EtherCAT Control Protocol

Version: V1.0

Date: 2024.12

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Catalog

1. Composition of the EtherCAT System

EtherCAT is a fieldbus protocol for real-time Ethernet communication that facilitates real-time data transmission and processing through data frames, achieving low latency and high bandwidth while maintaining low costs and a simple network structure.

EtherCAT adopts a master-slave architecture., consisting of one master device and multiple slave devices. The master sends control commands and data, while the slaves receive and execute these commands, transmitting output data such as sensor data, actuator status, and control commands in real-time. Any computer with a network interface and embedded devices with Ethernet control can serve as the master. For PC-based computers, the master controller often utilizes TwinCAT software developed by Beckhoff. Servo drives act as slaves, equipped with dedicated slave controllers. The communication cable between the master and slave must be Category 5 or higher, with a communication rate of 100Mbit/s, and the maximum communication distance between two stations is 100 meters.

The operational principle of the EtherCAT system is illustrated in Figure 1-1.

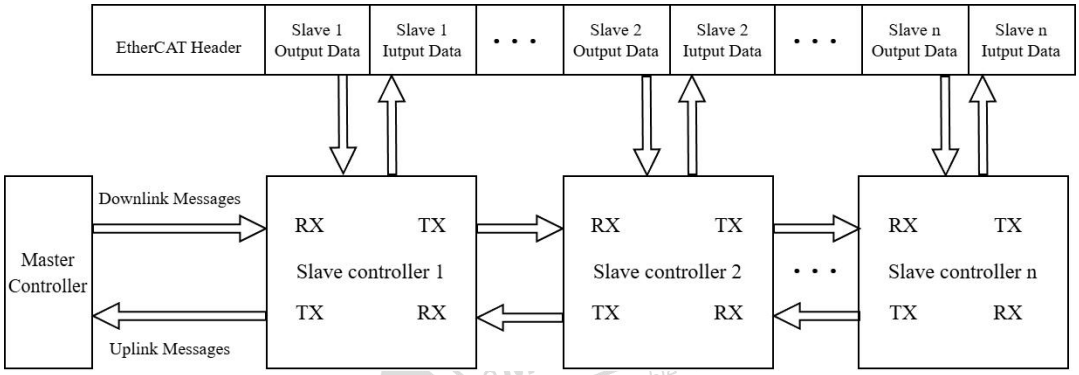

Figure 1-1 Schematic Diagram of the EtherCAT System

As shown in Figure 1-1, within one communication cycle, the master controller sends data frames to each slave station. Each slave station extracts corresponding data based on addressing and writes feedback information back into the data frame. After being sent to the last slave station, the data frame is returned and passes through each slave station back to the master station, thus completing data communication within one

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cycle.

Where,the master controller configures the functions and related object attributes of the slave controllers using the EtherCAT Slave Information (ESI) file. The ESI is an XML-formatted file that includes manufacturer information and slave controllers description information, as illustrated in Figure 1-2. One ESI file can contain data for multiple slave controllers. By importing the ESI file into the master controller's controller software, the master controller can identify and control each slave controller based on the configuration information in the ESI file.

