EZmotion

User Guide

MMJ Series Stepper Driver

Contents

Overview 8
Applicable Products 8
Safety Warnings 9
Section 1. Product Information 10
1.1 Introduce 10
1.2 Product Features 10
1.3 Product Series 11
1.4 Mechanical Size 11
1.5 Interface Definition 12
1.6 Parameters List 14
1.7 Optional Accessories 15
1.8 Supporting Software and Documentation 15
1.8.1 MotionLAB 15
1.8.2 ESI File 16
1.9 Description of System Wiring 16
1.9.1 Wiring Diagrams for Single-Axis System 16
1.9.2 Wiring Diagram of a Multi-Axis System 17
1.9.3 Wiring Diagram of I/O 17
Section 2. Communication 19
2.1 EtherCAT Introduction 19
2.1.1 EtherCAT State Machine (ESM) 19
2.1.2 Distributed Clock (DC) 20
2.1.3 CANopen over EtherCAT (CoE) 20
2.1.4 Process Data Objects (PDOs) 21
2.1.5 Explicit Device Identification 23
2.1.6 EtherCAT Slave Information (ESI) 23
2.2 Connect to EtherCAT MainDevice 23
2.2.1 Network Connection 23
2.2.2 Connection Guidance with Beckhoff MainDevice TwinCAT Example 24
2.3 Related Objects 26
2.4 MLink Introduction 29
Section 3. Operation and Commissioning 31
3.1 Commissioning Flowchart 31
3.2 Pre-Operation Check 31

3.3 Stepper Driver Start-Up....32
3.4 Parameter Settings....33
3.4.1 User Unit Settings....33
3.4.2 External I/O Settings....33
3.4.3 Protection Setting....35
Write/Save....35
3.5 Parameters....35
3.5.1 Function Description....35
3.5.2 Related Objects....36
3.5.3 Application Examples....36
3.6 Trial Operation....36
3.6.1 Stepper Motor Start....36
3.6.2 Stepper Motor Stop....36
3.6.3 Stepper Motor Fault....37
3.6.4 Related Objects....38
Section 4. Motion Control....40
4.1 State Machine....40
4.1.1 Function Description....40
4.1.2 Related Objects....42
4.2 Operation Mode....42
4.2.1 Function Description....42
4.2.2 Related Objects....42
4.3 Profile Position (PP) Mode....42
4.3.1 Function Description....42
4.3.2 Related Objects....47
4.3.3 Use of “Control Word” and “Status Word”....48
4.3.4 Application Examples....48
4.4 Homing Mode....49
4.4.1 Function Description....49
4.4.2 Related Objects....51
4.4.3 Use of “Control Word” and “Status Word”....51
4.4.4 Application Examples....52
4.5 Cyclic Synchronous Position (CSP) Mode....52
4.5.1 Function Description....52
4.5.2 Related Objects....52
4.5.3 Use of “Control Word” and “Status Word”....53

4.5.4 Application Examples 53
4.6 Jog Mode 53
4.6.1 Function Description 53
4.6.2 Related Objects 54
4.6.3 Application Examples 54
Section 5. Stepper Driver 55
5.1 Basic Settings 55
5.1.1 Function Description 55
5.1.2 Related Objects 55
5.1.3 Application Examples 55
5.2 Current Control 55
5.2.1 Function Description 55
5.2.2 Related Objects 56
5.2.3 Application Examples 56
Section 6. Fault and Protection 57
6.1 Driver Fault 57
6.1.1 Over-Current Protection (OCP) 57
6.1.2 Over-Voltage Protection (OVP) 57
6.1.3 Under-Voltage Lockout (UVLO) Protection 57
6.1.4 Over-Temperature Protection (OTP) 57
6.1.5 Open-Phase Protection (OPP) 57
6.1.6 Over-Temperature Warning 57
6.2 Motion Fault 57
6.2.1 Hardware Limit Protection 57
6.2.2 Software Limit Protection 58
6.2.3 Homing Protection 58
6.2.4 Position Error Warning 58
6.3 Stop Reason Instruction 58
6.4 Fault Clear 58
6.5 Alarm History 58
6.6 Related Objects 59
6.7 Application Examples 59
Section 7. Object Dictionary 60
7.1 Axis 1 Object Dictionary Group 60
7.1.1 1000h Group 60
7.1.2 2000h Group 64

7.1.3 6000h Group....65
7.2 Axis Common Object Dictionary Group....67
Section 8. Object Dictionary Description....68
2000h: Smoothing Time 1....68
2001h: Repetitive Motion Times 1....68
2002h: Repetitive Motion Mode 1....68
2003h: Repetitive Interval Time 1....68
2010h: Jog Acceleration 1....68
2011h: Jog Deceleration 1....69
2012h: Jog Target Velocity 1....69
2013h: Jog Positive Direction 1....69
2014h: Jog Negative Direction 1....69
2020h: Homing Maximum Distance 1....69
2030h: Slowdown Stop Time 1....70
2031h: I/O Control 1....70
2032h: I/O Function 1....71
2033h: Position Clear 1....71
2040h: Stop Enable 1....72
2042h: Touch Probe Position 1....72
2050h: Actual Acceleration 1....72
2052h: Position Reach 1....72
2053h: Positive Limit State 1....72
2054h: Negative Limit State 1....73
2055h: Homing State 1....73
2056h: Error State 1....74
2057h: Stop State 1....75
2070h: Drive Control 1....75
2071h: Idle Current 1....76
2072h: Operating Current 1....76
2073h: OCP Threshold 1....76
2074h: Phase Resistance 1....76
2075h: Phase Inductance 1....76
2077h: Current Loop Bandwidth 1....76
2078h: Axis Firmware Version 1....77
2079h: OVP Threshold 1....77

207Ah: UVLO Threshold 1 77
207Bh: TSD Threshold 1 77
207Ch: OTP Threshold 1 77
207Dh: Driver Temperature 1 78
207Fh: OPP Maximum Duty 1 78
F501h: Motor Connection State 78
F504h: Bus Voltage 78
F505h: Part Number 79
F506h: Firmware Version Number 79
F507h: Hardware Version Number 79
F508h: MLink Address 79
F509h: MLink Parity 79
F50Ah: MLink Baud Rate 79
F50Bh: Special Command 80
F50Ch: Explicit ID 80
603Fh: Error Code 1 80
6040h: Control Word 1 81
6041h: Status Word 1 82
605Ah: Quick Stop Option Code 1 82
605Bh: Shutdown Option Code 1 82
605Ch: Disable Operation Option Code 1 83
605Dh: Halt Option Code 1 83
605Eh: Fault Reaction Option Code 1 83
6060h: Modes of Operation 1 83
6061h: Modes of Operation Display 1 84
6064h: Position Actual Value 1 84
6065h: Following Error Window 1 84
606Ch: Velocity Actual Value 1 84
607Ah: Target Position 1 85
607Ch: Home Offset 1 85
607Dh:Software Position Limit 1 85
607Eh: Polarity 1 85
607Fh: Max Profile Velocity 1 86
6081h: Profile Velocity 1 86
6082h: End Velocity 1 86

6083h: Profile Acceleration 1 86
6084h: Profile Deceleration 1 86
6085h: Quick Stop Deceleration 1 86
6086h: Motion Profile Type 1 87
6091h: Gear Ratio 1 87
6092h: Feed Constant 1 87
6098h: Homing Method 1 88
6099h: Homing Speeds 1 88
609Ah: Homing Acceleration 1 88
60C2h: Interpolation Time Period 1 88
60C5h: Max Acceleration 1 89
60C6h: Max Deceleration 1 89
60F2h: Positioning Option Code 1 89
60FDh: Digital inputs 1 90
6502h: Supported Drive Modes 1 91

Overview

Applicable Products

Table 1 shows the applicable products for this user guide.

Table 1: Applicable Products

Serial Number	Applicable Product Serial Number
1	MMJ6N75-E
2	MMJ6N72-E

Safety Warnings

To prevent personal injury or damage to the drive, follow these guidelines:

- Secure the motor before powering it up, as the motor may unexpectedly move, jump, or fall during start-up.
- Keep hair and loose clothing away from the motor.
- Avoid touching the shaft and any additional mechanical parts when operating the motor.
- When the motor is installed in the system, connect the motor housing to the earth.
- Ensure that the power supply connected to the motor has a fuse or otherwise limits the current.

Section 1. Product Information

1.1 Introduce

The MMJ6N7X-E is a highly integrated stepper motor driver that provides motion control and drive for multi-axis stepper motors. Figure 1 shows that the MMJ6N7X-E integrates a 6-axis motion controller, motor driver, power inverter, communication interface, and external I/O into a single driver to provide a complete multi-axis stepper motor drive solution that simplifies the development of motor control systems.

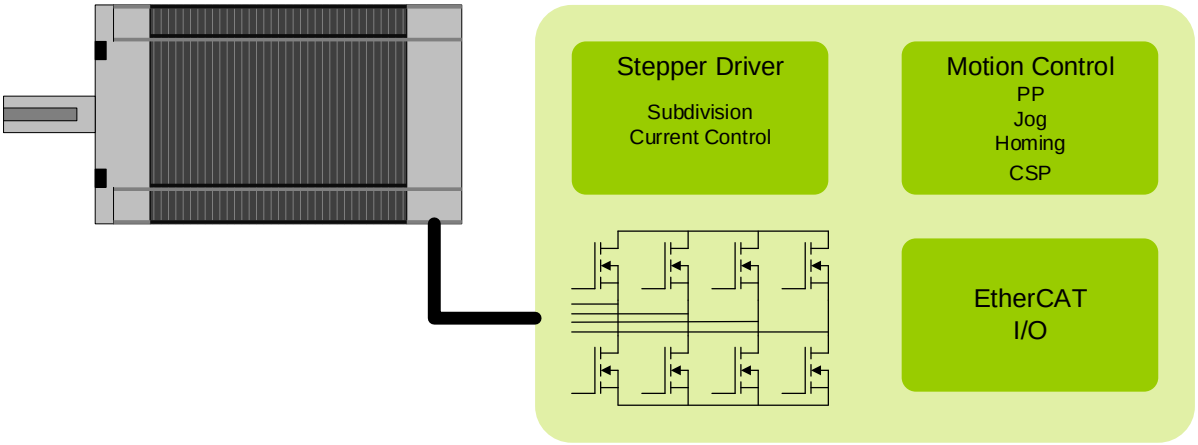


Figure 1: Stepper Motor Control Block Diagram

The driver can operate in profile position (PP), cyclic synchronous position (CSP), jog, and homing (HM) modes. The driver can be controlled via an EtherCAT interface with CANopen over EtherCAT (CoE) protocol. Parameters can be configured via the PC-based host computer program MotionLAB, which is connected to the driver via the MLink debugging interface. Once the parameters are optimized, they can be saved to the module's non-volatile memory (NVM).

1.2 Product Features

- Integrated 6-Axis Stepper Motor Driver
- Integrated Motion Controller
- Supports Up to 512 Step Subdivisions
- Maximum Current Capability (24V Rated Input):
  - The MMJ6N75-E Supports a Maximum of 5A Peak Current for a Single Axis and a 4A Peak Current for Six Axes
  - The MMJ6N72-E Supports a Maximum 2A Peak Current for Six Axes
- Maximum Current Capability (48V Rated Input):
  - The MMJ6N75-E Supports a Maximum of 5A Peak Current for a Single Axis and a 3A Peak Current for Six Axes
  - The MMJ6N72-E Supports Maximum 2A Peak Current for Six Axes
- Supports Motor Field-Oriented Control (FOC)
- 100Mbps EtherCAT Communication Interface with CoE Protocol, Dynamic Process Data Object (PDO), and Distributed Clock (DC)
- Conforms to Standard CiA402 Motion Control Protocol, Supports Profile Position (PP), Cyclic Synchronous Position (CSP), Jog, and Homing (HM) Modes

- External I/O Input, Supporting Touch Probe Function
- DC Input Voltage Detection
- Driver Temperature Detection
- Supports Over-Current Protection (OCP), Over-Voltage Protection (OVP), Under-Voltage Lockout (UVLO), Thermal Shutdown (TSD), Open-Phase Protection (OPP), and Motion Control Protection
- Power, Enable, Alarm, and Communication Status Indications

1.3 Product Series

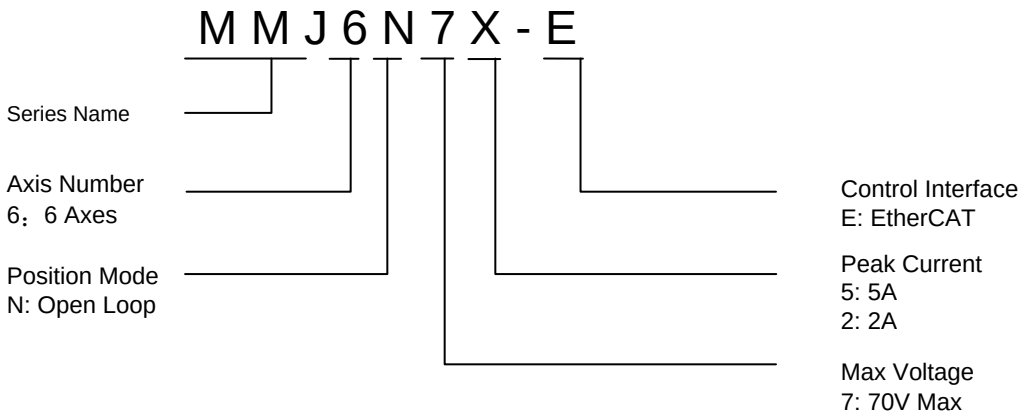


Figure 2: Naming Convention

1.4 Mechanical Size

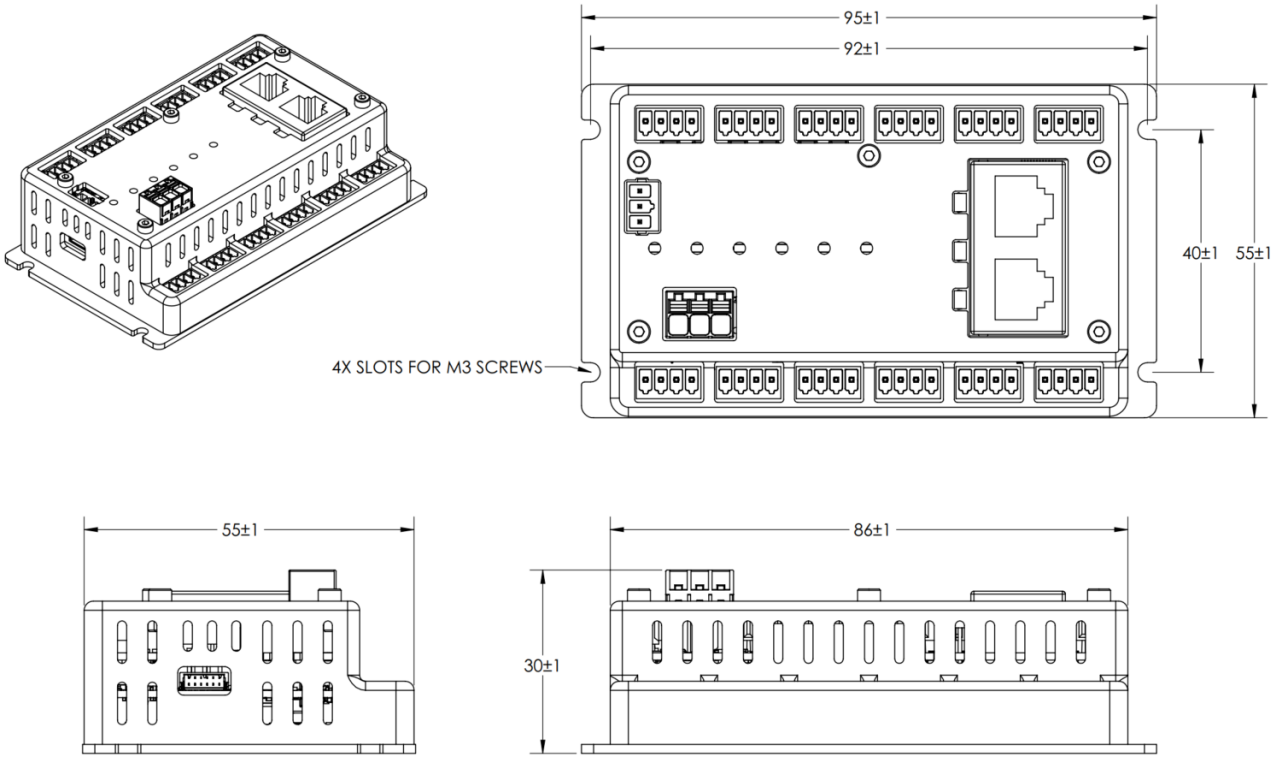


Figure 3: Mechanical Dimensions

1.5 Interface Definition

P1 is the DC main power input with an input range between 20V and 70V. P2 is the auxiliary power input, which supplies power to the isolated I/O interface circuit. There is no electrical connection between P1 and P2. X1~X6 is the output of the power stage, which is connected to the winding of the stepper motor. Y1~Y6 is the I/O input interface. ECAT IN and ECAT OUT are RJ45 communication interfaces (see Figure 4).

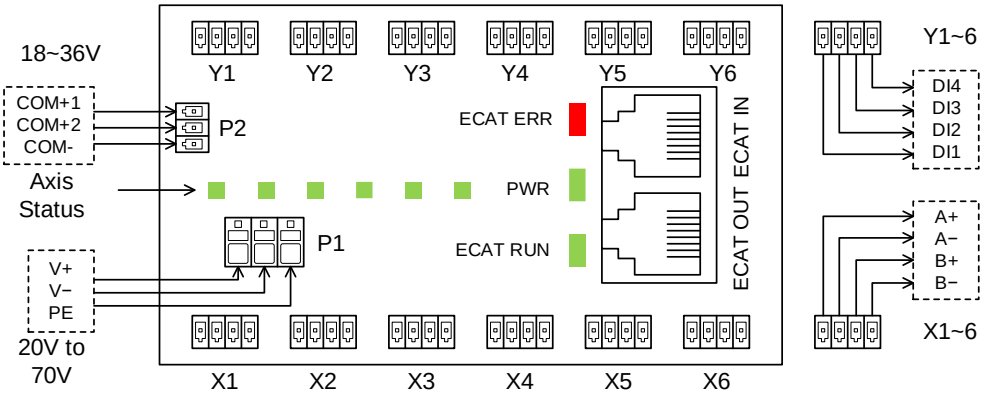


Figure 4: Driver Interface Definition Diagram

Mating Connector Type

Table 2: Mating Connector Types

Interface Name	Mating Connector	Description
Y1–Y6	LC8V_2.54_4P	2.54mm pitch; wire gauge 26-20AWG
X1–X6	LC8V_2.54_4P	2.54mm pitch; wire gauge 26-20AWG
ECAT IN, ECAT OUT	-	Standard RJ45 interface
P2	LC8V_2.54_3P	2.54mm pitch; wire gauge 26-20AWG

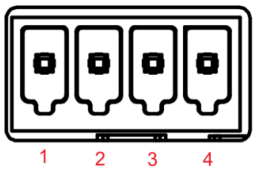
The Status of the LED

Table 3: LED Status

Name	Color	Description
Axis Status	Green	Axis enabled.
	Red	Axis error.
PWR	Green	Power is okay.
ECAT RUN	Flashing green	EtherCAT is in a pre-op state.
	Solid green	EtherCAT is in the op state.
ECAT ERR	Red	EtherCAT is error.

Y1~Y6: I/O Interfaces

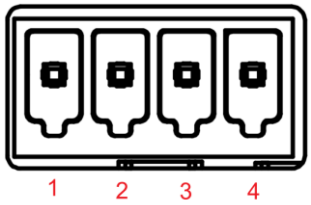
Table 4: I/O Interfaces



Pin Number	Name	Description
1	DI1	Digital input 1.
2	DI2	Digital input 2.
3	DI3	Digital input 3.
4	DI4	Digital input 4.

X1~X6: Motor Interface

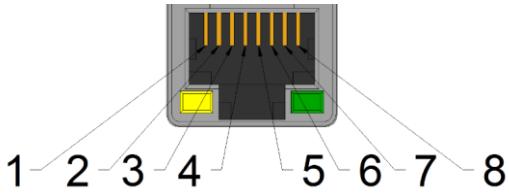
Table 5: Motor Interface



Pin Number	Name	Description
1	A+	The positive end of the stepper motor's phase A winding.
2	A-	The negative end of the stepper motor's phase A winding.
3	B+	The positive end of the stepper motor's phase B winding.
4	B-	The negative end of the stepper motor's phase B winding.

