:0	Reserved	Not used.

60F4h: Following Error Actual Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60F4h	00h	Following error actual value	RO	TPDO	INT32	UserUnit	INT32	-

Bits	Name	Description
31:0	Following error actual value	Displays the actual value of the position following error (user unit), which indicates the deviation between “Position demand value” (6062h) and “Position actual value” (6064h).

60FCh: Position Demand Internal Value

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FCh	00h	Position demand internal value	RO	TPDO	INT32	INC	INT32	-

Bits	Name	Description
31:0	Position demand internal value	Displays the internal position control loop command value (encoder unit).

60FDh: Digital Inputs

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FDh	00h	Digital inputs	RO	TPDO	UINT32	-	UINT32	-

Bits	Name	Description
31:26	Reserved	Not used.
25	DO2 status	Only models with DO2 are supported. 0: Logic not valid 1: Logic valid
24	DO1 status	0: Logic not valid 1: Logic valid
23:20	Reserved	Not used.
19	DI4 status	Only models with DI4 are supported. 0: Logic not valid 1: Logic valid.
18	DI3 status	0: Logic not valid 1: Logic valid
17	DI2 status	0: Logic not valid 1: Logic valid
16	DI1 status	0: Logic not valid 1: Logic valid
15:3	Reserved	Not used.
2	Home switch state	0: Logic not valid 1: Logic valid
1	Positive limit switch status	0: Logic not valid 1: Logic valid
0	Negative limit switch status	0: Logic not valid 1: Logic valid

60FEh: Digital Outputs

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FEh	01h	Physical outputs	R/W	TPDO	UINT32	-	UINT32	-

Bits	Name	Description
31:18	Reserved	Not used.
17	DO2 status	When 60FEh-02h, bit[17] and 60FEh-01h, bit[17] are both set to 1, and DO2 is set to forced output. 0: High level 1: Low level
16	DO1 status	When 60FEh-02h, bit[16] and 60FEh-01h, bit[16] are both set to 1, and DO2 is set to forced output.
15:0	Reserved	Not used.

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FEh	02h	Bits mask	R/W	TPDO	UINT32	-	UINT32	-

Bits	Name	Description
31:18	Reserved	Not used.
17	DO2 bitmask	0: Disable DO2 forced output 1: Enable DO2 forced output
16	DO1 bitmask	0: Disable DO1 forced output 1: Enable DO1 forced output
15:0	Reserved	Not used.

60FFh: Target Velocity

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
60FFh	00h	Target velocity	R/W	RPDO	INT32	UserUnit/s	INT32	0

Bits	Name	Description
31:0	Target velocity	Sets the input for the trajectory generator in profile velocity (PV) mode.

6502h: Supported Drive Modes

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6502h	00h	Supported drive modes	RO	No	UIN32	-	UINT32	3EDh

Bits	Name	Description
15:10	Reserved	Not used.
9	CST	0: Not supported 1: Supported
8	CSV	0: Not supported 1: Supported
7	CSP	0: Not supported 1: Supported
6	IP	0: Not supported 1: Supported
5	HM	0: Not supported 1: Supported
4	Reserved	Not used.
3	PT	0: Not supported 1: Supported
2	PV	0: Not supported 1: Supported
1	VM	0: Not supported 1: Supported
0	PP	0: Not supported 1: Supported

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	6/26/2025	Initial Release	-