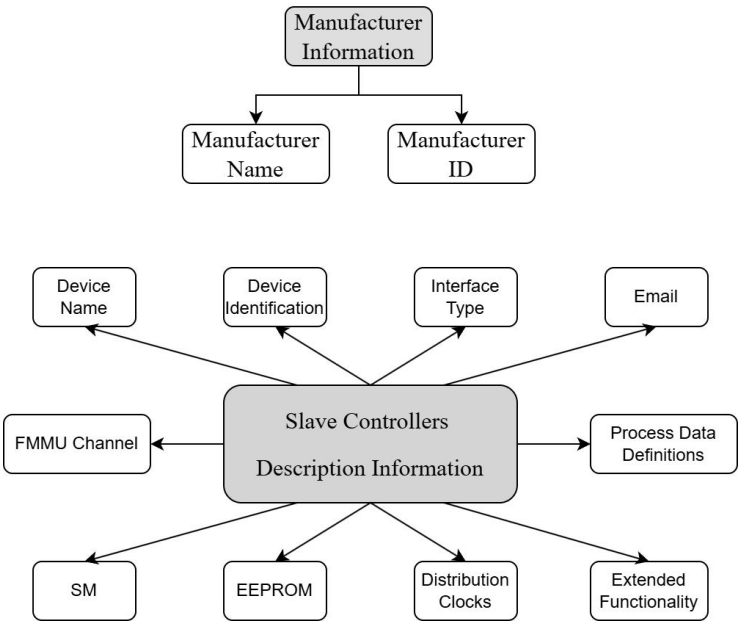

Figure 1-2 System Schematic diagram of ESI content

2. Basic Configuration

2.1. Interface definition

Figure 2-1 shows the definition of the EtherCAT interface.

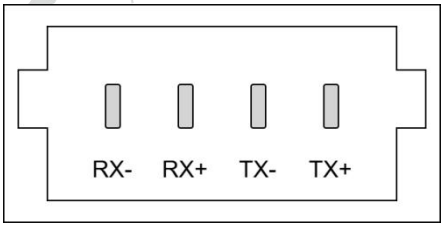

Figure 2-1 Schematic diagram of the EtherCAT interface

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As shown in Figure 2-1, RX- is the negative end of data reception, RX+ is the positive end of data reception, TX- is the negative end of data transmission, and TX+ is the positive end of data transmission.

2.2. Communication Connections

EtherCAT communication uses twisted pair cables, which are individually shielded, and the hardware connection mode is shown in Figure 2-2.

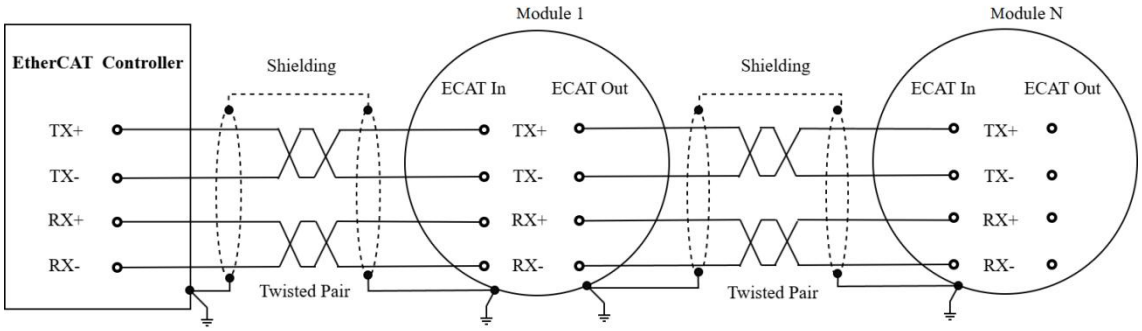

Figure 2-2 Schematic diagram of EtherCAT communication connections

2.3. ESI File Import

The ESI documents have been uploaded to our website,please download it yourself,the download link is below:https://www.myactuator.com.

3. Servo Status Control

During the EtherCAT communication, the master controller controls the servo drive according to the current actual state.The state can be changed through the control word 0x6040, and the status can be displayed through the status word 0x6041, note that in the process of state transition, you must confirm that the state has been changed through the 0x6041 before you can continue to send the command of the next state.

3.1. Control Word (0x6040) Description

The control word is uint16, and the running state of the servo drive is switched through the control word, and the control function table of each bit is shown in Table 3-1.

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Table 3-1 Control word(0x6040)function table

Bit	Name	Description
0	Switch on	1-valid，0-invalid
1	Enable Voltage	1-valid，0-invalid
2	Quick Stop	0-valid，quick stop；1-invalid
3	Enable Operation	1-valid，0-invalid
4~6	Operation Mode Specific	Related to Each Servo Operation Mode
7~8	Reserve	No Define
9	Operation Mode Specific	Related to Each Servo Operation Mode
10 ~ 15	Reserve	No Define

3.2. Status Word (0x6041) Description

The status word is uint16, which provides information about the running status, and the function table of each bit is shown in Table 3-2.