EtherCAT Interface Pin Definitions

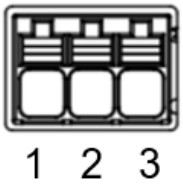
Table 6: EtherCAT Interface Pin Definitions



Pin Number	Name	Description
1	TX+	EtherCAT data is sent to the positive end.
2	TX-	EtherCAT data is sent at the negative end.
3	RX+	EtherCAT data receives the positive end.
4	MLink+	The positive end of the MLink debug port.
5	MLink-	The negative end of the MLink debug port.
6	RX-	EtherCAT data receives the negative end.
7	NC	Not connected.
8	NC	Not connected.

P1: Power Connector

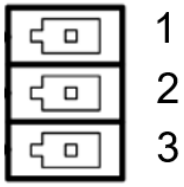
Table 7: Power Connector



Pin Number	Name	Description
1	V+	The DC power input is positive.
2	V-	The DC power input is negative.
3	PE	Enclosure ground.

P2: I/O Power Interface

Table 8: I/O Power Interface



Pin number	Name	Description
1	COM+1	Common anode common input.
2	COM+2	Common anode common input.
3	COM-	Common cathode common input.

1.6 Parameters List

Table 9: Driver Specification

Parameter		Description
Basic parameters	Rated Operating Voltage (V)	24 to 48
	Operating Voltage Range (V)	20 to 70
	Number of Axes	6
	Subdivision	Full step/half-step/4/8/16/32/64/128/256/512
	Output Current	5A version: Rated voltage is 24V, 5A peak current for single axis, 4A peak current for six axes; Rated voltage is 48V, 5A peak current for single axis, 3A peak current for six axes 2A version: Multi-axis 2A peak current
	Ingress Protection	IP20
Interface parameters	Number of DIs	4 per axis
	DI Voltage Range (V)	18 to 36
	DI Signal Maximum Frequency (kHz)	≤10
	DI Signal Minimum Time (μs)	30
Use environment	Operating Temperature	0°C to 40°C, derated for use when exceeding 40°C
	Storage Temperature	-40°C to +85°C
	Use Humidity	10% to 90%, non-condensing
	Store Humidity	5% to 95%, non-condensing

Table 9: Driver Specification *(continued)*

Parameter		Description
EtherCAT	Communication Protocols	CoE (PDO, SDO)
	Synchronization Mode	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 Distance	Less than 100m between two nodes
	Synchronous Jitter	<1μs
	Synchronize Snap-Ins	SM0: Mailbox output SM1: Mailbox input SM2: Process data outputs SM3: Process data inputs
	Process Data	Variable PDO mappings

1.7 Optional Accessories

Table 10: List of Accessories

Part Number	Items	Description	Number
MMA02-2001	MLink	Debugging tool to connect the driver PC to the MotionLAB host computer.	1
	USB cable	1.5m, USB Type-A to USB Type-B adapter cable.	1
MMA03-3003	LC8V_2.54_4P	Power connector female.	6
	LC8V_2.54_4P	I/O connector female.	6
	LC8V_2.54_3P	I/O power connector female.	1

1.8 Supporting Software and Documentation

1.8.1 MotionLAB

EZmotion offers a user-friendly, PC-based graphical user interface (GUI) called MotionLAB, which provides an easy way to configure and test the driver (see Figure 5 on page 16).

Figure 5: MotionLAB

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

1.8.2 ESI File

To establish communication between the MainDevice and driver SubDevice via EtherCAT, add an EtherCAT configuration file (e.g. 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 Wiring Diagrams for Single-Axis System

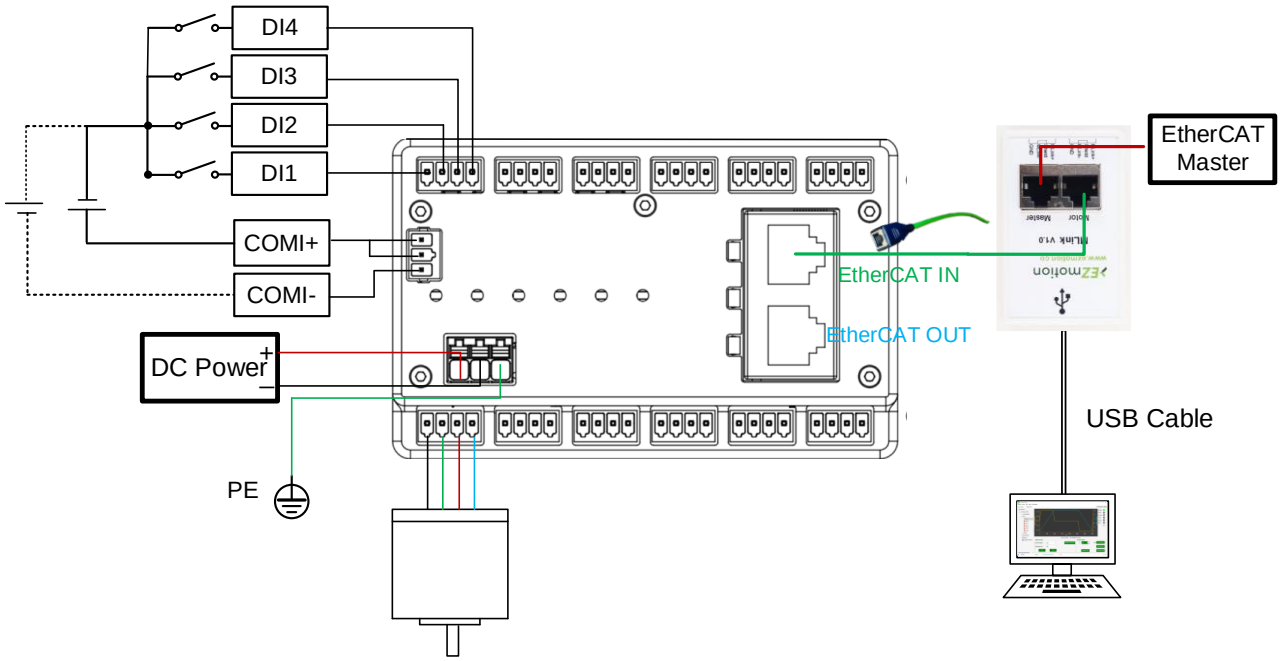


Figure 6: Wiring Diagrams for a Single-Axis System

It is recommended to follow the guidelines below:

1. Do not reverse the power cable, as the driver does not have an anti-reverse function.
2. Confirm that the unused motor leads are not short-circuited with other objects. Do not wire the motor leads to the ground or power supply.
3. The digital input interface supports NPN and PNP, and the recommended external input signal control power supply is 24V.
4. To prevent electric shock, ground the ground terminal.
5. The recommended wire diameter of the I/O interface and motor interface is 26-20AWG. To ensure good contact, the wire diameter should meet the specified range.

1.9.2 Wiring Diagram of a Multi-Axis System

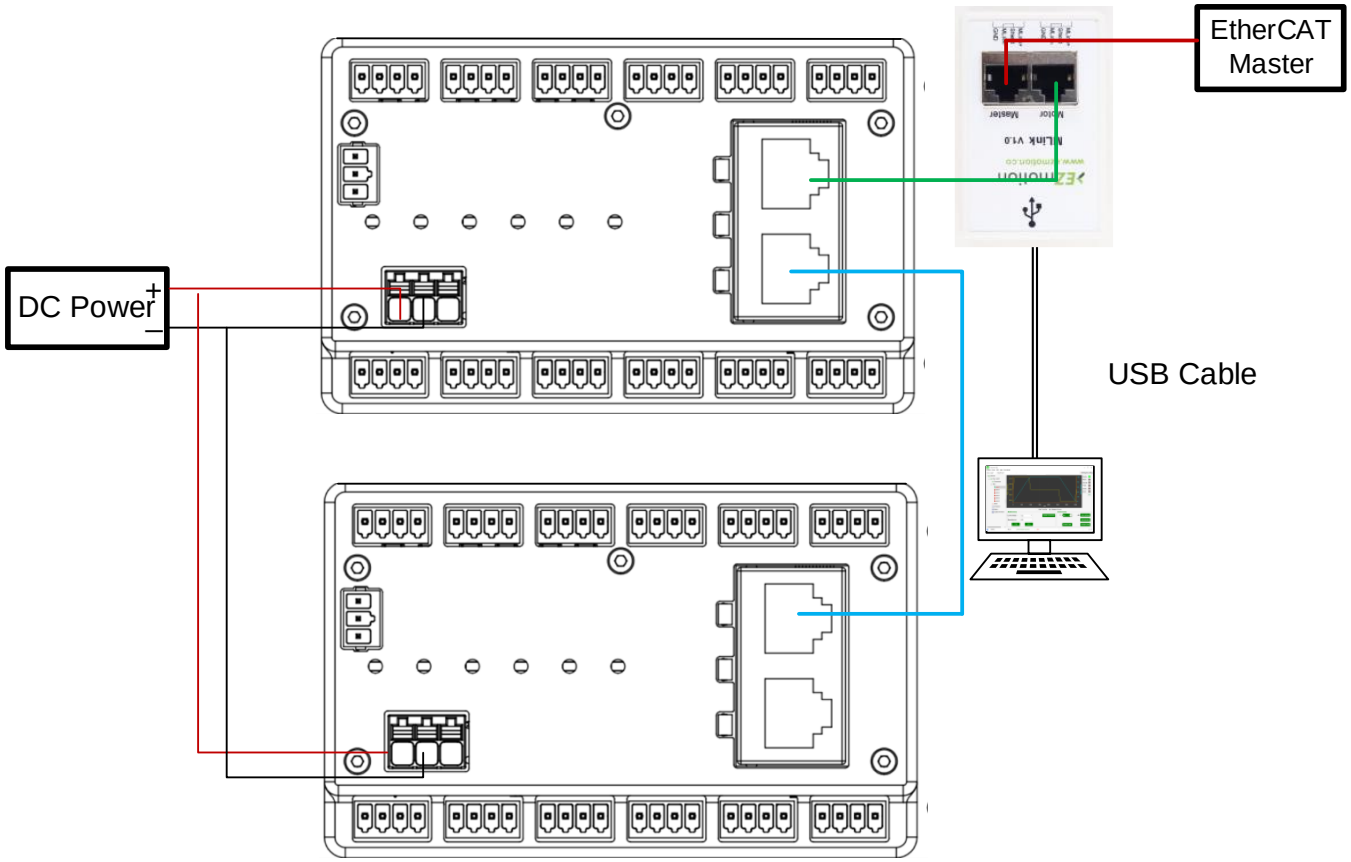


Figure 7: Wiring Diagram of Multi-Machine System

1.9.3 Wiring Diagram of I/O

Figure 8 on page 18 shows the digital input circuit diagram. The PNP or NPN inputs are supported but mixed cases, in which the input signal cannot be both PNP and NPN, are not supported. The voltage range of the external input signal control power supply is $18V_{DC}$ to $36V_{DC}$, and the recommended voltage is 24V.

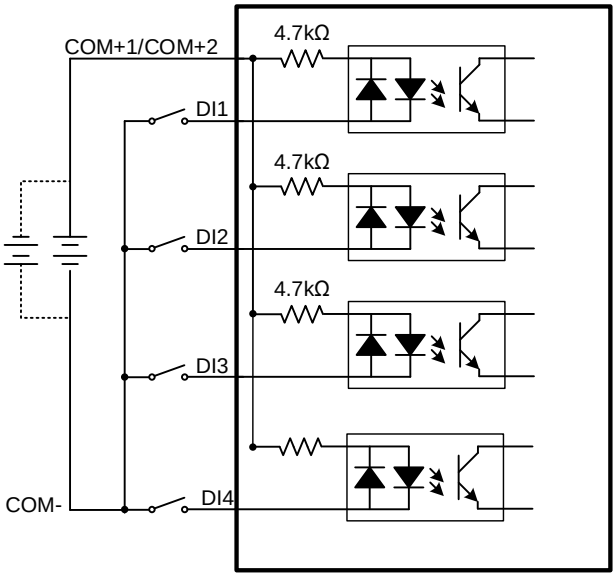


Figure 8: Digital Input Circuit Diagram

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 SubDevices are synchronized, and that the jitter is below 1μs. Table 11 shows the main features of EtherCAT.

Table 11: EtherCAT Slave Configuration

Project	Description
Synchronization manager	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
Sync mode	SM-synchronous, DC-synchronous

2.1.1 EtherCAT State Machine (ESM)

During start-up and operation, the EtherCAT state machine (ESM) coordinates with the MainDevice and SubDevice. The interaction between the MainDevice and SubDevice results in a state change that is related to the writing of the application layer control word AL Ctrl (0x0120) (see Figure 9).

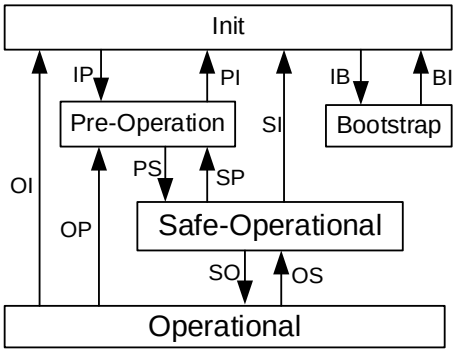


Figure 9: EtherCAT State Machine

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. There is no direct communication between the MainDevice and SubDevice. The MainDevice uses the Init state to initialize a configuration register and set and configure the sync manager.

If the SubDevice supports an 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, then the device can enter the safe-operational state. The SubDevice supports input, while the MainDevice requests input. 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, then the device can enter the operational state. The SubDevice application delivers the actual input data, and the MainDevice 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. Note that 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 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 application layer and communication profile (CiA DS301) standard. The SDO requests, SDO responses, and SDO complete access are supported. Figure 10 on page 21 shows the application layer structure.

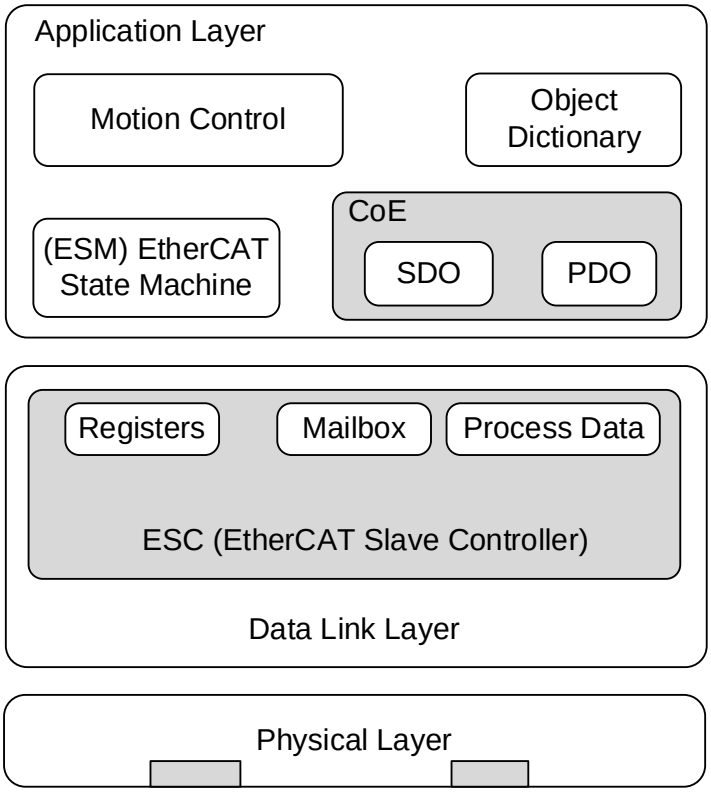


Figure 10: Communication Model

2.1.4 Process Data Objects (PDOs)

Process data objects (PDOs) are 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 status and other information.

There are 4 mutually mapped RPDOs and 4 mutably mapped TPDOs that can be selected according to the operating mode. Taking axis 1 in the drive as an example, the RPDO mapping object is defined by the objects 1600h~1603h, the TPDO mapping object is defined by the objects 1A00h~1A03h, and the PDO object index of the axes is offset by 0010h. For example, the RPDO mapping object of axis 2 is defined by objects 1610h~1613h, and the TPDO mapping object is defined by 1A10h~1A13h. The PDO mapping object is the same for each axis. Each PDO supports a maximum of 12 mapping objects.

Table 12 on page 22, Table 13 on page 22, and Table 23 on page 41 list the default mapping objects for each PDO.

Table 12: RPDO Default Mapping Objects

PDO Object Index	Sub-Index	Default Value	Description
1600h (support CSP mode)	01h	60400010h	Control word.
	02h	60600008h	Modes of operation.
	03h	607A0020h	Target position.
1601h (support PP mode)	01h	60400010h	Control word.
	02h	60600008h	Modes of operation.
	03h	607A0020h	Target position.
	04h	607E0008h	Polarity.
	05h	607F0020h	Max profile speed.
	06h	60810020h	Profile velocity.
	07	60820020h	End velocity.
	08h	60830020h	Profile acceleration.
	09h	60840020h	Profile deceleration.
1602h (support homing mode)	01h	60400010h	Control word.
	02h	60600008h	Modes of operation.
	03h	607E0008h	Polarity.
	04h	60980008h	Homing method.
	05h	60990120h	Speed for zero.
	06h	60990220h	Speed for switch.
	07h	609A0020h	Homing acceleration.
1603h (support Jog mode)	01h	60400010h	Control word.
	02h	20100020h	Jog acceleration.
	03h	20110020h	Jog deceleration.
	04h	20120020h	Jog target velocity.
	05h	20130010h	Jog positive direction.
	06h	20140010h	Jog negative direction.
	07h	60600008h	Modes of operation.
	08h	607E0008h	Polarity.

Table 13: TPDO Default Mapping Objects

PDO Object Index	Sub-Index	Default Value	Description
1A00h	01h	603F0010h	Error code.
	02h	60410010h	Status word.
	03h	60610008h	Modes of operation display.
	04h	60640020h	Position actual value.
	05h	60FD0020h	Digital inputs.
1A01h	01h	60410010h	Status word.
	02h	60610008h	Modes of operation display.
	03h	60640020h	Position actual value.
	04h	606C0020h	Velocity actual value.
1A02h	01h	60410010h	Status word.
	02h	60610008h	Modes of operation display.
	03h	60640020h	Position actual value.
	04h	606C0020h	Velocity actual value.
1A03h	01h	60410010h	Status word.
	02h	60610008h	Modes of operation display.
	03h	60640020h	Position actual value.
	04h	606C0020h	Velocity actual value.

The actual used PDO can be configured via object 1C12h and object 1C13h. The 1C12h object sets the RPDO that is actually used, and can be any value from 1600h to 1603h. The 1C13h object sets the TPDO that is actually used, and can be any value from 1A00h to 1A03h. If there is a need to add or delete mapped objects, the relevant PDO mappings are configured automatically during MainDevice start-up after the EtherCAT MainDevice has completed the set-up, and before the SubDevices are switched 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.

To configure a PDO mapping group:

1. Write the 00h sub-index of 1C12h or 1C13h to 0 to clear the original mapping group.
2. The 01h~06h subindex of 1C12h or 1C13h writes the mapped group number that needs to be mapped for each axis.
3. The 00h subindex of 1C12h or 1C13h is written to the number of mapped PDOs.

To configure the PDO mapping objects:

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

2.1.5 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 be able 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 a mix-up of these devices due to cable swapping.

“Explicit ID” (object F50Ch) can be used optionally for unique addressing. Users can change the address of the SubDevice by modifying the device identification value.

2.1.6 EtherCAT Slave 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).

2.2 Connect to EtherCAT MainDevice

There are various EtherCAT MainDevice solutions available for connecting and controlling EtherCAT slave devices. One example is Beckhoff’s TwinCAT and the open-source EtherCAT MainDevice (e.g. TwinCAT is used to demonstrate 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 the 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 11). Hubs can be used to achieve tree, star, or other topologies.

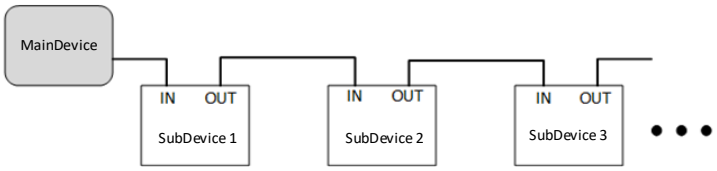


Figure 11: EtherCAT Line Topology

2.2.2 Connection Guidance with Beckhoff MainDevice TwinCAT 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 PC’s Ethernet port 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 device.
4. Start up the SubDevice.
5. Open TwinCAT by clicking on the TwinCAT icon in the lower right corner and selecting “TwinCAT XAE” (see Figure 12).

Figure 12: Open TwinCAT

6. Create a TwinCAT project.
   a. Select File > New > Project > TwinCAT XAE Project (XML format).
   b. Set the project name and select the file save location, then click OK to create the project.
7. Scan the devices.
   a. In solution explorer, right-click I/O > Devices, then select Scan (see Figure 13 on page 25).
   b. If the computer has more than one available port, select the correct Ethernet port (see Figure 14 on page 25).
   c. If TwinCAT asks to scan the boxes, click Yes. After a successful scan, the devices should be listed (see Figure 15 on page 25).

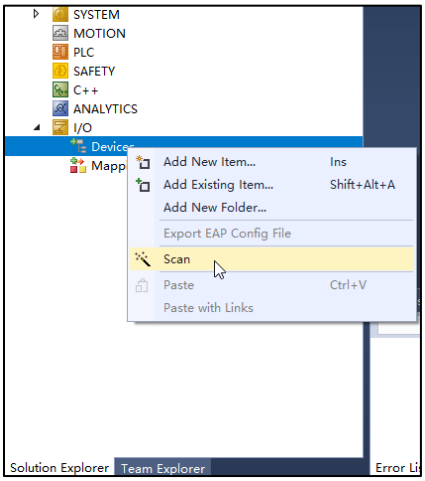


Figure 13: Scan Device

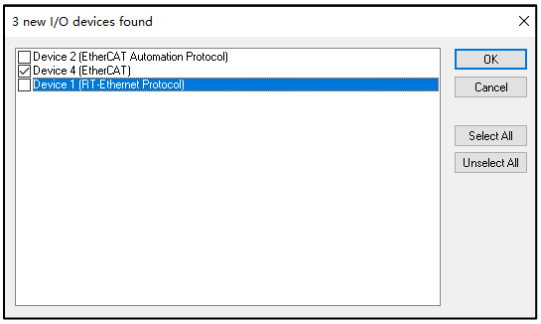


Figure 14: Choose the Ethernet Port

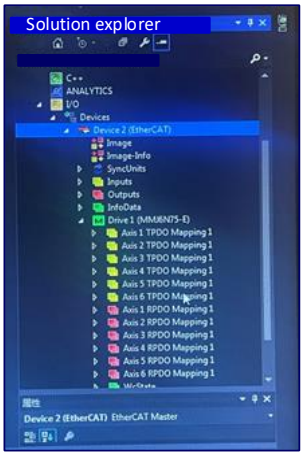


Figure 15: Device List

2.3 Related Objects

Using axis 1 as an example, the indexes of the other axes must be offset by 0010h, and the default value must be the same (see Table 14).

Table 14:Related Objects

Index	Sub-Index	Description	Access	PDO	Data type	Unit	Range	Default
RPDO Mapping 1								
1600h	00h	Number of mappings	RO	No	UINT8	-	-	03h
	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	-	-	0
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	0
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	No	UINT32	-	-	0
RPDO Mapping 2								
1601h	00h	Number of mappings	RO	No	UINT8	-	-	09h
	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	-	-	607E0008h
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	607F0020h
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	60810020h
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	60820020h
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	60830020h
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	60840020h
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping object 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	No	UINT32	-	-	0

Table 14:Related Objects *(continued)*

Index	Sub-Index	Description	Access	PDO	Data type	Unit	Range	Default
RPDO Mapping 3								
1602h	00h	Number of mappings	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	-	-	607E0008h
	04h	RPDO mapping object 4	R/W	No	UINT32	-	-	60980008h
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	60990120h
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	60990220h
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	609A0020h
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	No	UINT32	-	-	0
RPDO Mapping 4								
1603h	00h	Number of mappings	RO	No	UINT8	-	-	08h
	01h	RPDO mapping object 1	R/W	No	UINT32			60400010h
	02h	RPDO mapping object 2	R/W	No	UINT32	-	-	20100020h
	03h	RPDO mapping object 3	R/W	No	UINT32	-	-	20110020h
	04h	RPDO mapping object 4	R/W	No	UINT32	-	-	20120020h
	05h	RPDO mapping object 5	R/W	No	UINT32	-	-	20130010h
	06h	RPDO mapping object 6	R/W	No	UINT32	-	-	20140010h
	07h	RPDO mapping object 7	R/W	No	UINT32	-	-	60600008h
	08h	RPDO mapping object 8	R/W	No	UINT32	-	-	607E0008h
	09h	RPDO mapping object 9	R/W	No	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	No	UINT32	-	-	0
	0Bh	RPDO mapping object 11	R/W	No	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	No	UINT32	-	-	0

Table 14:Related Objects *(continued)*

Index	Sub-Index	Description	Access	PDO	Data type	Unit	Range	Default
TPDO Mapping 1								
1A00h	00h	Number of mappings	RO	No	UINT8	-	-	05h
	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	-	-	60FD0020h
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	No	UINT32	-	-	0
TPDO Mapping 2								
1A01h	00h	Number of mappings	RO	No	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	60410010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60610008h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60640020h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	606C0020h
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	No	UINT32	-	-	0

Table 14:Related Objects *(continued)*

Index	Sub-Index	Description	Access	PDO	Data type	Unit	Range	Default
TPDO Mapping 3								
1A02h	00h	Number of mappings	RO	No	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	60410010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60610008h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60640020h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	606C0020h
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	No	UINT32	-	-	0
TPDO Mapping 4								
1A03h	00h	Number of mappings	RO	No	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	No	UINT32	-	-	60410010h
	02h	TPDO mapping object 2	R/W	No	UINT32	-	-	60610008h
	03h	TPDO mapping object 3	R/W	No	UINT32	-	-	60640020h
	04h	TPDO mapping object 4	R/W	No	UINT32	-	-	606C0020h
	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 object 11	R/W	No	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	No	UINT32	-	-	0

2.4 MLink Introduction

To facilitate user debugging, as well as the real-time monitoring of the motor operation status and configuration of motor parameters, MotionLAB communicates with the stepper driver through MLink, which is an application layer communication protocol developed by EZmotion based on the RS485 protocol. This allows users to configure, debug, and monitor multiple motors through the MLink bus.

The multi-axis stepper motor driver is connected to the PC through the communication kit to achieve communication with the debugging software MotionLAB. The driver's communication parameters must be matched to the values set via the MLink to achieve correct communication; these parameters are the parity check mode and baud rate.

There are three parity check modes: odd parity check, even parity check, and no parity check. The default is even parity check. The baud rate supports 9600bps to 5Mbps, and the default baud rate is 2.5Mbps.

The driver's default address is 1. To achieve bus type multi-axis MLink communication, connect each driver to MotionLAB separately, and assign different SubDevice addresses for each driver to avoid

address conflicts with the same default address. Afterward, connect the stepper driver with different addresses to the MLink bus to achieve multi-axis configuration, debugging, and monitoring functions.

The parity check mode, baud rate, and SubDevice address can be configured via MotionLAB debugging software.

Section 3. Operation and Commissioning

3.1 Commissioning Flowchart

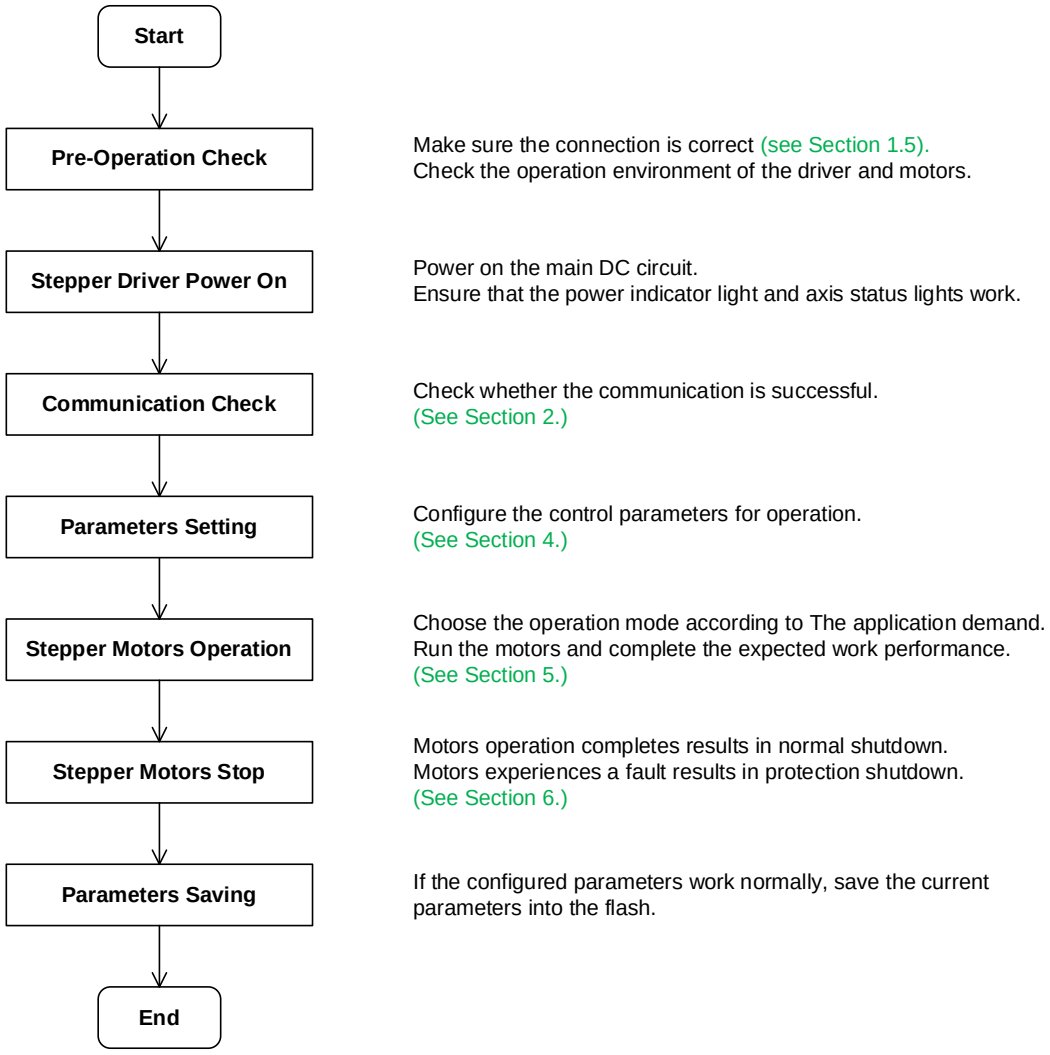


Figure 16: Trial Operation Flowchart

3.2 Pre-Operation Check

Before powering on, check the following:

- Ensure that the stepper driver's power input interface (V+, V-, and PE) is correctly connected to the DC power supply. The DC power supply's voltage must be within the allowable range, and it must have a current limit ability.
- Ensure that the motor output interfaces (A+, A-, B+, and B-) of the stepper driver are correctly connected.
- Ensure that the stepper driver's I/O power supply (COM+1, COM+2, and COM-) is correctly connected to the DC power supply. Ensure that the DC power supply's voltage is within the allowable range, and it has current limit ability.
- Ensure that the stepper driver's EtherCAT interface is correctly connected. The EtherCAT network port of the all-in-one machine follows the standard network cable interface protocol T-568B and uses

100Mbps Ethernet communication. To use the EtherCAT to communicate and the MLink at the same time, see Section 1.9.1 on page 16 to connect the MLink communication kit between the MainDevice and the first SubDevice in series to transfer between the two communication modes.

- Ensure that all cable specifications are within the allowable range.
- Ensure that the stepper driver and stepper motor are reliably grounded.

3.3 Stepper Driver Start-Up

After the stepper driver is correctly powered on, the power indicator light turns green, and each axis indicator light turns off. This indicates that the driver is working normally and waiting for the EtherCAT or MLink to give a control signal. When the power state of any axis is enabled, the corresponding axis indicator light turns green.

If any axis indicator lights turn red, connect to MotionLAB through MLink to check the fault status. If the power indicator light turns off, check the connection of the power cable. Figure 17 shows the power timing diagram.

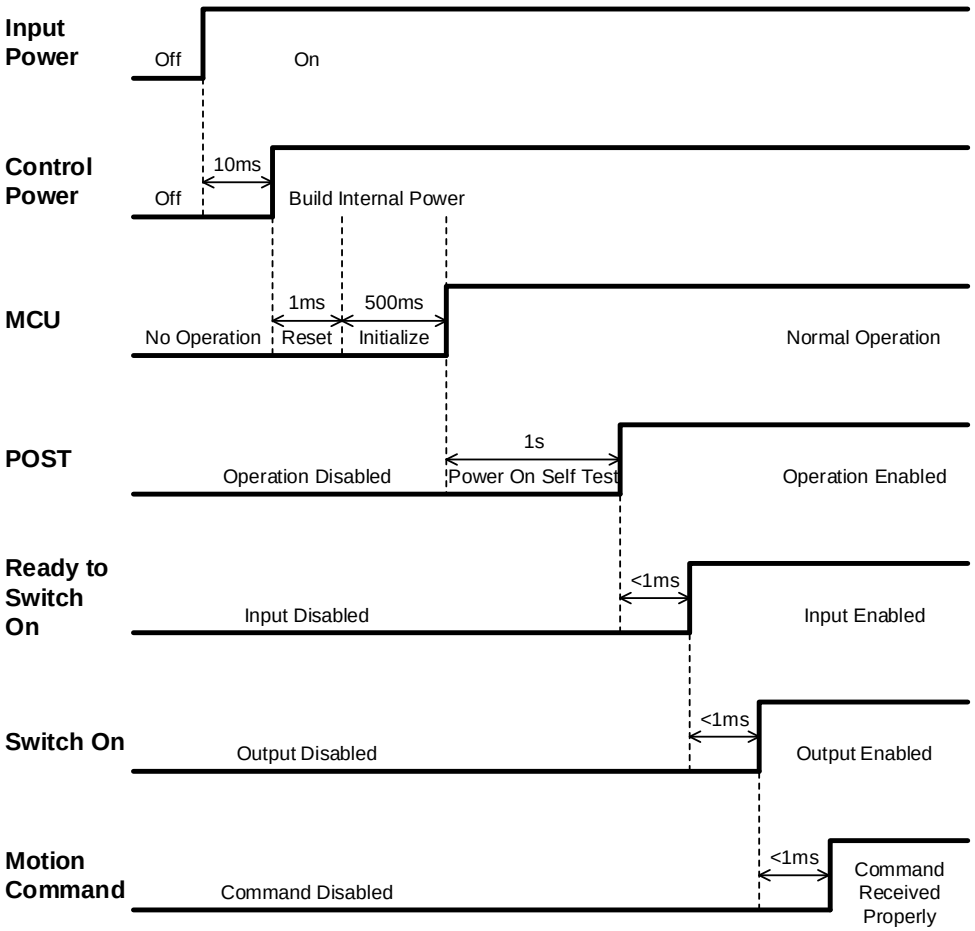


Figure 17: Start-Up Timing Diagram

⚠ Attention:

- After the external power supply is powered on, wait for the main microcontroller unit (MCU) initialization and self-test to complete before the driver can work normally.

- After the external power supply is powered on, the indicators of the six axes briefly turn green and then turn off, which is the drive's normal self-test process.
- The enable input refers to the state at which the driver can receive enable instructions, and the enable output refers to the state at which the driver can output power.

3.4 Parameter Settings

3.4.1 User Unit Settings

To adapt to the application of various industries and allow the user to define their own command units, the MMJ6N7X-E provides a user-defined setting function, which can convert any user unit into an operating unit inside the drive. To set the user unit, it is generally necessary to set the gear ratio via "Gear ratio 1" (object 6091h) and the feed constant via "Feed constant 1" (object 6092h).

The gear ratio represents the ratio between the input speed and the output speed, which refers to the demand turns for the motor when the output of gearbox goes one turn. It can be calculated with Equation (1):

$$\text{Gear Ratio} = \frac{\text{Motor Shaft Revolutions (6091h-01h)}}{\text{Driving Shaft Revolutions (6091h-02h)}} \quad (1)$$

The feed constant represents the position displacement in the user unit when the load shaft goes 1 turn. It can be estimated with Equation (2):

$$\text{Feed Constant (user unit/r)} = \frac{\text{Feed (6092h-01h)}}{\text{Driving Shaft Revolutions (6092h-02h)}} \quad (2)$$

The conversion formula between position command (user uint) and position internal demand can be calculated with Equation (3) and Equation (4), respectively:

$$\text{Pulse Per Revolution (pulse)} = \text{Step Subdivisions} \times 200\ \text{(Pulse)} \quad (3)$$

$$\text{Position Internal Demand (pulse)} = \text{Position Command (user unit)} \times \frac{\text{Pulse Per Revolution (pulse)} \times \text{Gear Ratio}}{\text{Feed Constant (user unit)}} \quad (4)$$

At the same time, the direction of rotation of the motor can be set through the polarity via "Polarity 1" (object 607Eh), and the rotation direction of the motor can be changed without changing the positive or negative input commands. The corresponding position information and speed information changes the polarity synchronously.

Related Objects

Table 15: Related Objects for User Unit Setting

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6091h	01h	Motor shaft revolutions	R/W	No	UINT32	REV	UINT32	1
	02h	Driving shaft revolutions	R/W	No	UINT32	REV	UINT32	1
6092h	01h	Feed	R/W	No	UINT32	User unit	UINT32	25600
	02h	Driving shaft revolutions	R/W	No	UINT32	REV	UINT32	1
607Eh	00h	Polarity	R/W	RPDO	UINT8	-	0 or 1	0

3.4.2 External I/O Settings

The stepper driver has four optocoupled-isolated input I/Os for each axis, which can be connected to either a common anode or a common cathode. By default, the driver uses the common anode connection. DI1~DI3 are used for the negative limit, positive limit, and homing, while DI4 is used for the touch probe

function or external shutdown function. Each I/O can be mapped to a specific function and valid polarity. For more details, see the related objects.

The effective polarity of each I/O is the level of optocoupler's output when the switch is blocked. When used for the touch probe function, the effective polarity and trigger edge polarity must also be set. The trigger edge of the touch probe can be selected to be triggered by being physically close to the negative limit switch or positive limit switch. When used for a shutdown signal, set the effective level to activate the shutdown signal.

The touch probe function records the motor's motion information when it passes a specific point during operation. When the touch probe signal is triggered, the system saves the current location information. If the touch probe stop function is enabled, the drive immediately controls the motor shutdown and records the current position information when the touch probe signal is triggered.

MotionLAB provides a convenient simulation and monitoring interface for I/O functions (see Figure 18). Users can monitor the external I/O condition through this software interface and utilize the simulation function. After the I/O functions are configured, users can execute convenient simulation tests through MotionLAB to give a virtual signal to simulate the external input/output. For more information about the interface, refer to the MotionLAB Quick User manual.

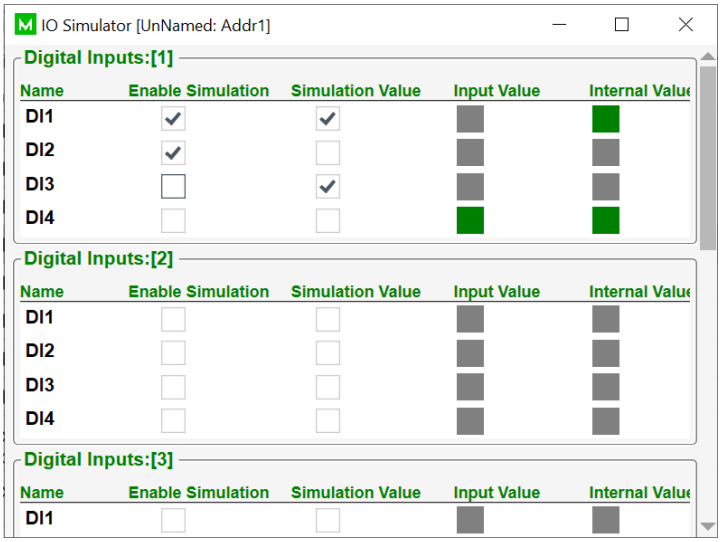


Figure 18: I/O Simulation and Monitor Interface

Related Objects

Table 16: Related Objects for External I/O Setting

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2031h	01h	I/O polarity	R/W	No	UINT16	-	0 to 31	0x0000
2031h	02h	I/O simulation enable	R/W	No	UINT16	-	0 to 15	0x0000
2031h	03h	I/O simulation input	R/W	No	UINT16	-	0 to 15	0x0000
2032h	00h	I/O function	R/W	No	UINT16	-	0 to 127	0x0024
2040h	00h	Stop enable	R/W	No	UINT16	-	0 to 7	2
2042h	00h	Touch probe position	RO	No	INT32	pulse	INT32	-
60FDh	00h	Digital inputs	RO	TPDO	UINT32	-	UINT32	-

3.4.3 Protection Setting

The MMJ6N7X-E series multi-axis stepper drives feature a variety of protection features. The protection function action electrically stops the machine and disables the driver. In the fault state, the red indicator light for the corresponding axis turns on, and the power stage cannot be enabled.

Before trial operation, the user establishes the necessary protection to open the drive. By default, the drive features over-current protection (OCP), over-voltage protection (OVP), under-voltage protection (UVP), over-temperature protection (OTP), hardware limit protection, and a return to zero travel limit. See Section 6 on page 58 for a detailed description of the fail-safe.