Table 3-2 Status word (0x6041) function table

Bit	Name	Description
0	Ready to Switch on	1-valid，0-invalid
1	Switched on	1-valid，0-invalid
2	Operation Enabled	1-valid，0-invalid
3	Fault	1-valid，0-invalid
4	Voltage Enabled	1-valid，0-invalid
5	Quick Stop	1-valid，0-invalid
6	Switch on Disabled	1-valid，0-invalid
7	Warning	1-valid，0-invalid
8	Reserve	No Define
9	Remote	1-valid，0-invalid
10	Target Reach	1-valid，0-invalid
11	Internal Limit Active	1-valid，0-invalid
12~ 13	Operation Mode Specific	Related to Each Servo Operation Mode

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14~15	Reserve	No Define

4. Operating Mode Control

At present, there are three modes: periodic synchronization position mode, periodic synchronization speed mode, and periodic synchronization torque mode, and the desired mode is set 0x6060 the operating mode object, and the object is displayed using the operating mode 0x6061 read the current operating mode.

4.1. Operating Mode Settings

The operating mode object 0x6060 used to set the operating mode, as shown in Table 4-1, and is activated immediately when the setting is changed.

Table 4-1 Operating Mode Settings（0x6060）

Value	Mode of operation
0x08	Periodic Synchronization Position Mode
0x09	Periodic Synchronization Speed Mode
0x0A	Periodic Synchronization Torque Mode

4.2. Operating Mode Display

Use the 0x6061 to read the current running mode, as shown in Table 4-2.

Table 4-2 Operating mode display（0x6061）

Value	Operating Mode Display
0x08	Periodic Synchronization Position Mode
0x09	Periodic Synchronization Speed Mode
0x0A	Periodic Synchronization Torque Mode

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5. Mode of operation

5.1. Cyclic Synchronous Position Mode

5.1.1. Control Block Diagram

When the status word 0x6060=8, the module works in periodic synchronization position mode. The master controller carries out trajectory planning and sends the target position, velocity offset, and torque offset to the module in each communication cycle. The driver control loop of the module is closed and acts as a follower for position commands, as shown in Figure 5-1.

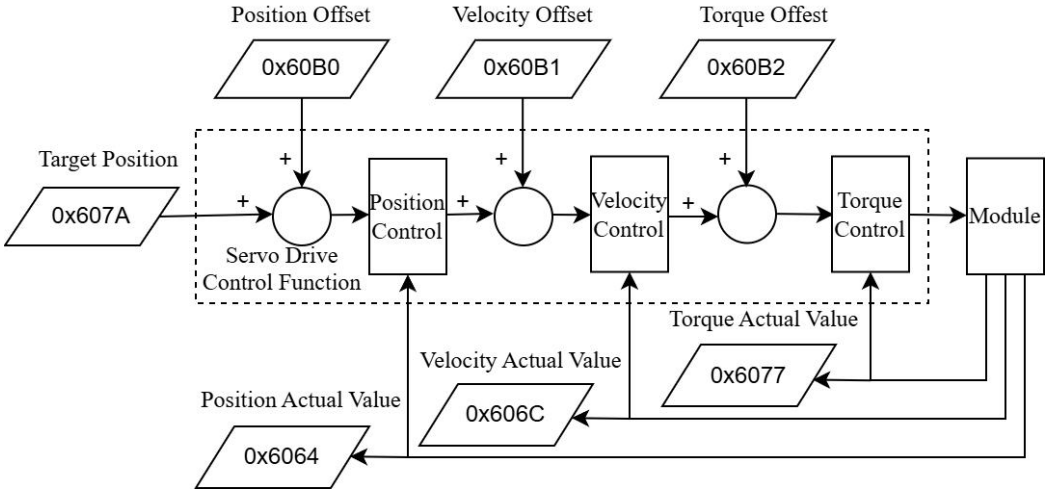

Figure 5-1 Block diagram of periodic synchronous position mode

5.1.2. Control Commands

For the periodic synchronous position mode, table 5-1 describes the definitions of each bit of the control word 0x6040.