3.5 Write/Save Parameters

3.5.1 Function Description

To save the user's configured parameters to the device's non-volatile memory (NVM), updating the parameters or saving the operations can be performed via the MotionLAB software (see Figure 19). Specific function codes can be sent to the "Special command" (object F50Bh) dictionary via EtherCAT communication.

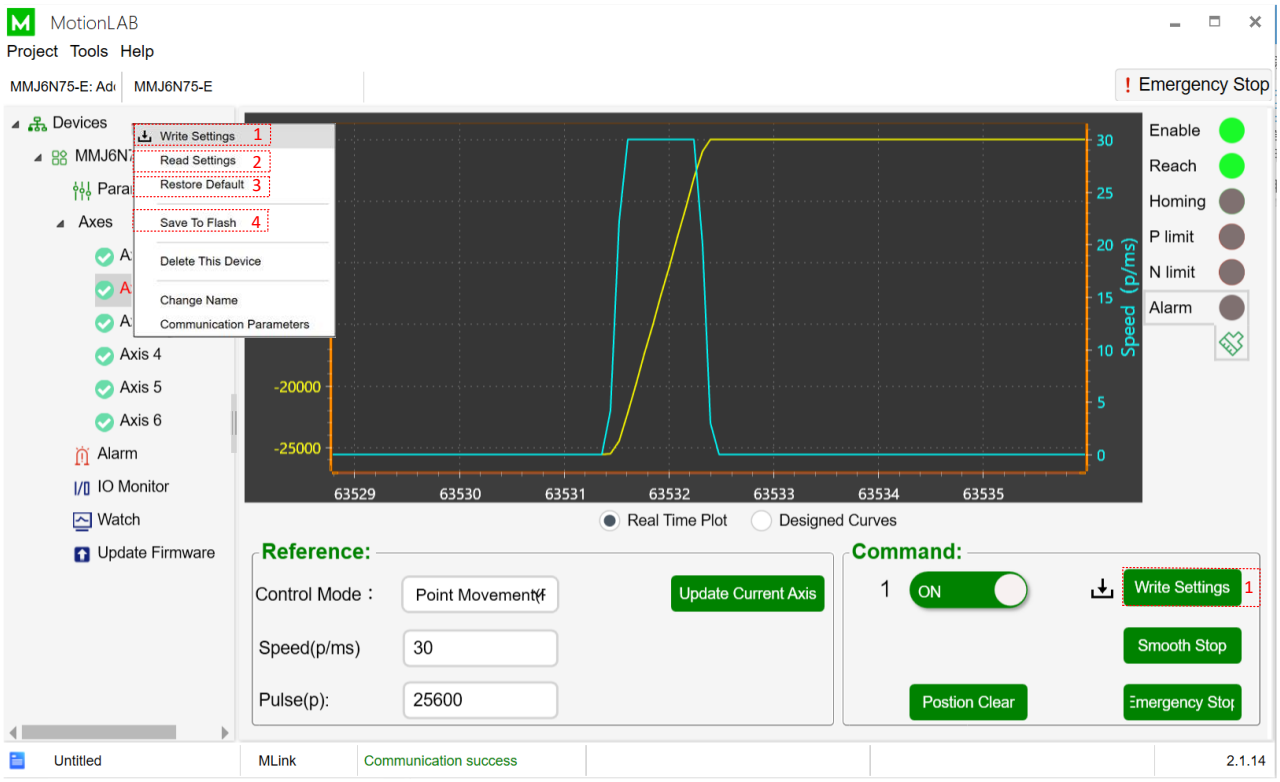


Figure 19: MotionLAB Parameters Read and Save Interface

When MotionLAB completes read-write operations, as shown in Figure 19, there are marked keys, described below:

1. Load parameters: Write the current control parameters of the MotionLAB into the motor. This instruction should be sent after the new configuration. Control words, status words, operating modes, and trajectory planning parameters do not require this function to update.
2. Read parameters: Read the control parameters in the current motors to the MotionLAB display.
3. Restore default parameters: Restore all parameters to the factory default values.
4. Save to motor: Save MotionLAB's current control parameters to the motor's NVM.

Table 17 shows how to use EtherCAT to read and write the specific “Special command” (object F50Bh).

Table 17: Related Command Code to Save Parameters

Function	Code	Description
Save to Motor	0x65766173	Save all user parameters to the drive’s NVM.
Restore Default	0x64616F6C	Restore all parameters to the factory defaults.
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.

3.5.2 Related Objects

Table 18: Related Objects to Save Parameters

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
F50Bh	00h	Special command	R/W	No	UINT32	-	UINT32	0

3.5.3 Application Examples

Table 19 shows an example when saving parameters.

Table 19: Application Example to Save Parameters

Steps	Index and Sub-Index	Data	Description
1	F50Bh	0x65766173	Save all user parameters to the drive’s NVM.

3.6 Trial Operation

After the necessary parameter settings are written to the driver, a trial operation can begin. It is recommended to use MotionLAB for the trial operation.

3.6.1 Stepper Motor Start

When running the motor for the first time, set the appropriate motion mode and motion trajectory to ensure that the motor rotates at a low speed and confirm whether the motor rotation is normal. It is recommended to use jog motion mode to confirm whether the stepper motor can work normally and that there is no abnormal vibration or sound when rotating. Confirm whether the motor’s position information and speed information are abnormal, and check whether the motor is running according to the set movement trajectory.

After the above motor operation status is confirmed, the relevant parameters can be adjusted to make the motor work under the expected conditions.

3.6.2 Stepper Motor Stop

To stop the motor, choose one of three methods: halt, quick stop, and shutdown drive.

There are two types of halts: smooth stop and emergency stop (denoted as 3 and 4 in Figure 20 on page 38, respectively). The halting type can be configured via the halt option.

Quick stop mode supports three shutdown modes, which can be selected according to the quick stop option, and the power output turns off after shutdown is complete. The shutdown drive directly shuts down the power output (denoted as 1 in Figure 20 on page 38, which changes from start to stop).

Table 20 on page 38 shows the three stopping modes for halt, quick stop, and shutdown drive using axis 1 as an example.

Table 20: Three Ways to Stop

Stop Methods	Register Operations	Stop Modes	Description
Halt	• Write “Control word” (object 6040h), bit[9] to 1 • Write “Halt option code 1” (object 605Dh) to 1	1	The halt mode is a smooth stop. The motor decelerates from the current speed to a standstill according to “Slowdown stop time 1” (2030h), and the drive switches on.
	• Write “Control word” (object 6040h), bit[9] to 1 • Write Halt option code (object 605Dh) to 2	2	The halt mode is an emergency stop. The motor stops immediately and the drive switches on.
Quick stop	• Write “Control word” (object 6040h) to 0x0B • Write “Quick stop option code 1” (object 605Ah) to 0	0	Directly turn off the driver. The driver status immediately switches to the switch on disabled state.
	• Write “Control word “(object 6040h) to 0x0B • Write “Quick stop option code 1” (object 605Ah) to 1	1	Deceleration stops. After shutdown is completed, the drive switches to the switch on disabled state.
	• Write “Control word” (object 6040h) to 0x0B • Write the quick stop option code (object 605Ah) to 2	2	Emergency shutdown. The drive switches to switch on disabled state.
Disable the driver	Write “Control word” (object 6040h) to 0x06	-	Directly turn off the driver. The driver switches to the switch on disabled state.

3.6.3 Stepper Motor Fault

If the driver fails during operation, the motor stops and enters a state without power output, depending on the type of fault and selected shutdown method. For the fault type, see Section 6.1 on page 58 and Section 6.2 on page 58. At this time, MotionLAB displays the fault status.

Click the alarm interface to check the corresponding fault cause (denoted as 7 in Figure 20 on page 38) to. Click the clear alarm button to reset the last fault (denoted as 6 in Figure 20 on page 38).

Table 21 shows the failure shutdown modes.

Table 21: Failure Shutdown Mode

Type of Failure	Register Operations	Stop Modes	Description
Motion fault	Write “Fault reaction option code 1” (object 605Eh) to 0	0	Free shutdown. The status switches to the disabled state.
	Write “Fault reaction option code 1” (object 605Eh) to 1	1	Deceleration stops. The status switches to switch on disabled.
	Write “Fault reaction option code 1” (object 605Eh) to 2	2	Emergency shutdown. The drive switches to the switch on disabled state.
Driver fault	-	-	Emergency shutdown. The drive switches to the switch on disabled state

Table 23 on page 41 shows the transition events and actions as well as the different types of faults that can cause shutdowns using axis 1 as an example.

3.6.4 Related Objects

Table 22: Related Objects to Stop

Index	Sub-Index	Descriptions	Access	PDO	Data Type	Unit	Range	Default
2030h	00h	Slowdown stop time	R/W	No	UINT16	ms	UINT16	1000
6040h	00h	Control word	R/W	RPDO	UINT16		UINT16	0
6041h	00h	Status word	R/O	TPDO	UINT16		UINT16	0
605Ah	00h	Quick stop option code	R/W	No	INT16		0-2	2
605Dh	00h	Halt option code	R/W	No	INT16		0-2	1
605Eh	00h	Fault reaction option code	R/W	No	INT16		0-2	2

Figure 20 shows the MotionLAB control interface.

Figure 20: MotionLAB Motion Control Interface

When MotionLAB is used to complete trial operations, Figure 20 shows the marked keys, described in greater detail below:

1. Drive on/off: When the drive is enabled, the drive is in the enabled power output state. If no motion instruction is input at this time, the stepper motor does not rotate and is in the positioning state. When the drive turns off, the drive is in a state without power output, and the motor stops running.
2. Update: The motion mode and related trajectory parameters are written to the driver, and the motor runs according to the set motion parameters.

3. Smooth stop: If the motor is in a rotating state, the motor decelerates to rest according to the set deceleration time.
4. Emergency stop: If the motor is in a rotating state, the motor stops immediately.

Section 4. Motion Control

4.1 State Machine

4.1.1 Function Description

The driver uses a finite state machine (FSM) to control the motor's state transition. The state changes according to the current state, control word or local signals, and fault signals. Figure 21 shows the finite state automation diagram.

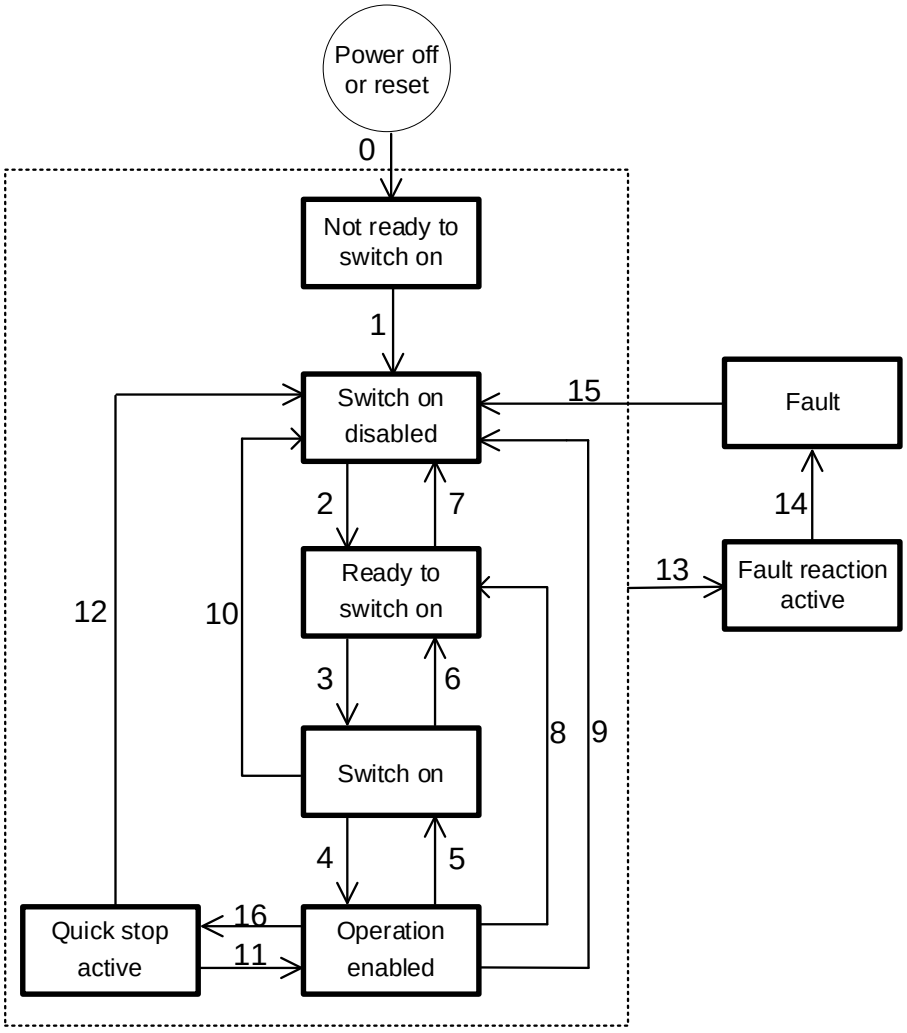


Figure 21: Motion Control Finite State Machine

The drive device should support the transitions and relevant actions (see Table 23 on page 41). The events shall initiate the transition. The transition is terminated after the action has been performed.

Table 23: 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 24 shows the command codes for “Control word” (object 6040h) while using the “Control word” (object 6040h) of the first axis as an example. In this table, “x” means the value can be 0 or 1.

Table 24: Command Codes for “Control Word”

Command	Bits of “Control Word”					Transitions
	Bit[7]	Bit[3]	Bit[2]	Bit[1]	Bit[0]	
Shutdown	0	x	1	1	0	2, 6, 8
Switch on	0	0	1	1	1	3
Switch on + enable operation	0	1	1	1	1	3 + 4
Disable voltage	0	x	x	0	x	7, 9, 10, 12
Quick stop	0	x	0	1	x	5
Disable operation	0	0	1	1	1	4, 16
Enable operation	0	1	1	1	1	15

Table 25 shows the bit combinations that code the power drive system (PDS) finite state automaton (FSA) states.

Table 25: Status Word Coding

Statusword	State
xxxx xxxx x0xx 0000	Not ready to switch on
xxxx xxxx x1xx 0000	Switch on disabled
xxxx xxxx x01x 0001	Ready to switch on
xxxx xxxx x01x 0011	Switch on
xxxx xxxx x01x 0111	Operation enabled
xxxx xxxx x00x 0111	Quick stop active
xxxx xxxx x0xx 1111	Fault reaction active
xxxx xxxx x0xx 1000	Fault

4.1.2 Related Objects

Table 26: Related Objects for State Machine

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	-

4.2 Operation Mode

4.2.1 Function Description

The MMJ6N7X-E supports Profile Position Mode (PP), Homing Mode (Homing), Cyclic Synchronous Profile Mode (CSP), and Jog Motion (Jog). The choice of mode is achieved by changing the value of “Modes of operation 1” (object 6060h) (taking the first axis as an example). The relationship between the control mode and object 6060h is listed in Table 19.

Table 27: Relationship between the Control Mode and Object 6060h

Control Mode	Value in Object 6060h
Profile position mode	1
Homing mode	6
Cyclic synchronous profile mode	8
Jog mode	-1

When the operation mode is switched — that is, when the value of “Modes of operation 1” (object 6060h) changes — “Modes of Operation Display 1” (object 6061h) also updates the mode state synchronously.

4.2.2 Related Objects

Table 28: Related Objects for Operation Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-1 to +8	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +8	-

4.3 Profile Position (PP) Mode

4.3.1 Function Description

Profile position (PP) mode receives the user-set speed, acceleration, deceleration, and target position commands to design the trajectory (see Figure 22 on page 43). The stepper driver unit controls each axis to move from the initial position to the target position according to the designed trajectory.

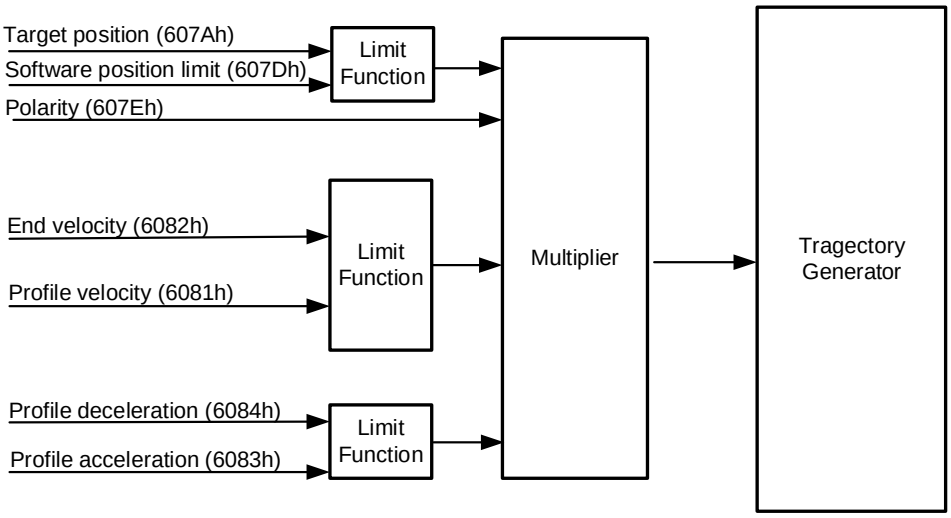


Figure 22: Profile Mode Trajectory Generator

PP mode supports two modes: an S-shaped curve and a trapezoidal curve, as set by “Motion profile type 1” (object 6086h). When the value of object 6086h is set to -1, the S-curve is selected; when its set to +1, a trapezoidal curve is selected.

Figure 23 on page 44 shows the trajectory planning curves generated by the motion control unit in S-curve mode. The velocity curve is S-shaped, and the acceleration curve is continuous. P_{TGT} represents the target position (set via “Target position 1” (object 607Ah)), V_{MAX} represents the profile velocity (indicated via “Profile velocity 1” (object 6081h)), V_{END} represents the end velocity (indicated via “End velocity 1” (object 6082h)), $Ā_{ACCE}$ represents profile acceleration (indicated via “Profile acceleration 1” (object 6083h)), $Ā_{DECE}$ represents profile deceleration (indicated via “Profile deceleration 1” (object 6084h)) of the deceleration process, and t_{SS} represents the smoothing time (set via “Smoothing time 1” (object 2000h)).

The typical motion trajectory curve is 7 segments, and the trajectory curve presents different profiles depending on the parameters set by the user.

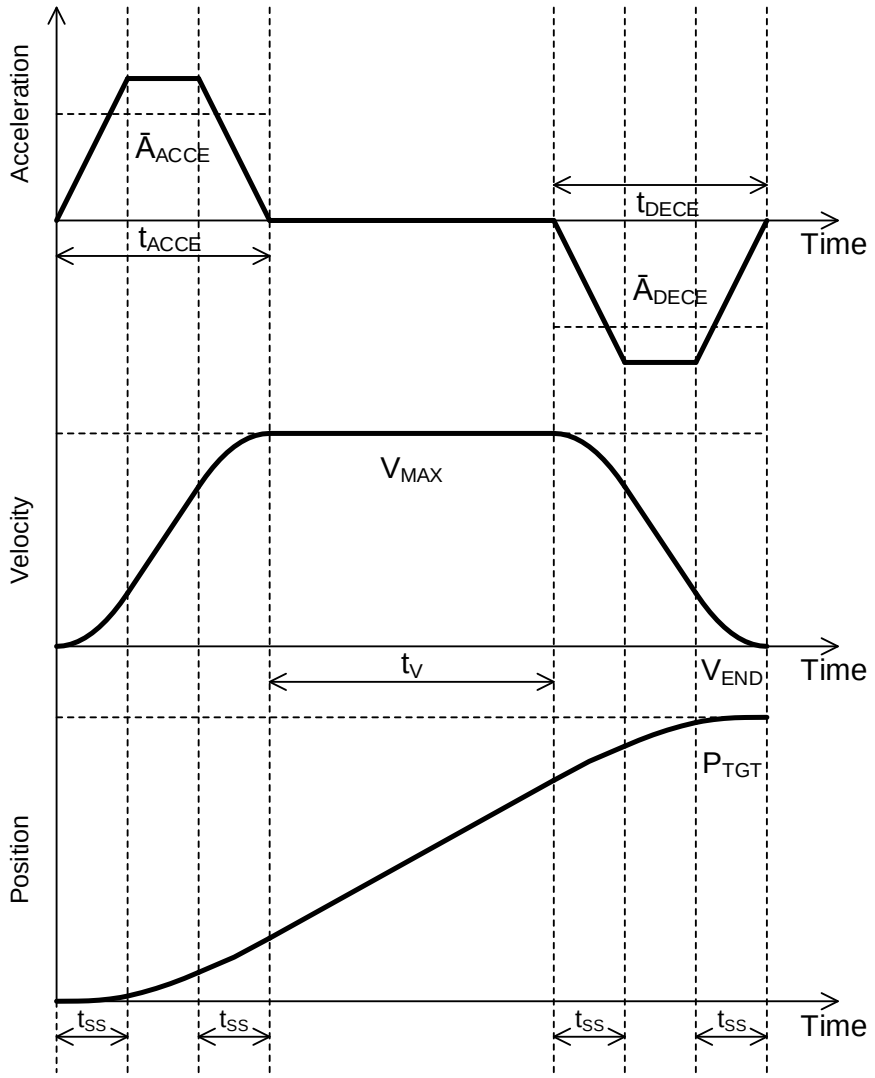


Figure 23: Diagram of the S-shaped Curve in PP Mode

Figure 24 on page 45 shows the trajectory planning curves generated by the motion control unit in trapezoidal curve mode. The velocity curve is trapezoidal and the acceleration curve is discontinuous. Except for the absence of a smoothing time, the parameters in trapezoidal curve mode are the same as those in S-curve mode.

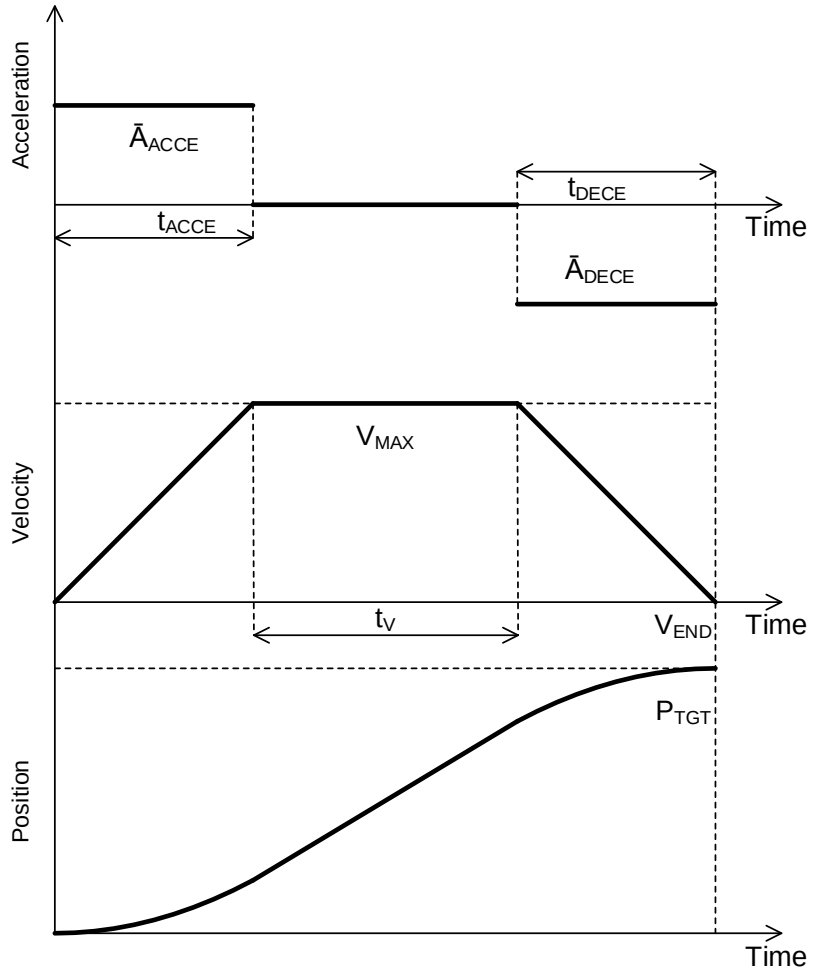


Figure 24: Diagram of the Trapezoidal Curve OF Point Movement

In PP mode, if the position command is updated during motor movement (“Control word” (object 6040h), bit[5] changes from 0 to 1), the target position updates immediately and the curve is updated. Figure 25 on page 46 shows a diagram of the trajectory curve when the target position is modified during movement. The black dotted line denotes the trajectory curve before the instruction is modified, while the red solid line denotes the trajectory curve after the instruction is modified.

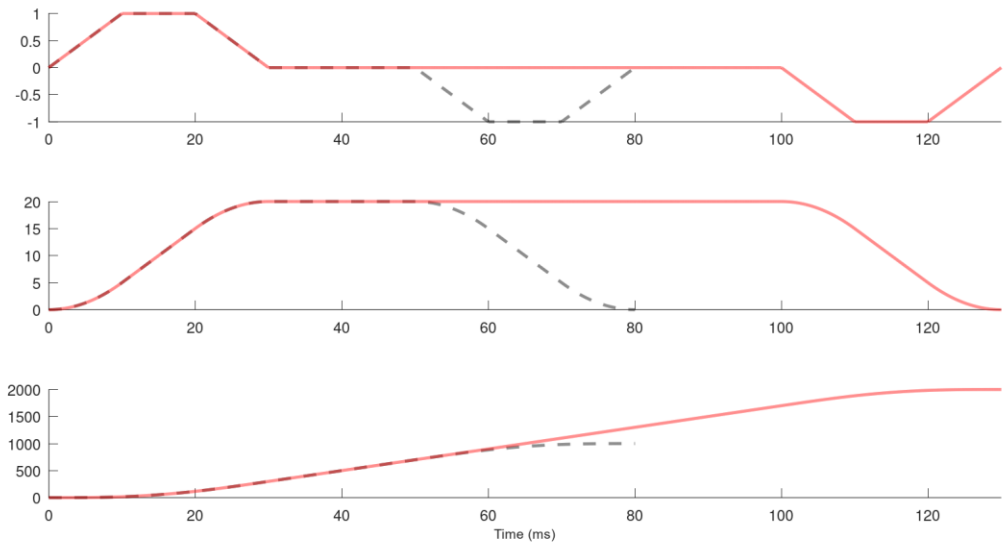


Figure 25: Update Position or Maximum Speed Commands During Motion

PP mode supports different position command modes, including the absolute position mode, relative target position mode, and relative current position mode, which can be set via “Control word” (object 6040h) and “Positioning option code 1” (object 60F2h). In absolute position mode, P_{TGT} is the target position based on the zero position. In relative target position mode, P_{TGT} is the target position based on the previous target position. In relative to current position mode, P_{TGT} is the target position based on the position at the time of the command update.

Figure 26 shows a diagram of the movement for the different position command modes. The motor stops after 100 pulses and receives a new P_{TGT} command for 200 pulses. The black arrow denotes the movement distance for 200 pulses. When moving to 150 pulses, the motor receives a new P_{TGT} command for 300 pulses. The red arrow denotes the movement distance for the next 300 pulses.

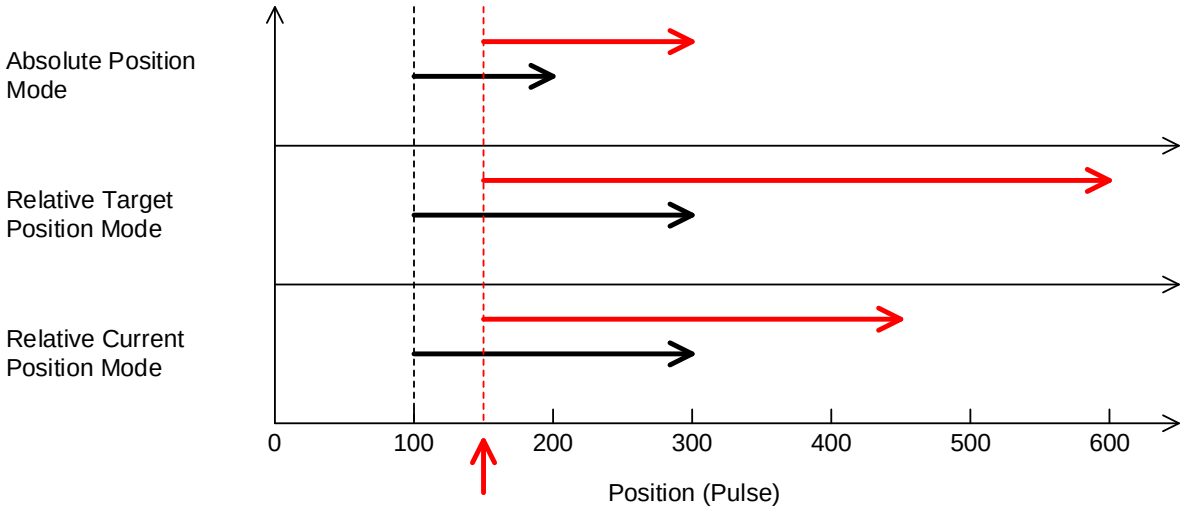


Figure 26: Diagram of the Movement of the Different Position Command Modes

4.3.2 Related Objects

Table 29 shows the object dictionaries required for the profile position pattern while using the first axis as an example.

Table 29: Related Objects for Profile Positions Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2000h	00h	Smoothing time	R/W	NO	UINT16	ms	UINT16	100
2001h	00h	Repetitive motion times	R/W	NO	UINT32	-	UINT32	1
2002h	00h	Repetitive motion mode	R/W	NO	UINT16	-	0 or 1	0
2003h	00h	Repetitive interval time	R/W	NO	UINT32	ms	UINT32	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	-	-1 to +8	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +8	-
6064h	00h	Position actual value	RO	TPDO	INT32	User unit	INT32	-
607Ah	00h	Target position	R/W	RPDO	INT32	User unit	INT32	256000
607Dh	01h	Min position limit	R/W	NO	INT32	User unit	INT32	-2000000
	02h	Max position limit	R/W	NO	INT32	User unit	INT32	2000000
6081h	00h	Profile velocity	R/W	RPDO	UINT32	User unit/s	UINT32	100000
6082h	00h	End velocity	R/W	RPDO	UINT32	User unit/s	UINT32	0
6083h	00h	Profile acceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
6084h	00h	Profile deceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
6086h	00h	Motion profile type	R/W	NO	INT16	-	0	0
60F2h	00h	Positioning option code	R/W	NO	UINT16	-	UINT16	0

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

Table 30: Use of “Control Word” and “Status Word” in PP Mode

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	The function is not defined					
8		Halt	1: Perform the stop action according to the pause option (605Dh-00h) shutdown mode 0: Invalid					
7		Fault reset	0 to 1: Performs an error reset					
6		Absolute/relative mode	0: Absolute position mode 1: Relative position mode					
5		Reserved	The function is not defined					
4		New set point	0 to 1: Updates the target position and profile motion parameters					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:13		Reserved	The function is not defined					
12		Set point acknowledge	1: The previous set value is still being processed, and the setting value can be overridden 0: The previous setting value has been processed; waiting for the new setting value					
10		Target reached	1: Positioning completed 0: Positioning is not complete					

4.3.4 Application Examples

Table 31 shows an example when controlling the first axis motor to operate in PP mode. The motor goes to 25600 pulses and then to 51200 pulses in absolute position mode.

Table 31: Application Example for PP Mode

Steps	Index - Sub-Index	Data	Description
1	6060h-00h	0x01	Sets the position of the operation mode bit profile.
2	6040h-00h	0x0006	Shutdown instructions.
3	6040h-00h	0x000F	Switch on + enables.
4	607Ah-00h	0x0000 6400	Set the target position to 25600 user units.
	6081h-00h	0x0001 86A0	The speed is set to 100,000 user units/s.
	6082h-00h	0x0000 0000	The final velocity is set to 0
	6083h-00h	0x0001 86A0	The average acceleration is set to 100,000 user units/s^2.
	6084h-00h	0x0001 86A0	The average deceleration is set at 100,000 user units/s^2.
5	6040h-00h	0x001F	The new target point is enabled.
6	6041h-00h	bit 10	Check the target arrival signs.
7	607Ah-00h	0x0000 C800	Set the target position to 51200 user units.
8	6040h-00h	0x000F	Clear the new target point start bit.
9	6040h-00h	0x001F	The new target point is enabled.

4.4 Homing Mode

4.4.1 Function Description

Homing mode finds the motor's zero point. The stepper driver usually uses the limit switch or home switch to research the zero point. The limit switch is placed at the first and last ends of the route, and the home switch is placed in the middle of the stroke. Depending on the limit switches and home switches, there are several different methods to implement homing.

The basic motion parameters include the homing method, homing acceleration, homing deceleration, switching speed, zero speed, home offset, and the maximum homing displacement.

The home offset represents the difference between the zero point and home switch. If the device finds its home switch during the homing process, then the device moves to the new zero point in point mode and resets the current position to zero (see Figure 27).

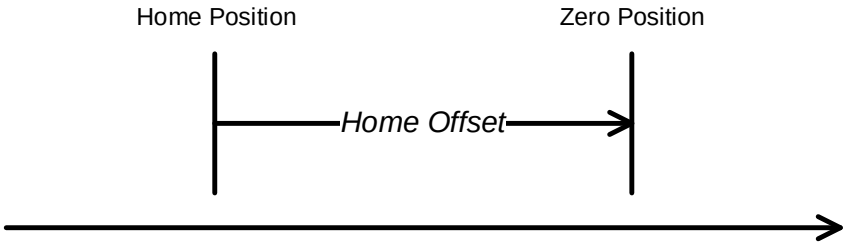
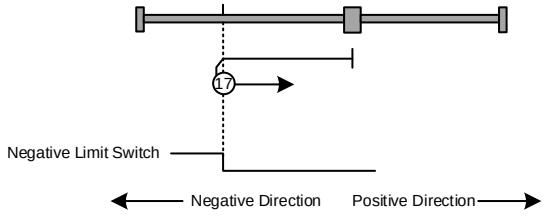
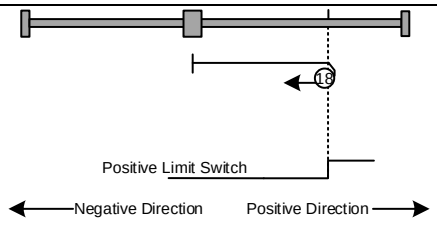
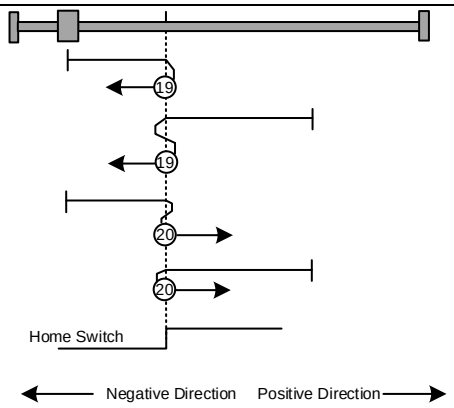
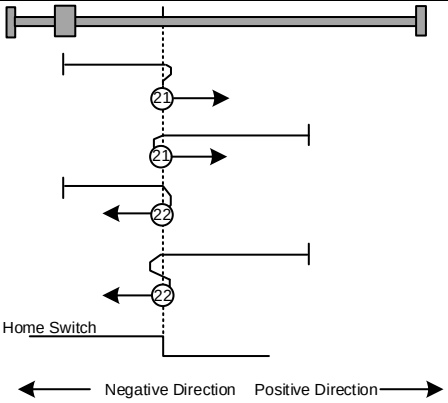
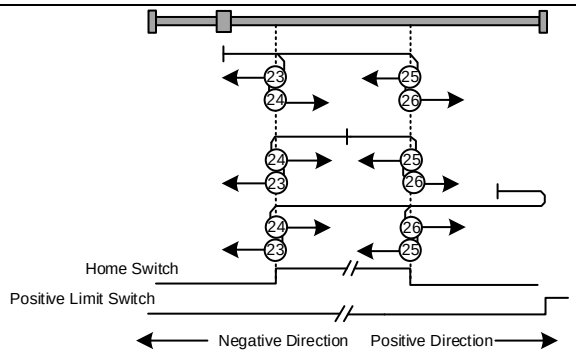
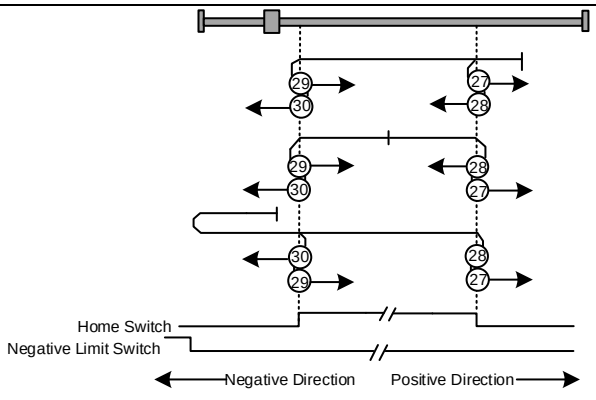


Figure 27: Home Offset Diagram

The stepper controller supports homing methods 17–30, as defined in the CiA DSP 402 standard. Table 32 shows descriptions and diagrams of each homing method.

Table 32: Related Description and Diagram of the Homing Method

Method	Description	Diagram
17	Homing on the negative limit switch.	
18	Homing on the positive limit switch.	

19, 20	Homing on the positive home switch.	
21, 22	Homing on the negative home switch.	
23–26	Homing on the home switch and index pulse — positive initial motion.	
27–30	Homing on the home switch and index pulse — negative initial motion.	

4.4.2 Related Objects

Table 33: Related Objects for Homing Mode

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2020h	00h	Homing maximum distance	R/W	No	UINT32	pulse	UINT32	5000000
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	-	-1 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +10	-
607Ch	00h	Home offset	R/W	NO	INT32	User units	INT32	0
6098h	00h	Homing method	R/W	RPDO	INT8	-	17 to 30	23
6099h	01h	Speed for switch	R/W	RPDO	UINT32	User unit/s	UINT32	50000
	02h	Speed for zero	R/W	RPDO	UINT32	User unit/s	UINT32	10000
609Ah	00h	Homing acceleration	R/W	RPDO	UINT32	User unit/s2	UINT32	0

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

Table 34: Use of “Control Word” and “Status Word” in Homing Mode

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:9		Reserved	This function is not defined.					
8		Halt	1: Perform the stop action according to the “Halt option code 1” (605Dh) 0: Invalid					
7		Fault reset	0 to 1: Performs an error reset					
6:5		Reserved	This function is not defined.					
4		Homing operation start	1: Enable the homing operation 0: Disable the homing action					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits			**Description**					
Bit[13]	**Bit[12]**	**Bit[10]**						
0	0	0	Homing is operating.					
0	0	1	Homing has not yet begun.					
0	1	1	Homing is successful.					
1	0	0	An error has occurred during homing, and the speed is not zero.					
1	0	1	An error has occurred during homing, and the speed is zero.					

4.4.4 Application Examples

Table 35 shows an example of a motor controlling the first axis while performing homing in mode 23.

Table 35: Application Example of Homing Mode

Steps	Index - Sub-Index	Data	Description
1	6060h-00h	0x06	Controls the motor to work in homing mode.
2	6040h-00h	0x0006	Shutdown instructions.
3	6040h-00h	0x000F	Switch on + enables.
4	8098h-00h	0x17	Sets the homing method to 23.
	6099h-01h	0x0000 C350	Sets the homing switch seed to 500,000 user units/s.
	6099h-02h	0x0000 2710	Sets the homing zero speed to 10,000 user units/s.
	609Ah-00h	0x0001 86A0	Sets the homing acceleration to 100,000 user units/s^2.
5	6040h-00h	0x001F	Enables homing mode to work.
6	6041h-00h	Bit[10] = 1, Bit[12] = 1, Bit[13] = 0	Homing success.

4.5 Cyclic Synchronous Position (CSP) Mode

4.5.1 Function Description

Unlike in PP mode, the trajectory generator in cyclic synchronous position (CSP) mode is in the control device, which provides the drive device with a target position given in a cyclic synchronization manner.

4.5.2 Related Objects

Table 36: Related Objects for 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	-	-1 to +8	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +8	-
6064h	00h	Position actual value	RO	TPDO	INT32	User units	INT32	-
606Ch	00h	Velocity actual value	RO	TPDO	INT32	User unit/s	INT32	-
607Ah	00h	Target position	R/W	RPDO	INT32	User units	INT32	0
607Dh	01h	Min position limit	R/W	NO	INT32	User units	INT32	-2e6
	02h	Max position limit	R/W	NO	INT32	User units	INT32	2e6

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

Table 37 shows that in CSP mode, “Control word” (object 6040h) does not have a specific function bit.

Table 37: Use of “Control Word” and “Status Word” in CSP Mode

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
12		Target position ignored	1: The target position is used as the input to the position control loop 0: Ignores the target position					

4.5.4 Application Examples

Table 38 shows an example of a motor controlling the first axis operating in CSP mode.

Table 38: Application Example for CSP Mode

Steps	Index - Sub-Index	Data	Description
1	6060h-00h	0x08	The control motor works in CSP mode.
2	6040h-00h	0x0006	Shutdown instructions.
3	6040h-00h	0x000F	Switch on + enables.