Table 5-1 Control word(0x6040)function table

Bit	Name	Description
0	Switch on	1-valid，0-invalid
1	Enable Voltage	1-valid，0-invalid
2	Quick Stop	0-valid，quick stop；1-invalid
3	Enable Operation	1-valid，0-invalid
4~6	CSP mode reservation	No Define

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7~8	Reserve	No Define
9	CSP mode reservation	No Define
10 ~ 15	Reserve	No Define

Table 5-2 describes the definitions of each bit 0x6041 status word.

Table 5-2 Status word (0x6041) function table

Bit	Name	Description
0	Ready to Switch on	1-valid，0-invalid
1	Switched on	1-valid，0-invalid
2	Operation Enabled	1-valid，0-invalid
3	Fault	1-valid，0-invalid
4	Voltage Enabled	1-valid，0-invalid
5	Quick Stop	1-valid，0-invalid
6	Switch on Disabled	1-valid，0-invalid
7	Warning	1-valid，0-invalid
8	Reserve	No Define
9	Remote	1-valid，0-invalid
10	Target Reach	1-valid，0-invalid
11	Internal Limit Active	1-valid，0-invalid
12	Follow the target location	1-already followed,0-not followed
13	Follow the position error alarm	1-position deviation alarm,0-no position deviation alarms
14~ 15	Reserve	No Define

5.1.3. Control steps

The steps are as follows:

1) Set 0x6060=8 to make the module work in periodic synchronous position mode;

2) Read the position actual value 0x6064, and set the target location 0x607A to the current position actual value;

3) Set the control word 0x6040 and set the module to the enabled state by the following methods:

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3-1: Set the control word 0x6040=6 to keep the module disabled;

3-2: Set the control word 0x6040=7, and the module is ready to be enabled;

3-3: Set the control word 0x6040=15 and enable the module.

4) Control word 0x607A periodically send the target position planned by the master controller to the module.

5.2. Cyclic Synchronous Velocity Mode

5.2.1. Control Block Diagram

When the status word 0x6060=9, the module works in periodic synchronous speed mode. The master controller plans the trajectory and sends the target speed, speed offset, and torque offset to the module in each communication cycle. The module performs velocity control and torque control, as shown in Figure 5-2.

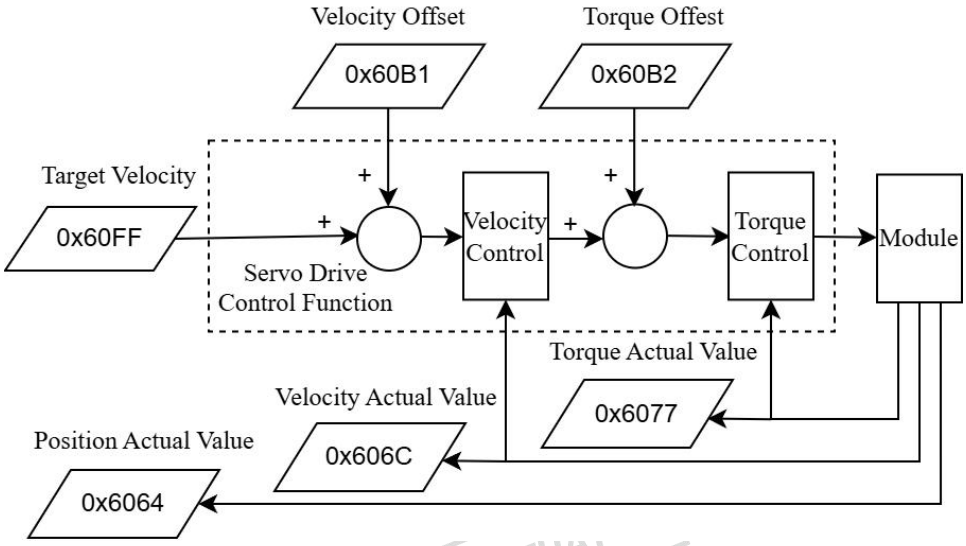

Figure 5-2 Block diagram of the control of the cyclic synchronous velocity mode

5.2.2. Control Commands

For the periodic synchronous velocity mode, table 5-3 describes the definitions of each bit of the control word 0x6040.

Table 5-3 Control word(0x6040)function table

Bit	Name	Description

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0	Switch on	1-valid，0-invalid
1	Enable Voltage	1-valid，0-invalid
2	Quick Stop	0-valid，quick stop；1-invalid
3	Enable Operation	1-valid，0-invalid
4~6	CSV mode reservation	No Define
7~8	Reserve	No Define
9	CSV mode reservation	No Define
10 ~ 15	Reserve	No Define

Table 5-4 describes the definitions of each bit 0x6041 status word.

Table 5-4 Status word (0x6041) function table

Bit	Name	Description
0	Ready to Switch on	1-valid，0-invalid
1	Switched on	1-valid，0-invalid
2	Operation Enabled	1-valid，0-invalid
3	Fault	1-valid，0-invalid
4	Voltage Enabled	1-valid，0-invalid
5	Quick Stop	1-valid，0-invalid
6	Switch on Disabled	1-valid，0-invalid
7	Warning	1-valid，0-invalid
8	Reserve	No Define
9	Remote	1-valid，0-invalid
10	CSV mode reservation	No Define
11	Internal Limit Active	1-valid，0-invalid
12	Follow the target velocity	1-already followed,0-not followed
13	CSV mode reservation	No Define
14~ 15	Reserve	No Define

5.2.3. Control steps

The steps are as follows:

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1) Set 0x6060=9 to make the module work in periodic synchronous velocity mode;

2) Set the target speed 0x60FF=0plus/s, because the module will run at the target speed immediately after switching the enabled state, set it to 0 first to ensure safety;

3) Set the control word 0x6040 and set the module to the enabled state by the following methods:

3-1: Set the control word 0x6040=6 to keep the module disabled;

3-2: Set the control word 0x6040=7, and the module is ready to be enabled;

3-3: Set the control word 0x6040=15 and enable the module.

4) Set the target speed 0x60FF.

5.3. Cyclic Synchronous Torque Mode

5.3.1. Control Block Diagram

When the status word 0x6060=10, the module works in periodic synchronous torque mode. The master controller plans the torque, and transmit the target torque and torque offset to the module within each communication cycle. The module performs torque control, as shown in Figure 5-3.

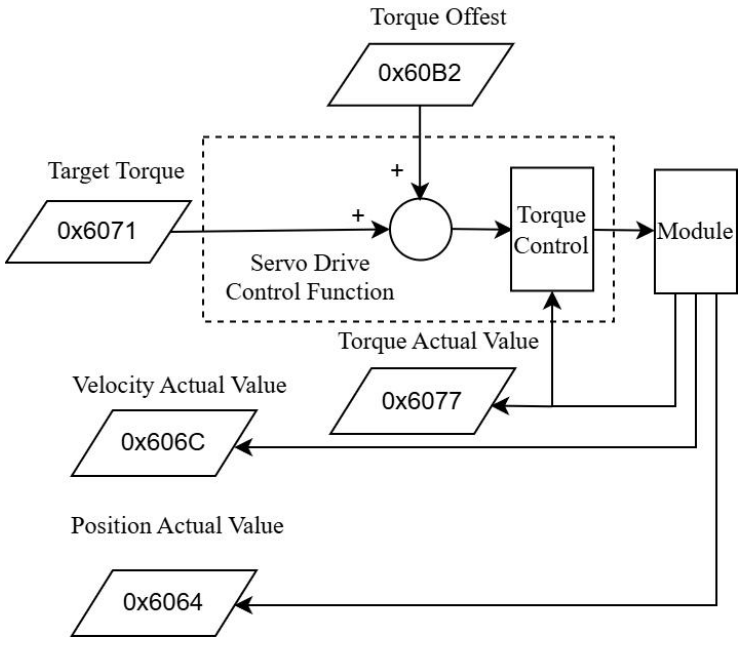

Figure 5-3 Block diagram of the periodic synchronous torque mode

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5.3.2. Control Commands

For the periodic synchronous torque mode, table 5-5 describes the definitions of each bit of the control word 0x6040.