4.6 Jog Mode

4.6.1 Function Description

Jog motion mode means that when the control button is pressed, the motor moves to the maximum speed with the set acceleration, and then runs at a constant speed. After the control button is released, the motor decelerates to a standstill with the set deceleration. The jog motion has two buttons, forward and reverse, which can control the forward and reverse movement of the motor independently. When the positive direction of motion set by the user is opposite to the default positive direction, the direction can be unified by setting “Polarity” (object 607Eh), bit[7] to 1.

Figure 28 shows a diagram of the rotational speed command for the jog movement. V_{TGT} is the target speed, D_{POS} is the forward motion instruction, and D_{NEG} is the negative motion command. The green curve denotes the acceleration waveform, and the red curve denotes the deceleration waveform. The jog motion supports the modification of the target speed during the movement.

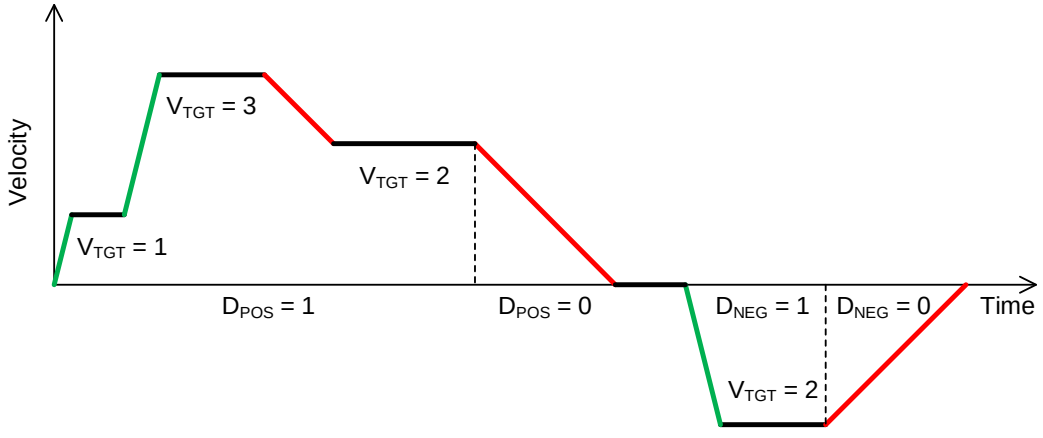


Figure 28: Diagram of the Jog Movement

4.6.2 Related Objects

Table 39: Related Objects for Jog Mode

Index	Sub-Index	Description	Access	POD	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	-	-1 to +10	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +10	-
2010h	00h	Jog acceleration	R/W	RPDO	UINT32	pulse/s^2	UINT32	100000
2011h	00h	Jog deceleration	R/W	RPDO	UINT32	pulse/s^2	UINT32	100000
2012h	00h	Jog target velocity	R/W	RPDO	UINT32	pulse/s	UINT32	100000
2013h	00h	Jog positive direction	R/W	RPDO	UINT16	-	0 or 1	0
2014h	00h	Jog negative direction	R/W	RPDO	UINT16	-	0 or 1	0

4.6.3 Application Examples

Table 40 shows an example of a motor controlling the first axis while running in jog mode, and while the direction of motion is in the forward direction.

Table 40: Application Example in Jog Mode

Steps	Index - Sub-Index	Data	Description
1	6060h-00h	-1	Controls the motor to work in jog mode.
2	6040h-00h	0x0006	Shutdown instructions.
3	6040h-00h	0x000F	Switch on + enables.
4	2010h-00h	0x0001 86A0	The jog acceleration is set to 100,000 pulse/s^2.
	2011h-00h	0x0001 86A0	The jog acceleration is set to 100,000 pulse/s^2.
	2012h-00h	0x0001 86A0	The jog target speed is set to 100,000 pulse/s.
5	2013h-00h	0x0001	The motor moves in the forward direction.
6	2013h-00h	0x0000	The motor decelerates and stops.

Section 5. Stepper Driver

5.1 Basic Settings

5.1.1 Function Description

Each axis of the stepper driver supports separate subdivision, operating current, and idle current settings. The controller supports the following settings: full-step, half-step, 4 subdivisions, 8 subdivisions, 16 subdivisions, 32 subdivisions, 64 subdivisions, 128 subdivisions, 256 subdivisions, and 512 subdivisions. The idle current is set as a percentage of the working current with the range from 0% to 100%.

Each axis of the stepper driver supports a maximum operating current of 5A (5A version). When multiple axes are used at the same time, it is recommended to use the peak current limit of the multiple axes when considering heat generation. The multi-axis peak current is limited to 4A when a 24V power supply is provided; the multi-axis peak current is limited to 3A when the 48V power supply is provided.

5.1.2 Related Objects

Table 41: Related Objects of Stepper Driver Setting

Index	Sub-Index	Description	Read and Write Type	PDO	Data Type	Unit	Range	Default
2070h	00h	Drive control	R/W	NO	UINT16	-	-	0x0F07
2071h	00h	Idle current	R/W	NO	UINT16	%	0 to 100	50
2072h	00h	Operating current	R/W	NO	UINT16	(1/256) A	0 to 5A	256

5.1.3 Application Examples

Table 42 shows an example when setting the stepper drive parameter to 128 subdivisions with a 1A operating current and 50% idle current.

Table 42: Application Example of Stepper Driver Setting

Steps	Index- Sub-Index	Data	Description
1	2070h-00h	0x0F07	Sets the step segment to 128 segments (25600 pulse on the lap).
2	2071h-00h	50	Sets the idle current to 50%.
3	2072h-00h	256	Sets the operating current to 1A.

5.2 Current Control

5.2.1 Function Description

The stepper controller uses field-oriented control (FOC) to drive the stepper motor. When using FOC, the currents of phase A and phase B must be transformed into the D-Q axis coordinate system through the Park transform. Then the D-axis current and Q-axis current are controlled by the PI controller. The output voltages of the PI controllers are converted back to the A-B axis coordinate system by the IPark transform. Then the four pulse-width modulation (PWM) signals required to drive the stepper motor are generated through the space vector pulse-width modulation (SVPWM).

Figure 29 on page 56 shows the motor's FOC block diagram.

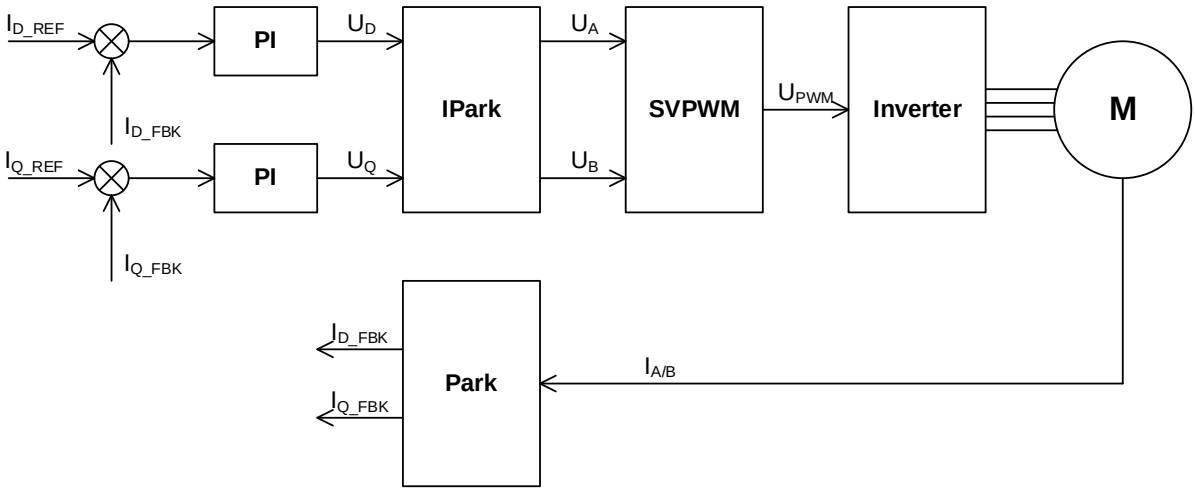


Figure 29: Motor FOC Control Block Diagram

The current PI controller in FOC affects the stepper motor's dynamic and steady-state performance and operation. When designing a PI controller, the motor winding parameters must be set. To improve control performance, it is recommended that the user write the correct parameters and set the appropriate current loop bandwidth before use.

5.2.2 Related Objects

Table 43: Related Objects for Stepper Driver Current Control

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2074h	00h	Phase resistance	R/W	NO	UINT16	mΩ	UINT16	758
2075h	00h	Phase inductance	R/W	NO	UINT16	μH	UINT16	2728
2077h	00h	Current loop bandwidth	R/W	NO	UINT16	Hz	0 to 1000	100

5.2.3 Application Examples

Table 44 shows an example when setting the parameters of a current loop.

Table 44: Application Example for Stepper Driver Current Control

Steps	Index - Sub-Index	Data	Description
1	2074h-00h	758	Sets the phase resistance to 758mΩ.
2	2075h-00h	2728	Sets the phase inductance to 2728μH.
3	2077h-00h	100	Sets the current loop bandwidth to 100Hz.

Section 6. Fault and Protection

Stepper drivers provide a great deal of protection against damage to the system during use. When the motor fails, the fault indicator corresponding to the motor turns red. Faults are mainly divided into drive faults and motion faults, and users can query the fault type via “Error state 1” (object 2056h) . Users can also check “Error code 1” (object 603Fh) if over-current (OC), under-voltage (UV), or over-temperature (OT) protection occur. The user can set the fault shutdown mode via “Fault reaction option code 1” (object 605Eh). If a motor fault is reported, the state of the axis switches to fault reaction active. The motor speed is reduced according to “Fault reaction option code 1” (object 605Eh), then automatically switches to the fault state.

6.1 Driver Fault

6.1.1 Over-Current Protection (OCP)

If the current flowing through any phase of the motor exceeds the over-current protection (OCP) threshold set via “OCP threshold 1” (object 2073h), the driver shuts down the power stage output and reports the OC fault. The OCP threshold is set based on a percentage of the operating current. The maximum values for the OCP threshold are 3A (for the 2A version) and 6A (for the 5A version). OCP can be enabled or disabled via “Drive control 1” (object 2070h), bit[8].

6.1.2 Over-Voltage Protection (OVP)

If the device detects that the bus voltage exceeds the over-voltage protection (OVP) threshold set via “OVP threshold 1” (object 2079h), the driver shuts down the power stage output and reports an OV fault. OVP can be enabled or disabled via “Drive control 1” (object 2070h), bit[9].

6.1.3 Under-Voltage Lockout (UVLO) Protection

If the device detects that the bus voltage is below the under-voltage lockout (UVLO) threshold set via “UVLO threshold 1” (object 207Ah), the driver shuts down the power stage output and reports a UV fault. UVLO can be enabled or disabled via “Drive control 1” (object 2070h), bit[10].

6.1.4 Over-Temperature Protection (OTP)

If the device detects that the driver board temperature is above the thermal shutdown (TSD) threshold set via “TSD threshold 1” (object 207Bh), the driver shuts down the power stage output and reports an OT fault. OTP can be enabled or disabled via “Drive control 1” (object 2070h), bit[11].

6.1.5 Open-Phase Protection (OPP)

When the driver powers up, it outputs a voltage and detects the current flowing through both phases of the motor. If the current is below than the open-phase protection (OPP) maximum duty set via “OPP maximum duty 1” (object 207Fh), the driver report a phase fault failure. Phase loss protection cannot be removed.

6.1.6 Over-Temperature Warning

If the device detects that the driver board exceeds the OTP threshold set via “OTP threshold 1” (object 207Ch) but is below the TSD threshold set via “TSD threshold 1” (object 207Bh), the driver reports an over-temperature warning, and the driver does not turn off the output of the power stage.

6.2 Motion Fault

6.2.1 Hardware Limit Protection

During motor movement, if the hardware limit protection is enabled, when the motor reaches the limit switches, it will trigger a shutdown and reports the hardware limit fault. There are three shutdown modes to select which are determined by “Fault Reaction option code 1”(object 605Eh). . In homing mode, the limit switch can also be used as a signal for homing. In this scenario, a protection is not triggered, even the hardware limit protection is enabled when the motor reaches the limit switches. If the limit switch is not used as a signal for homing, then the limit switch triggers a protection when the motor reaches the

limit switches when hardware limit protection is enabled. Hardware limit protection can be enabled or disabled via “Stop enable 1” (object 2040h), bit[1].

6.2.2 Software Limit Protection

During motor movement, if the current position exceeds the travel range set via “ Min position limit 1” (object 607Dh-01h) or “ Max position limit 1” (object 607Dh-02h), the motor triggers a shutdown and reports the software limit fault. There are three shutdown modes to select, which are determined by “Fault Reaction option code 1”(object 605Eh). . Software limit protection can be enabled or disabled via “Stop enable 1” (object 2040h), bit[2].

The value of the software’s positive and negative limits are the absolute position relative to the zero point. If the home offset is not 0, the user must correct the values for the software positive and negative limits. The corrected minimum position limit and corrected maximum position limit can be calculated with Equation (5) and Equation (6), respectively:

$$\text{Corrected Min Position Limit} = \text{Min Position Limit} - \text{Home Offset} \quad (5)$$

$$\text{Corrected Max Position Limit} = \text{Max Position Limit} - \text{Home Offset} \quad (6)$$

6.2.3 Homing Protection

During homing, the motor’s maximum homing distance set via “Homing maximum distance 1” (object 2020h) can be limited. This prevents the motor from running incorrectly due to a limit switch failure. If the absolute coordinates of the current position exceed the maximum displacement, the motor triggers a shutdown and reports a maximum homing displacement fault. There are three shutdown modes to select which are determined by “Fault reaction option code 1”(object 605Eh).

6.2.4 Position Error Warning

When the system successfully finds the zero point through the homing mode, the position coordinates are cleared. In the next movement of the motor, whenever the motor passes through the home switch, the driver compares the position coordinates to the home switch’s coordinates. If the difference between the two coordinates exceeds the error window defined via “Following error window 1” (object 6065h), the driver reports a large position error warning.

6.3 Stop Reason Instruction

If there is a drive failure or motion failure, the motor stops in an emergency. At this point, “Stop state 1” (object 2057h) indicates the reason for the motor’s shutdown. In addition to a shutdown due to a drive failure or motion failure, there are also emergency shutdowns, I/O shutdowns, and shaft shutdowns. If there is an emergency stop command, the axis’s status switches to switch disabled.

6.4 Fault Clear

In the event of a fault, the corresponding “Error state 1” (object 2056h) is set to 1, the shaft remains in the fault state, and the red light of the corresponding shaft on the drive is lit. Before the next movement, send the fault reset command (the rising edge of “Control word” (6040h), bit[7]) to the shaft. The shaft enters the switch on disabled state and sends the “switch on + enable operation” command to re-enable the motor so that it works. To clear all the faults of all the axes at the same time, write 0x11111121 to “Special command” (object F50Bh).

6.5 Alarm History

In the event of a fault, the motor adds the current fault to the historical alarm and saves it to the NVM. The stepper drive stores the last 20 failures. To clear all the historical alarms at the same time, write 0x11111120 to “Special command” (object F50Bh).

6.6 Related Objects

Table 45: Related Objects for Fault and Protection

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
2020h	00h	Homing maximum distance	R/W	No	UINT32	pulse	UINT32	5e6
2030h	00h	Slowdown stop time	R/W	No	UINT16	ms	UINT16	1000
2040h	00h	Stop enabled	R/W	No	UINT16	-	-	0
2056h	00h	Error state	RO	No	UINT32	-	-	-
2057h	00h	Stop state	RO	No	UINT16	-	-	-
2070h	00h	Drive control	R/W	No	UINT16	-	-	0x0F07
2073h	00h	OCP threshold	R/W	No	UINT16	%	0 to 1000	200
2079h	00h	OVP threshold	R/W	No	UINT16	(1/256)V	UINT16	18432
207Ah	00h	UVLO threshold	R/W	No	UINT16	(1/256)V	UINT16	4608
207Bh	00h	TSD threshold	R/W	No	UINT16	°C	UINT16	150
207Ch	00h	OTP threshold	R/W	No	UINT16	°C	UINT16	125
605Ah	00h	Quick stop option code	R/W	No	UINT16		UINT16	0
605Eh	00h	Fault reaction option code	R/W	No	INT16	-	0 to 2	0
6065h	00h	Following error window	R/W	No	UINT32	User units	UINT32	2e5
607Dh	01h	Min position limit	R/W	No	UINT32	pulse	INT32	2e6
607Dh	02h	Max position limit	R/W	No	UINT32	pulse	INT32	-2e6

6.7 Application Examples

Table 46 shows an example of setting up protection-related registers.

Table 46: Application Example for Fault and Protection

Steps	Index-Sub-Index	Data	Description
1	2020h-00h	5e6	The maximum homing displacement is set to 5e6 pulses.
	2021h-00h	2e5	The following error window is set to 2e5 pulses.
	2073h-00h	200	The OCP threshold is set to 200% of the operating current.
	2079h-00h	18432	The OVP threshold is set to 72V.
	207Ah-00h	4068	The UVLO threshold is set to 18V.
	207Bh-00h	150	The TSD threshold is set to150°C.
	207Ch-00h	125	The OTP threshold is set to 125°C.
	605Eh-01h	-2e6	The software negative limit coordinates are set to -2e6 pulses.
	605E h-02h	2e6	The software positive limit coordinates are set to 2e6 pulses.
2	2041h-00h	3	Enables hardware limit shutdown and software limit shutdown.

Section 7. Object Dictionary

The six-axis driver shares the same object dictionary definition. Only the index has a certain offset for a different axis (see Table 47).

Table 47: Object dictionary offset

Object Dictionary Group	Offset	Description
1000h group	10h	Sets the communication parameter. See an example below. 1600h: Axis 1 RPDO mapping 1 1610h: Axis 2 PROD mapping 1
2000h group	100h	Sets manufacture-specific objects. See an example below. 2000h: Axis 1 smoothing time 2100h: Axis 2 smoothing time
6000h group	800h	Sets device profile objects, defined in the CiA402 standard. See an example below. 6040h: Axis 1 control word 6840h: Axis 2 control word

7.1 Axis 1 Object Dictionary Group

7.1.1 1000h Group

Table 48: 1000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
RPDO Mapping 1								
1600h	00h	Number of mappings	RO	NO	UINT8	-	-	03h
	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	-	-	0
	05h	RPDO mapping object 5	R/W	NO	UINT32	-	-	0
	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 object 11	R/W	NO	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	NO	UINT32	-	-	0

Table 48: 1000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
RPDO Mapping 2								
1601h	00h	Number of mappings	RO	NO	UINT8	-	-	09h
	01h	RPDO mapping object 1	R/W	NO	UINT32	-	-	60400010 h
	02h	RPDO mapping object 2	R/W	NO	UINT32	-	-	60600008 h
	03h	RPDO mapping object 3	R/W	NO	UINT32	-	-	607A0020 h
	04h	RPDO mapping object 4	R/W	NO	UINT32	-	-	607E0008 h
	05h	RPDO mapping object 5	R/W	NO	UINT32	-	-	607F0020 h
	06h	RPDO mapping object 6	R/W	NO	UINT32	-	-	60810020 h
	07h	RPDO mapping object 7	R/W	NO	UINT32	-	-	60820020 h
	08h	RPDO mapping object 8	R/W	NO	UINT32	-	-	60830020 h
	09h	RPDO mapping object 9	R/W	NO	UINT32	-	-	60840020 h
	0Ah	RPDO mapping object 10	R/W	NO	UINT32	-	-	0
	0Bh	RPDO mapping object 11	R/W	NO	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	NO	UINT32	-	-	0
RPDO Mapping 3								
1602h	00h	Number of mappings	RO	NO	UINT8	-	-	07h
	01h	RPDO mapping object 1	R/W	NO	UINT32	-	-	60400010 h
	02h	RPDO mapping object 2	R/W	NO	UINT32	-	-	60600008 h
	03h	RPDO mapping object 3	R/W	NO	UINT32	-	-	607E0008 h
	04h	RPDO mapping object 4	R/W	NO	UINT32	-	-	60980008 h
	05h	RPDO mapping Object 5	R/W	NO	UINT32	-	-	60990120 h
	06h	RPDO mapping object 6	R/W	NO	UINT32	-	-	60990220 h
	07h	RPDO mapping object 7	R/W	NO	UINT32	-	-	609A0020 h
	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 object 11	R/W	No	UINT32	-	-	0