Table 5-5 Control word(0x6040)function table

Bit	Name	Description
0	Switch on	1-valid，0-invalid
1	Enable Voltage	1-valid，0-invalid
2	Quick Stop	0-valid，quick stop；1-invalid
3	Enable Operation	1-valid，0-invalid
4~6	CST mode reservation	No Define
7~8	Reserve	No Define
9	CST mode reservation	No Define
10 ~ 15	Reserve	No Define

Table 5-6 describes the definitions of each bit 0x6041 status word.

Table 5-6 Status word (0x6041) function table

Bit	Name	Description
0	Ready to Switch on	1-valid，0-invalid
1	Switched on	1-valid，0-invalid
2	Operation Enabled	1-valid，0-invalid
3	Fault	1-valid，0-invalid
4	Voltage Enabled	1-valid，0-invalid
5	Quick Stop	1-valid，0-invalid
6	Switch on Disabled	1-valid，0-invalid
7	Warning	1-valid，0-invalid
8	Reserve	No Define
9	Remote	1-valid，0-invalid
10	CST mode reservation	No Define
11	Internal Limit Active	1-valid，0-invalid
12	Follow the target velocity	1-already followed,0-not followed

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13	CST mode reservation	No Define
14~ 15	Reserve	No Define

5.3.3. Control steps

The steps are as follows:

1) Set 0x6060=10 to make the module work in periodic synchronous torque mode;

2) Set the target torque 0x6071=0, because the module will run at the target torque immediately after switching the enabled state, set it to 0 first to ensure safety;

3) Set the control word 0x6040 and set the module to the enabled state by the following methods:

3-1: Set the control word 0x6040=6 to keep the module disabled;

3-2: Set the control word 0x6040=7, and the module is ready to be enabled;

3-3: Set the control word 0x6040=15 and enable the module.

4) Set the target speed 0x607.

6. Object dictionary

6.1. 0x6040 Control Word

Data Type	Default Data	Max Data	Min Data
UINT	0x0000	0xFFFF	0x0000
Access	Backup	Update	PDO Mapping
RW	YES	Immediately	RxPDO
Bit	Meaning		
0	Switch on		
1	Enable voltage		
2	Quick stop		
3	Operation enable		
4~6	Mode specific		
7~8	Reserved		

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9	Mode specific
10 ~ 15	Reserved

6.2. 0x6041 Status Word

Data Type	Default Data	Max Data	Min Data
UINT	0x0000	0xFFFF	0x0000
Access	Backup	Update	PDO Mapping
RO	NO	\	TxPDO
Bit	Meaning		
0	Ready to switch on		
1	Switch on		
2	Operation enable		
3	Fault		
4	Enable voltage		
5	Quick stop		
6	Switch on disabled		
7	Warning		
8	Reserved		
9	Remote		
10	Target reached		
11	Internal limit active		
12~13	Operation mode specific		
14~ 15	Reserved		

6.3. 0x6060 Operating Mode Settings

Data Type	Default Data	Max Data	Min Data

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SINT	0x08	0x0A	0x00
Access	Backup	Update	PDO Mapping
RW	YES	Immediately	RxPDO

Value	Operating mode
0x08	Cyclic synchronous position mode
0x09	Cyclic synchronous velocity mode
0x0A	Cyclic synchronous torque mode

6.4. 0x6061 Operating Mode Display

Data Type	Default Data	Max Data	Min Data
SINT	0x08	0x0A	0x00
Access	Backup	Update	PDO Mapping
RO	NO	\	TxPDO

Value	Operating mode
0x08	Cyclic synchronous position mode
0x09	Cyclic synchronous velocity mode
0x0A	Cyclic synchronous torque mode

6.5. 0x6064 Position Actual Value

Data Type	Default Data	Max Data		Min Data
DINT	0x00000000	0x7FFFFFFF		0x80000000
Access	Backup	Unit	Update	PDO Mapping
RO	NO	plus	\	TxPDO
Description: Indicates the actual location of the encoder feedback at the output.				

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6.6. 0x6077 Torque Actual Value

Data Type	Default Data	Max Data	Min Data
INT	0x0000	0x7FFF	0x8000
Access	Backup	Unit	PDO Mapping
RO	NO	0.1%	TxPDO
Note: Indicates the instantaneous torque of the motor, measured in thousandths of the rated current.			

6.7. 0x607A Target Position

Data Type	Default Data	Max Data		Min Data
DINT	0x00000000	0x7FFFFFFF		0x80000000
Access	Update	Unit	Backup	PDO Mapping
RW	Immediately	plus	YES	RxPDO
Description: The target location is the set position to which the drive should be moved in periodic synchronous position mode.				

6.8. 0x60B0 Position Offset

Data Type	Default Data	Max Data		Min Data
DINT	0x00000000	0x7FFFFFFF		0x80000000
Access	Update	Unit	Backup	PDO Mapping
RW	Immediately	plus	YES	RxPDO
Description: Indicates the position offset value between the target position and the actual position when the motor is stopped.				

6.9. 0x60B1 Velocity Offset

Data Type	Default Data	Max Data	Min Data
DINT	0x00000000	0x7FFFFFFF	0x80000000

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Access	Update	Unit	Backup	PDO Mapping
RW	Immediately	plus/s	YES	RxPDO
Description: Takes the speed command value from the master controller and then adds it to the command of the speed ring, including the input amount of speed feedforward in CSP mode; Contains the offset of the drive device speed instruction in CSV mode.				

6.10. 0x60B2 Torque Offset

Data Type	Default Data	Unit		Access
INT	0x0000	per thousand of rated current		RW
Max Data	Min Data	Update	Backup	PDO Mapping
0x7FFF	0x8000	Immediately	YES	RxPDO
Explanation: Takes the torque command value from the master controller and then adds it to the command of the current loop, including the input amount of torque feed forward in CSP mode; Include the additional torque of the drive instruction in CST mode and add it to the target torque.				

6.11. 0x606C Velocity Actual Value

Data Type	Default Data	Max Data		Min Data
DINT	0x00000000	0x7FFFFFFF		0x80000000
Access	Unit	Update	Backup	PDO Mapping
RO	plus/s	\	NO	TxPDO
Description: Velocity coupling with the input of the speed controller.				

7. Operation Guide

7.1. Connect

When you open the file, right-click Devieces in the TwinCAT Project6, select Scan,

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and after starting the scan, select OK, Yes, or OK for each dialog box.