Table 48: 1000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
1602h	0Ch	RPDO mapping object 12	R/W	No	UINT32	-	-	0
RPDO Mapping 4								
1603h	00h	Number of mappings	RO	NO	UINT8	-	-	08h
	01h	RPDO mapping object 1	R/W	NO	UINT32			60400010h
	02h	RPDO mapping object 2	R/W	NO	UINT32	-	-	20100020h
	03h	RPDO mapping object 3	R/W	NO	UINT32	-	-	20110020h
	04h	RPDO mapping object 4	R/W	NO	UINT32	-	-	20120020h
	05h	RPDO mapping object 5	R/W	NO	UINT32	-	-	20130010h
	06h	RPDO mapping object 6	R/W	NO	UINT32	-	-	20140010h
	07h	RPDO mapping object 7	R/W	NO	UINT32	-	-	60600008h
	08h	RPDO mapping object 8	R/W	NO	UINT32	-	-	607E0008h
	09h	RPDO mapping object 9	R/W	NO	UINT32	-	-	0
	0Ah	RPDO mapping object 10	R/W	NO	UINT32	-	-	0
	0Bh	RPDO mapping object 11	R/W	NO	UINT32	-	-	0
	0Ch	RPDO mapping object 12	R/W	NO	UINT32	-	-	0
TPDO Mapping 1								
1A00h	00h	Number of mappings	RO	NO	UINT8	-	-	05h
	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	-	-	60FD0020h
	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

Table 48: 1000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
TPDO Mapping 1								
1A00h	0Bh	TPDO mapping object 11	R/W	NO	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	NO	UINT32	-	-	0
TPDO Mapping 2								
1A01h	00h	Number of Mappings	RO	NO	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	NO	UINT32	-	-	60410010 h
	02h	TPDO mapping object 2	R/W	NO	UINT32	-	-	60610008 h
	03h	TPDO mapping object 3	R/W	NO	UINT32	-	-	60640020 h
	04h	TPDO mapping object 4	R/W	NO	UINT32	-	-	606C0020 h
	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 object 11	R/W	NO	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	NO	UINT32	-	-	0
TPDO Mapping 3								
1A02h	00h	Number of mappings	RO	NO	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	NO	UINT32	-	-	60410010 h
	02h	TPDO mapping object 2	R/W	NO	UINT32	-	-	60610008 h
	03h	TPDO mapping object 3	R/W	NO	UINT32	-	-	60640020 h
	04h	TPDO mapping object 4	R/W	NO	UINT32	-	-	606C0020 h
	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

Table 48: 1000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
TPDO Mapping 3								
1A02h	0Ah	TPDO mapping object 10	R/W	NO	UINT32	-	-	0
	0Bh	TPDO mapping object 11	R/W	NO	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	NO	UINT32	-	-	0
TPDO Mapping 4								
1A03h	00h	Number of mappings	RO	NO	UINT8	-	-	04h
	01h	TPDO mapping object 1	R/W	NO	UINT32	-	-	60410010h
	02h	TPDO mapping object 2	R/W	NO	UINT32	-	-	60610008h
	03h	TPDO mapping object 3	R/W	NO	UINT32	-	-	60640020h
	04h	TPDO mapping object 4	R/W	NO	UINT32	-	-	606C0020h
	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 Ma mapping object 10	R/W	NO	UINT32	-	-	0
	0Bh	TPDO mapping object 11	R/W	NO	UINT32	-	-	0
	0Ch	TPDO mapping object 12	R/W	NO	UINT32	-	-	0

7.1.2 2000h Group

Table 49: 2000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
Controller Section								
2000h	00h	Smoothing time	R/W	NO	UINT32	ms	UINT32	100
2001h	00h	Repetitive motion times	R/W	NO	UINT32	-	UINT32	1
2002h	00h	Repetitive motion mode	R/W	NO	UINT16	-	0 or 1	0
2003h	00h	Repetitive interval time	R/W	NO	UINT32	ms	UINT32	100
2010h	00h	Jog acceleration	R/W	RPDO	UINT32	pulse/s^2	UINT32	100000
2011h	00h	Jog deceleration	R/W	RPDO	UINT32	pulse/s^2	UINT32	100000
2012h	00h	Jog target velocity	R/W	RPDO	UINT32	pulse/s	UINT32	100000
2013h	00h	Jog positive direction	R/W	RPDO	UINT16	-	0 or 1	0
2014h	00h	Jog negative direction	R/W	RPDO	UINT16	-	0 or 1	0

Table 49: 2000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
Controller Section								
2020h	00h	Homing maximum distance	R/W	NO	UINT32	pulse	UINT32	5000000
2030h	00h	Slowdown stop time	R/W	NO	UINT16	ms	UINT16	1000
2031h	**I/O Control**							
	00h	Max sub-index	RO	NO	UINT8	-	3	3
	01h	IO polarity	R/W	NO	UINT16	-	0 to 31	0x0000
	02h	IO simulation enable	R/W	NO	UINT16	-	0 to 15	0x0000
	03h	IO simulation input	R/W	NO	UINT16	-	0 to 15	0x0000
2032h	00h	IO function	R/W	NO	UINT16	-	0 to 127	0x0024
2033h	00h	Position clear	R/W	NO	UINT16	-	0 or 1	0
2040h	00h	Stop enable	R/W	NO	UINT16	-	0 to 7	2
2042h	00h	Touch probe position	RO	NO	INT32	User unit	INT32	-
2050h	00h	Actual acceleration	RO	NO	INT32	User unit/s^2	INT32	-
2052h	00h	Position reach	RO	NO	UINT16	-	0 or 1	-
2053h	00h	Positive limit state	RO	NO	UINT16	-	0 or 1	-
2054h	00h	Negative limit state	RO	NO	UINT16	-	0 or 1	-
2055h	00h	Homing state	RO	NO	UINT16	-	0 or 1	-
2056h	00h	Error state	RO	NO	UINT32	-	UINT32	-
2057h	00h	Stop state	RO	NO	UINT16	-	UINT16	-
Driver Section								
2070h	00h	Drive control	R/W	NO	UINT16	-	UINT16	0x0F07
2071h	00h	Idle current	R/W	NO	UINT16	%	0 to 100	50
2072h	00h	Operating current	R/W	NO	UINT16	(1/256) A	0 to 5A	256
2073h	00h	OCP threshold	R/W	NO	UINT16	%	0 to 1000	200
2074h	00h	Phase resistance	R/W	NO	UINT16	mΩ	UINT16	758
2075h	00h	Phase inductance	R/W	NO	UINT16	μH	UINT16	2728
2077h	00h	Current loop bandwidth	R/W	NO	UINT16	Hz	0 to 1000	100
2078h	00h	Axis firmware version	RO	NO	UINT16	-	UINT16	-
2079h	00h	OVP threshold	R/W	NO	UINT16	(1/256) V	0 to 100V	17920
207Ah	00h	UVLO threshold	R/W	NO	UINT16	(1/256) V	0 to 100V	4608
207Bh	00h	TSD threshold	R/W	NO	UINT16	°C	0 to 200	150
207Ch	00h	OTP threshold	R/W	NO	UINT16	°C	0 to 150	125
207Dh	00h	Driver temperature	RO	NO	INT16	°C	INT16	-
207Fh	00h	OPP maximum duty	R/W	NO	UINT16	0.05%	0 to 420	200

7.1.3 6000h Group

Table 50: 3000h Group

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
603Fh	00h	Error code	RO	TPDO	UINT16	-	UINT16	-
6040h	00h	Control word	R/W	RPDO	UINT16	-	UINT16	0

Table 50: 3000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word	RO	TPDO	UINT16	-	UINT16	-
605Ah	00h	Quick stop option code	R/W	NO	INT16	-	0 to 2	2
605Bh	00h	Shutdown option code	R/W	NO	INT16	-	0 or 1	0
605Ch	00h	Disable operation option code	R/W	NO	INT16	-	0 or 1	0
605Dh	00h	Halt option code	R/W	NO	INT16	-	0 to 2	1
605Eh	00h	Fault reaction option code	R/W	NO	INT16	-	0 to 2	2
6060h	00h	Modes of operation	R/W	RPDO	INT8	-	-1 to +8	0
6061h	00h	Modes of operation display	RO	TPDO	INT8	-	-1 to +8	-
6064h	00h	Position actual value	RO	TPDO	INT32	User unit	INT32	-
6065h	00h	Following error window	R/W	NO	UINT32	User unit	UINT32	200000
606Ch	00h	Velocity actual value	RO	TPDO	INT32	User unit/s	INT32	-
607Ah	00h	Target position	R/W	RPDO	INT32	User unit	INT32	256000
607Ch	00h	Home offset	R/W	NO	INT32	User unit	INT32	0
607Dh	**Software Position Limit**							
	00h	Max sub-index	RO	NO	UINT8	-	2	2
	01h	Min position limit	R/W	NO	INT32	User unit	INT32	-2000000
	02h	Max position limit	R/W	NO	INT32	User unit	INT32	2000000
607Eh	00h	Polarity	R/W	RPDO	UINT8	-	UINT8	0
607Fh	00h	Max profile velocity	R/W	RPDO	UINT32	User unit/s	UINT32	2000000
6081h	00h	Profile velocity	R/W	RPDO	UINT32	User unit/s	UINT32	100000
6082h	00h	End velocity	R/W	RPDO	UINT32	User unit/s	UINT32	0
6083h	00h	Profile acceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
6084h	00h	Profile deceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
6085h	00h	Quick stop deceleration	R/W	NO	UINT32	User unit/s^2	UINT32	100000
6086h	00h	Motion profile type	R/W	NO	INT16	-	0	0
6091h	**Gear Ratio**							
	00h	Max sub-index	RO	NO	UINT8	-	2	2
	01h	Motor shaft revolutions	R/W	NO	UINT32	REV	UINT32	1
	02h	Driving 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	User unit	UINT32	25600
	02h	Driving shaft revolutions	R/W	NO	UINT32	REV	UINT32	1
6098h	00h	Homing method	R/W	RPDO	INT8	-	17 To 30	23

Table 50: 3000h Group *(continued)*

Index	Sub-Index	Description	Access	PDO	Data Type	Unit	Range	Default
6099h	**Homing Speeds**							
	00h	Max sub-index	RO	RPDO	UINT8	-	2	2
	01h	Speed for switch	R/W	RPDO	UINT32	User unit/s	UINT32	50000
	02h	Speed for zero	R/W	RPDO	UINT32	User unit/s	UINT32	10000
609Ah	00h	Homing acceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
60C2h	**Interpolation Time Period**							
	00h	Max sub-index	RO	NO	UINT8	-	2	2
	01h	Interpolation time period value	R/W	NO	UINT8	-	UINT8	1
	02h	Interpolation time index	R/W	NO	INT8	-	-3	-3
60C5h	00h	Max acceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	10000000
60C6h	00h	Max deceleration	R/W	RPDO	UINT32	User unit/s^2	UINT32	10000000
60F2h	00h	Positioning option code	R/W	NO	UINT16	-	UINT16	0
60FDh	00h	Digital inputs	RO	TPDO	UINT32	-	UINT32	-
6502h	00h	Supported drive modes	RO	NO	UINT32	-	UINT32	0xA1

7.2 Axis Common Object Dictionary Group

Table 51: Axis-Common Object Dictionary Group

Index	Sub-Index	Description	Access	PDO	Access	Unit	Range	Default
F501h	00h	Motor connection state	RO	NO	UINT16	-	0 to 63	-
F504h	00h	Bus voltage	RO	NO	UINT16	(1/256) V	0V to 120V	-
F505h	00h	Part number	RO	NO	UINT16	-	UINT16	0x6720
F506h	00h	Firmware version number	RO	NO	UINT16	-	UINT16	-
F507h	00h	Hardware version number	RO	NO	UINT16	-	UINT16	-
F508h	00h	MLink address	R/W	NO	UINT8	-	UINT8	1
F509h	00h	MLink parity	R/W	NO	UINT8	-	0 to 2	2
F50Ah	00h	MLink baud rate	R/W	NO	UINT32	bps	9.6k to 5M	2500000
F50Bh	00h	Special command	R/W	NO	UINT32	-	UINT32	0
F50Ch	00h	Explicit ID	R/W	NO	UINT16	-	UINT16	0x0005

Section 8. Object Dictionary Description

This section lists detailed descriptions of object dictionaries that are common to all axes and used separately.

2000h: Smoothing Time 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2000h	00h	Smoothing time 1	R/W	No	UINT32	ms	UINT16	100
Bits		**Name**	**Description**					
15:0		Smoothing time	Sets the time for the jerk stage in profile position (PP) mode.					

2001h: Repetitive Motion Times 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2001h	00h	Repetitive motion times 1	R/W	No	UINT32	-	UINT32	1
Bits		**Name**	**Description**					
31:0		Repetitive motion times	(If Repetitive motion mode 1 = 0) Number of motion times = repetitive motion times (If Repetitive motion mode 1 = 1) Number of motion times = 2 x repetitive motion times					

2002h: Repetitive Motion Mode 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2002h	00h	Repetitive motion mode 1	R/W	No	UINT16	-	0 or 1	0
Bits		**Name**	**Description**					
0		Repetitive motion mode	0: One-way repetitive motion 1: Back-and-forth repetitive motion					

2003h: Repetitive Interval Time 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2003h	00h	Repetitive interval time	R/W	No	UINT32	ms	UINT32	100
Bits		**Name**	**Description**					
31:0		Repetitive interval time	Sets the time interval between two movements.					

2010h: Jog Acceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2010h	00h	Jog acceleration 1	R/W	RPDO	UINT32	pulse/s^2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Jog acceleration	Sets the acceleration in jog mode.					

2011h: Jog Deceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2011h	00h	Jog deceleration 1	R/W	RPDO	UINT32	pulse/s 2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Jog deceleration	Sets the deceleration in jog mode.					

2012h: Jog Target Velocity 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2012h	00h	Jog target velocity 1	R/W	RPDO	UINT32	pulse/s	UINT32	100000
Bits		**Name**	**Description**					
31:0		Jog target velocity	Sets the target velocity in jog mode.					

2013h: Jog Positive Direction 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2013h	00h	Jog positive direction 1	R/W	RPDO	UINT16	-	0 or 1	0
Bits		**Name**	**Description**					
0		Jog positive direction	1: The motor accelerates forward to the target speed according to the set acceleration 0: The motor decelerates forward to standstill according to the set deceleration					

2014h: Jog Negative Direction 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2014h	00h	Jog negative motion**1**	R/W	RPDO	UINT16	-	0 or 1	0
Bits		**Name**	**Description**					
0		Jog negative motion	1: The motor accelerates backward to the target speed according to the set acceleration 0: The motor decelerates backward to standstill according to the set deceleration					

2020h: Homing Maximum Distance 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2020h	00h	Homing maximum distance 1	R/W	RPDO	UINT32	pulse	UINT32	5000000
Bits		**Name**	**Description**					
31:0		Homing maximum distance	Sets the maximum allowable displacement in homing mode.					

2030h: Slowdown Stop Time 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2030h	00h	Slowdown stop time 1	R/W	No	UINT16	ms	UINT16	1000
Bits		**Name**	**Description**					
15:0		Slowdown stop time	Sets the time during which the motor slows down from its current speed to zero.					

2031h: I/O Control 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2031h	01h	IO polarity 1	R/W	No	UINT16	-	0 to 31	0x0000
Bits		**Name**	**Description**					
4		Touch Probe Edge	0: The touch probe triggers at the edge near the negative limit switch 1: The touch probe triggers at the edge near the positive limit switch					
3		IO4 polarity	0: The optocoupler input is active low 1: The optocoupler input is active high					
2		IO3 polarity	0: The optocoupler input is active low 1: The optocoupler input is active high					
1		IO2 polarity	0: The optocoupler input is active low 1: The optocoupler input is active high					
0		IO1 polarity	0: The optocoupler input is active low 1: The optocoupler input is active high					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2031h	02h	IO simulation enable 1	R/W	No	UINT16	-	0 to 15	0x0000
Bits		**Name**	**Description**					
3		IO4 simulation enable	0: The I/O4 simulation function is disabled 1: The I/O4 simulation function is enabled					
2		IO3 simulation enable	0: The I/O3 simulation function is disabled 1: The I/O3 simulation function is enabled					
1		IO2 simulation enable	0: The I/O2 simulation function is disabled 1: The I/O2 simulation function is enabled					
0		IO1 simulation enable	0: The I/O1 simulation function is disabled 1: The I/O1 simulation function is enabled					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2031h	03h	IO simulation input 1	R/W	No	UINT16	-	0 to 15	0x0000
Bits		**Name**	**Description**					
3		IO4 simulation input	0: The IO4 simulation input is inactive 1: The IO4 simulation input is active					
2		IO3 simulation input	0: The IO3 simulation input is inactive 1: The IO3 simulation input is active					
1		IO2 simulation input	0: The IO2 simulation input is inactive 1: The IO2 simulation input is active					
0		IO1 simulation input	0: The IO1 simulation input is inactive 1: The IO1 simulation input is active					

2032h: I/O Function 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2032h	00h	IO function 1	R/W	No	UINT16	-	0 to 127	0x0024
Bits		**Name**	**Description**					
6		IO4 function	0: Touch probe switch 1: External stop signal					
5:4		IO3 function	00: Negative limit switch 01: Positive limit switch 10: Homing switch					
3:2		IO2 function	00: Negative limit switch 01: Positive limit switch 10: Homing switch					
1:0		IO1 function	00: Negative limit switch 01: Positive limit switch 10: Homing switch					

2033h: Position Clear 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2033h	00h	Position clear 1	R/W	No	UINT16	-	0 or 1	0
Bits		**Name**	**Description**					
0		Position clear	Write 1 to set the current position to zero. This bit is cleared by the software.					

2040h: Stop Enable 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2040h	00h	Stop enable 1	R/W	No	UINT16	-	0 to 7	2
Bits		**Name**	**Description**					
0		Touch probe stop enable	0: Motor does not stop when the touch probe is triggered 1: Motor stops when the touch probe is triggered					
1		Hardware limit stop enable	0: Hardware limit protection is disabled 1: Hardware limit protection is enabled					
2		Software limit stop enable	0: Software limit protection is disabled 1: Software limit protection is enabled					

2042h: Touch Probe Position 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2042h	00h	Touch probe position 1	RO	No	INT32	-	INT32	-
Bits		**Name**	**Description**					
31:0		Touch probe position	The motor's position is recorded when the touch probe is triggered.					

2050h: Actual Acceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2050h	00h	Actual acceleration 1	RO	No	INT32	user unit/s^2	INT32	-
Bits		**Name**	**Description**					
31:0		Actual acceleration	Sets the curve's acceleration for the stepper motor in PP mode.					

2052h: Position Reach 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2052h	00h	Position reach 1	RO	No	UINT16	-	0 or 1	-
Bits		**Name**	**Description**					
15:0		Position reach	0: The profile position is not finished 1: The profile position is finished					

2053h: Positive Limit State 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2053h	00h	Positive limit state 1	RO	No	UINT16	-	0 or 1	-
Bits		**Name**	**Description**					
15:0		Positive limit state	0: The movement range does not exceed the software positive limit or the hardware positive limit 1: The movement range exceeds the software positive limit or the hardware positive limit					

2054h: Negative Limit State 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2054h	00h	Negative limit state 1	RO	No	UINT16	-	0 or 1	-
Bits		**Name**	**Description**					
15:0		Negative limit state	0: The movement range does not exceed the software negative limit or the hardware negative limit 1: The movement range exceeds the software negative limit or the hardware negative limit					

2055h: Homing State 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2055h	00h	Homing state 1	RO	No	UINT16	-	0 or 1	-
Bits		**Name**	**Description**					
15:0		Homing state	0: The motor has not found the zero point (or was looking for the zero point) 1: The motor has found the zero point in homing mode					

2056h: Error State 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2056h	00h	Error state 1	RO	No	UINT32	-	UINT32	-

Bits	Name	Description
25	Motion incomplete warning	0: The motor does not have a motion incomplete warning 1: The motor has a motion incomplete warning
24	Following error Large warning	0: The motor does not have a position following error large warning 1: The motor has a position following error large warning
16	OTP warning	0: The drive does not have an over-temperature (OT) warning 1: An OT warning has occurred on the drive
12	Homing maximum distance fault	0: The motor does not have a homing maximum displacement fault 1: The motor has a homing maximum displacement fault
11	SNL fault	0: The motor does not have a software negative limit fault 1: The motor has a software negative limit fault
10	SPL fault	0: The motor does not have a software positive limit fault 1: The motor has a software positive limit fault
9	HNL fault	0: The motor does not have a hardware negative limit fault 1: The motor has a hardware negative limit fault
8	HPL fault	0: The motor does not have a hardware positive limit fault 1: The motor has a hardware positive limit fault
4	OPH fault	0: The drive does not have an open phase fault 1: The drive has an open phase fault
3	TSD fault	0: The drive does not have a thermal shutdown fault 1: The drive has a thermal shutdown fault
2	UVLO fault	0: The drive does not have a under-voltage lockout (UVLO) fault 1: The drive has a UVLO fault
1	OVP fault	0: The drive does not have an over-voltage (OV) fault 1: The drive has an OV fault
0	OCP fault	0: The drive does not have an over-current (OC) fault 1: The drive has an OC fault

2057h: Stop State 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2057h	00h	Stop state 1	RO	No	UINT16	-	UINT16	-

Bits	Name	Description
7	Quick stop command stop	0: The motor did not stop due to a quick stop command 1: The motor has stopped due to a quick stop command
5	Axis disable command stop	0: The motor did not stop due to disable command 1: The motor has stopped due to a disable command
4	External IO stop	0: The motor did not stop due to an external I/O signal 1: The motor has stopped due to an external I/O signal
3	Touch probe stop	0: The motor has stopped due to a touch probe signal 1: The motor is stop due to touch probe signal
2	Halt command stop	0: The motor did not stop due to halt command 1: The motor has stopped due to a halt command
1	Motion fault stop	0: The motor did not stop due to motion fault 1: The motor has stopped due to a motion fault
0	Driver fault stop	0: The motor did not stop due to a driver fault 1: The motor has stopped due to a driver fault

2070h: Drive Control 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2070h	00h	Drive control 1	R/W	No	UINT16	-	UINT16	0x0F07

Bits	Name	Description
11	TSD EN	0: Thermal shutdown protection is disabled 1: Thermal shutdown protection is enabled
10	UVLO EN	0: Under-voltage lockout (UVLO) protection is disabled 1: UVLO protection is enabled
9	OVP EN	0: Over-voltage protection (OVP) is disabled 1: OVP is enabled
8	OCP EN	0: Over-current protection (OCP) is disabled 1: OCP is enabled
3:0	Step subdivision	0: Full step (200 pulses per lap) 1: Half-step (400 pulses per lap) 2: 4 subdivisions (800 pulses per lap) 3: 8 subdivisions (1600 pulses per lap) 4: 16 subdivisions (3200 pulses per lap) 5: 32 subdivisions (6400 pulses per lap) 6: 64 subdivisions (12800 pulses per lap) 7: 128 subdivisions (25600 pulses per lap) 8: 256 subdivisions (51200 pulses per lap) 9: 512 subdivisions (102400 pulses per lap)

2071h: Idle Current 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2071h	00h	Idle current 1	R/W	No	UINT16	%	0 to 100	50
Bits		**Name**	**Description**					
15:0		Idle current	Sets the phase current's peak value in the idle state. The idle current is set as a percentage of the operating current					

2072h: Operating Current 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2072h	00h	Operating current 1	R/W	No	UINT16	1/256A	0 to 5A	256
Bits		**Name**	**Description**					
15:0		Operating current	Sets the peak current when the motor is working. The default value is 1A.					

2073h: OCP Threshold 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2073h	00h	OCP threshold 1	R/W	No	UINT16	%	0 to 1000	200
Bits		**Name**	**Description**					
15:0		OCP threshold	Sets the threshold for over-current protection (OCP). The OCP threshold is set as a percentage of the operating current					

2074h: Phase Resistance 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2074h	00h	Phase resistance 1	R/W	No	UINT16	mΩ	UINT16	758
Bits		**Name**	**Description**					
15:0		Phase resistance	Sets the stepper motor's phase resistance.					

2075h: Phase Inductance 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2075h	00h	Phase inductance 1	R/W	No	UINT16	μH	UINT16	2728
Bits		**Name**	**Description**					
15:0		Phase inductance	Sets the stepper motor's phase inductance.					

2077h: Current Loop Bandwidth 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2077h	00h	Current loop bandwidth 1	R/W	No	UINT16	Hz	0 to 1000	100
Bits		**Name**	**Description**					
15:0		Current loop bandwidth	Sets the current loop controller's bandwidth.					

2078h: Axis Firmware Version 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2078h	00h	Driver firmware version 1	RO	No	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:0		Driver firmware version	Sets the drive's firmware version number.					

2079h: OVP Threshold 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
2079h	00h	OVP threshold 1	R/W	No	UINT16	(1/256) V	0 to 100V	17920
Bits		**Name**	**Description**					
15:0		OVP threshold	Sets the threshold for over-voltage protection (OVP). The default value is 70V.					

207Ah: UVLO Threshold 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
207Ah	00h	UVLO threshold 1	R/W	No	UINT16	(1/256) V	0 to 100V	4608
Bits		**Name**	**Description**					
15:0		UVLO threshold	Sets the threshold value for under-voltage lockout (UVLO) protection. The default value is 18V.					

207Bh: TSD Threshold 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
207Bh	00h	TSD threshold 1	R/W	No	UINT16	°C	0 to 200	150
Bits		**Name**	**Description**					
15:0		TSD threshold	Set the threshold for thermal shutdown (TSD) protection. The default value is 150°C.					

207Ch: OTP Threshold 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
207Ch	00h	OTP threshold	R/W	No	UINT16	°C	0 to 150	125
Bits		**Name**	**Description**					
15:0		OTP threshold	Sets the threshold for an over-temperature protection (OTP) warning. The default value is 125°C.					

207Dh: Driver Temperature 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
207Dh	00h	Driver temperature 1	RO	No	INT16	°C	INT16	-
Bits		**Name**	**Description**					
15:0		Driver temperature	Indicates the value of the driver's temperature					

207Fh: OPP Maximum Duty 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
207Fh	00h	OPP maximum duty 1	R/W	No	UINT16	0.05%	0 to 420	200
Bits		**Name**	**Description**					
15:0		OPP maximum duty	Sets the voltage duty for open-phase protection (OPP). The default value is 10%, and the maximum voltage duty can be calculated with the following equation: Maximum Voltage Duty = 207Fh x 0.05%					

F501h: Motor Connection State

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F501h	00h	Motor connection state	RO	No	UINT16	-	0 to 63	-
Bits		**Name**	**Description**					
5		Axis 6 connection state	0: Axis 6 is not connected, or the phase is open 1: Axis 6 is connected normally					
4		Axis 5 connection state	0: Axis 5 is not connected, or the phase is open 1: Axis 5 is connected normally					
3		Axis 4 connection state	0: Axis 4 is not connected, or the phase is open 1: Axis 4 is connected normally					
2		Axis 3 connection state	0: Axis 3 is not connected, or the phase is open 1: Axis 3 is connected normally					
1		Axis 2 connection state	0: Axis 2 is not connected, or the phase is open 1: Axis 2 is connected normally					
0		Axis 1 connection state	0: Axis 1 is not connected, or the phase is open 1: Axis 1 is connected normally					

F504h: Bus Voltage

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F504h	00h	Bus voltage	RO	No	UINT16	1/256 V	0 to 120V	-
Bits		**Name**	**Description**					
15:0		Bus voltage	Indicates the voltage value of the input DC power supply.					

F505h: Part Number

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F505h	00h	Part number	RO	No	UINT16	-	UINT16	0x6720
Bits		**Name**	**Description**					
15:0		Part number	Indicates the driver's part number.					

F506h: Firmware Version Number

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F506h	00h	Firmware version number	RO	No	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:0		Firmware version number	Indicates the firmware version number of the driver.					

F507h: Hardware Version Number

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F507h	00h	Hardware version number	RO	No	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:0		Hardware version number	Indicates the hardware version number of the driver					

F508h: MLink Address

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F508h	00h	MLink address	R/W	No	UINT8	-	UINT8	1
Bits		**Name**	**Description**					
15:0		MLink address	Sets the current device's MLink communication address.					

F509h: MLink Parity

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F509h	00h	MLink parity	R/W	No	UINT8	-	0 to 2	2
Bits		**Name**	**Description**					
15:0		MLink parity	Sets the data frame's parity. 0: No parity 1: Odd parity 2: Even parity					

F50Ah: MLink Baud Rate

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F50Ah	00h	MLink baud rate	R/W	No	UINT32	bps	9.6k to 5M	2500000
Bits		**Name**	**Description**					
15:0		MLink baud rate	Sets the current device's MLink communication baud rate.					

F50Bh: Special Command

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F50Bh	00h	Special command	R/W	No	UINT32	-	UINT32	-
Bits		**Name**	**Description**					
31:0		Special command	Special commands. This includes storing parameters to the flash, restoring default parameters, resetting the system, updating the firmware, and clearing the error history.					

F50Ch: Explicit ID

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
F50Ch	00h	Explicit ID	R/W	No	UINT16	-	UINT16	-
Bits		**Name**	**Description**					
15:0		Explicit ID	Sets the device identification value.					

603Fh: Error Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
603Fh	00h	Error code 1	RO	TPDO	UINT16	-	UINT16	0
Bits		**Name**	**Description**					
15:0		Error code	2300h: Over-current (OC) fault 3210h: Over-voltage (OV) fault 3220h: Under-voltage lockout (UVLO) 4210h: Over-temperature (OT) fault 3130h: Open-phase fault FF01h: Hardware positive limit FF02h: Hardware negative limit FF03h: Software positive limit FF04h: Software negative limit FF05h: Homing maximum distance					

6041h: Status Word 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6041h	00h	Status word 1	RO	TPDO	UINT16	-	UINT16	-

Bits	Name	Description
15:14	ms	Manufacturer-specific. For more details, refer to the relevant sections of the 402 protocol.
13:12	oms	Operating mode specific. For more details, refer to the relevant sections of the 402 protocol.
11	ila	Not used.
10	tr	Not used.
9	rm	Not used.
8	ms	Manufacturer-specific. For more details, refer to the relevant sections of the 402 protocol.
7	w	0: No warning 1: Warning
6	sod	0: Switch on enabled 1: Switch on disabled
5	qs	0: Quick stop function is being executed (or cannot be executed). 1: Quick stop can be executed
4	ve	0: Voltage disabled 1: Voltage enabled
3	f	0: No fault 1: Fault
2	oe	0: Operation disabled 1: Operation enabled
1	so	0: Switched off 1: Switched on
0	rtso	0: Not ready to switch on 1: Ready to switch on

605Ah: Quick Stop Option Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
605Ah	00h	Quick stop option code 1	R/W	No	INT16	-	0 to 2	2

Bits	Name	Description
15:0	Quick stop option code	When the quick stop command is received, the power drive turns off and the status is switch on disabled

605Bh: Shutdown Option Code 1

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

Bits	Name	Description
15:0	Shutdown option code	Not used.

605Ch: Disable Operation Option Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
605Ch	00h	Disable operation option code1	R/W	No	INT16	-	0 or 1	0
Bits		**Name**	**Description**					
15:0		Disable operation option code	Not used.					

605Dh: Halt Option Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
605Dh	00h	Halt option code 1	R/W	No	INT16	-	0 to 2	1
Bits		**Name**	**Description**					
15:0		Halt option code	Indicates what action is performed when the halt function is executed. 0: Not used 1: Slow down on slow down ramp and stay in operation enabled 2: Slow down on quick stop ramp and stay in operation enabled					

605Eh: Fault Reaction Option Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
605Eh	00h	Fault reaction option code 1	R/W	No	INT16	-	0 to 2	2
Bits		**Name**	**Description**					
15:0		Fault reaction option code	Indicates what action is performed if a fault is detected in the power drive system (PDS). 0: Disable drive function, motor is free to rotate 1: Slow down on the slow down ramp 2: Slow down on the quick stop ramp					

6060h: Modes of Operation 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6060h	00h	Modes of operation 1	R/W	RPDO	INT8	-	-1 to 8	0
Bits		**Name**	**Description**					
7:0		Mode of operation	Indicates the requested operation mode. -1: Jog mode (jog) 1: Profile position (PP) mode 6: Homing mode (HOME) 8: Cyclic synchronous position (CSP) mode					

6061h: Modes of Operation Display 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6061h	00h	Modes of operation display 1	RO	TPDO	INT8	-	-1 to 8	-
Bits		**Name**	**Description**					
7:0		Mode of operation display	-1: Jog mode (jog) 1: Profile position (PP) mode 6: Homing mode (HOME) 8: Cyclic synchronous position (CSP) mode					

6064h: Position Actual Value 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6064h	00h	Position actual value 1	RO	TPDO	INT32	User unit	INT32	-
Bits		**Name**	**Description**					
31:0		Position actual value	Represents the real-time position instruction value					

6065h: Following Error Window 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6065h	00h	Following error window 1	R/W	No	UINT32	User unit	UINT32	200000
Bits		**Name**	**Description**					
31:0		Following error window	Sets the detection threshold for the position following error. When the system successfully finds the zero position through the homing mode, the position coordinate is cleared to zero. In the subsequent movement process, when the motor passes the home switch, the driver compares the current position to the home switch. If the difference between these two coordinates exceeds the following error window, the driver reports the position error large warning.					

606Ch: Velocity Actual Value 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
606Ch	00h	Velocity actual value 1	RO	TPDO	INT32	User unit/s	INT32	-
Bits		**Name**	**Description**					
31:0		Velocity actual value	Represents the real-time velocity instruction value.					

607Ah: Target Position 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Ah	00h	Target position 1	R/W	RPDO	INT32	User unit	INT32	256000
Bits		**Name**	**Description**					
31:0		Target position	Sets the commanded position in position profile (PP) mode. The value of this object is interpreted as an absolute or relative, depending on the absolute/relative flag in “Control word” (object 6040h) and “Positioning option code 1” (object 60F2h).					

607Ch: Home Offset 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Ch	00h	Home offset 1	R/W	RPDO	INT32	User unit	INT32	0
Bits		**Name**	**Description**					
31:0		Home offset	Indicates the configured difference between the zero position for the application and the machine home position. The zero position is offset from the home position by adding the home offset to the home position. All subsequent absolute moves shall be taken relative to this new zero position.					

607Dh:Software Position Limit 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Dh	01h	Min position limit 1	R/W	No	INT32	User unit	INT32	-2000000
Bits		**Name**	**Description**					
31:0		Min position limit	Indicates the configured minimum absolute position limits for the position command value.					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Dh	02h	Max position limit 1	R/W	No	INT32	User unit	INT32	2000000
Bits		**Name**	**Description**					
31:0		Max position limit	Indicates the configured maximum absolute position limits for the position command value.					

607Eh: Polarity 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Eh	00h	Polarity 1	R/W	RPDO	UINT8	-	0 or 1	0
Bits		**Name**	**Description**					
7		Polarity	Sets whether the position command value should be multiplied by 1 or -1. This bit is used in profile position (PP) mode and cyclic synchronous position (CSP) mode, as well as homing mode and jog mode. 0: Multiply by 1 1: Multiply by -1					
6:0		-	Not used.					

607Fh: Max Profile Velocity 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
607Fh	00h	Max profile velocity 1	R/W	RPDO	UINT32	User unit/s	UINT32	2000000
Bits		**Name**	**Description**					
31:0		Max profile velocity	Indicates the configured maximal allowed velocity in either direction during a profiled motion.					

6081h: Profile Velocity 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6081h	00h	Profile velocity 1	R/W	RPDO	UINT32	User unit/s	UINT32	100000
Bits		**Name**	**Description**					
31:0		Profile velocity	Indicates the uniform velocity in profile position (PP) mode.					

6082h: End Velocity 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6082h	00h	End velocity 1	R/W	RPDO	UINT32	User unit/s^2	UINT32	0
Bits		**Name**	**Description**					
31:0		End velocity	Indicates the end velocity in profile position (PP) mode.					

6083h: Profile Acceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6083h	00h	Profile acceleration 1	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Profile acceleration	Indicates the average acceleration in profile position (PP) mode.					

6084h: Profile Deceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6084h	00h	Profile deceleration1	R/W	RPDO	UINT32	User unit/s^2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Profile deceleration	Indicates the average deceleration in profile position (PP) mode.					

6085h: Quick Stop Deceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6085h	00h	Quick stop deceleration	R/W	No	UINT32	User unit/s^2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Quick stop deceleration	Not used.					

6086h: Motion Profile Type 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6086h	00h	Motion profile type 1	R/W	No	INT16	-	0	0
Bits		**Name**	**Description**					
15:0		Motion profile type	-1: S-curve 1: T-curve					

6091h: Gear Ratio 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6091h	01h	Motor shaft revolutions 1	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Motor shaft revolutions	Indicates the ratio between the motor shaft revolutions and driving shaft revolutions. See 6091h-02h below for more details.					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6091h	02h	Driving shaft revolutions 1	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Driving shaft revolutions	Indicates the ratio between motor shaft revolutions and driving shaft revolutions. The gear ratio can be calculated with the following equation: $\text{Gear Ratio} = \frac{\text{Motor Shaft Revolutions (6091h-01h)}}{\text{Driving Shaft Revolutions (6091h-02h)}}$					

6092h: Feed Constant 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6092h	01h	Feed	R/W	No	UINT32	User unit	UINT32	25600
Bits		**Name**	**Description**					
31:0		Feed	Indicates the user-defined position feed per driving shaft revolutions. See 6092h-02h below for more details.					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6092h	02h	Driving shaft revolutions 1	R/W	No	UINT32	REV	UINT32	1
Bits		**Name**	**Description**					
31:0		Driving shaft revolutions	Indicates the configured number of driving shaft revolutions. The feed constant can be calculated with the following equation: $\text{Feed constant} = \frac{\text{Feed (6092h-01h)}}{\text{Driving Shaft Revolutions (6092h-02h)}}$					

6098h: Homing Method 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6098h	00h	Homing method 1	R/W	No	INT8	-	17 - 30	23
Bits		**Name**	**Description**					
7:0		Homing method	Indicates the configured homing method that shall be used. 17~34: Methods 17–34 (see section 3.4.1 on page 34 for details)					

6099h: Homing Speeds 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6099h	01h	Speed for switch 1	R/W	No	UINT32	User unit/s	UINT32	500000
Bits		**Name**	**Description**					
31:0		Speed for switch	Indicates the homing speed when searching for a switch signal.					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6099h	02h	Speed for zero 1	R/W	No	UINT32	User unit/s	UINT32	100000
Bits		**Name**	**Description**					
31:0		Speed for zero	Indicates the homing speed when searching for a zero signal.					

609Ah: Homing Acceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
609Ah	00h	Homing acceleration 1	R/W	No	UINT32	User unit/s^2	UINT32	100000
Bits		**Name**	**Description**					
31:0		Homing acceleration	Indicates the configured acceleration and deceleration to be used during homing operation.					

60C2h: Interpolation Time Period 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60C2h	01h	Interpolation time period value 1	R/W	No	UINT8	-	UINT8	1
Bits		**Name**	**Description**					
7:0		Interpolation time period value	Determines the interpolation time period with 60C2h-02h below. For example, if 60C2h-01h is 1 and 60C2h-02h is -3, then the interpolation time period is 1^(-3)s = 1ms.					

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60C2h	02h	Interpolation time index 1	R/W	No	INT8	-	-3	-3
Bits		**Name**	**Description**					
31:0		Interpolation time index	See 60C2h-01h above for more details.					

60C5h: Max Acceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60C5h	00h	Max acceleration 1	R/W	No	UINT32	User unit/s^2	UINT32	10000000
Bits		**Name**	**Description**					
31:0		Max acceleration	Indicates the configured maximum acceleration. This object limits the acceleration to an acceptable value to prevent the motor and the moved mechanics from being destroyed.					

60C6h: Max Deceleration 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60C6h	00h	Max deceleration	R/W	No	UINT32	User unit/s^2	UINT32	10000000
Bits		**Name**	**Description**					
31:0		Max deceleration	Indicates the configured maximum deceleration. This object limits the deceleration to an acceptable value to prevent the motor and the moved mechanics from being destroyed.					

60F2h: Positioning Option Code 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60F2h	00h	Positioning option code 1	R/W	No	UINT16	-	0 or 2	0
Bits		**Name**	**Description**					
1:0		Relative option	Controls the behavior of positioning tasks in detail when the absolute/relative bit (“Control word” (object 6040h), bit[6]) is set to 1 in profile position (PP) mode. 0: Relative to target position value (607Ah) 2: Relative to current position value (6064h) Others: Reserved					

60FDh: Digital inputs 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
60FDh	00h	Digital inputs 1	RO	TPDO	UINT32	-	UINT32	-

Bits	Name	Description
31:20	Reserved	Reserved.
19	DI4 state	0: The logic is invalid 1: The logic is valid
18	DI3 state	0: The logic is invalid 1: The logic is valid
17	DI2 state	0: The logic is invalid 1: The logic is valid
16	DI1 state	0: The logic is invalid 1: The logic is valid
15:3	Reserved	Not used.
2	Homing switch state	0: The logic is invalid 1: The logic is valid
1	Positive limit switch state	0: The logic is invalid 1: The logic is valid
0	Negative limit switch state	0: The logic is invalid 1: The logic is valid

6502h: Supported Drive Modes 1

Index	Sub-Index	Name	Access	PDO	Data Type	Unit	Range	Default
6502h	00h	Supported drive modes 1	RO	No	UINT32	-	UINT32	A1h

Bits	Name	Description
31:10	R	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	R	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	9/5/2025	Initial Release	-