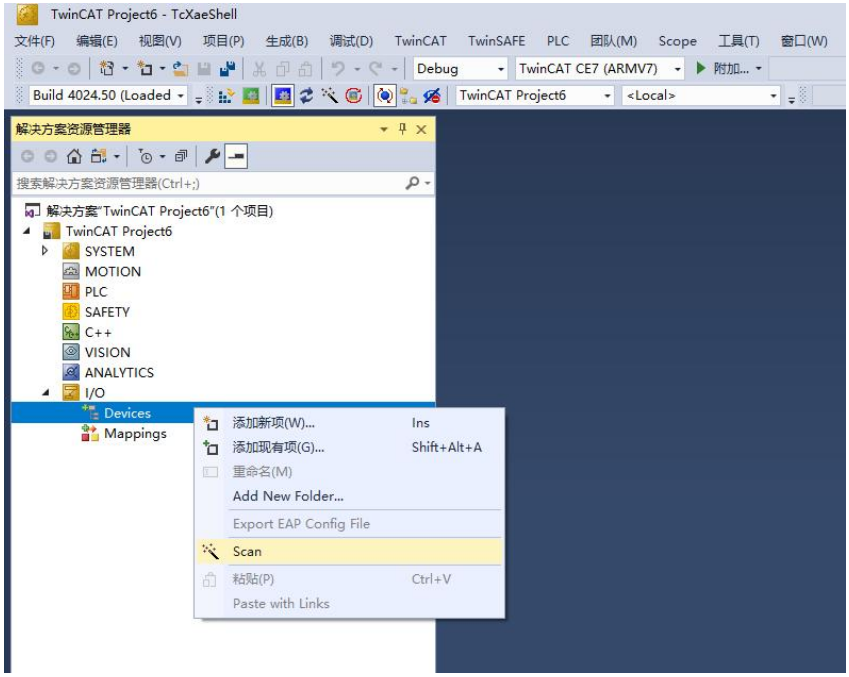

Figure 7-1 Scanning for communication connections

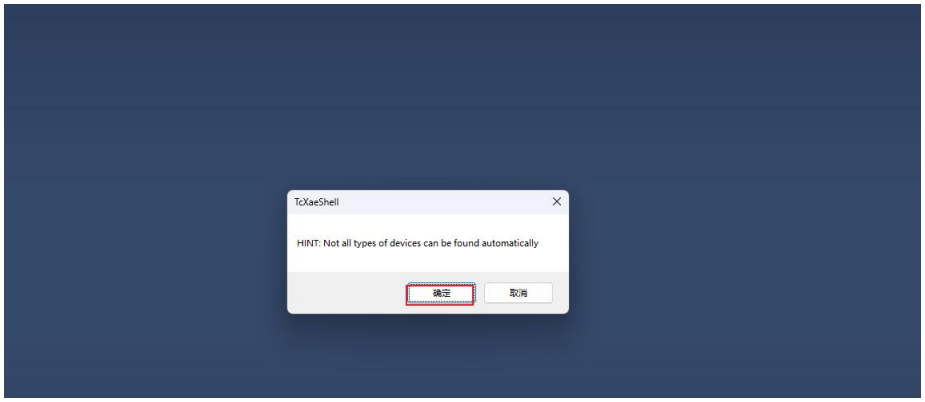

Figure 7-2 Pop-up window

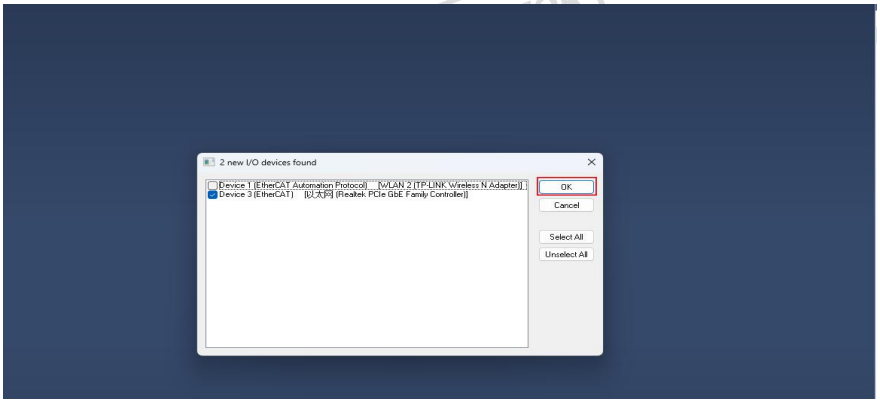

Figure 7-3 Configure I/O Ports

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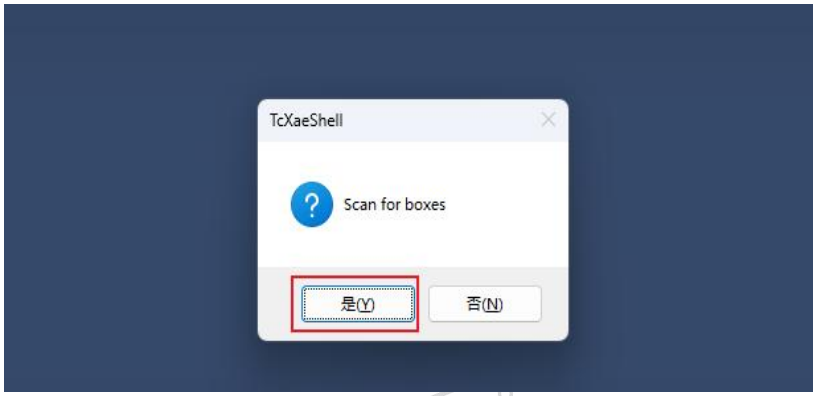

Figure 7-4 Pop-up window

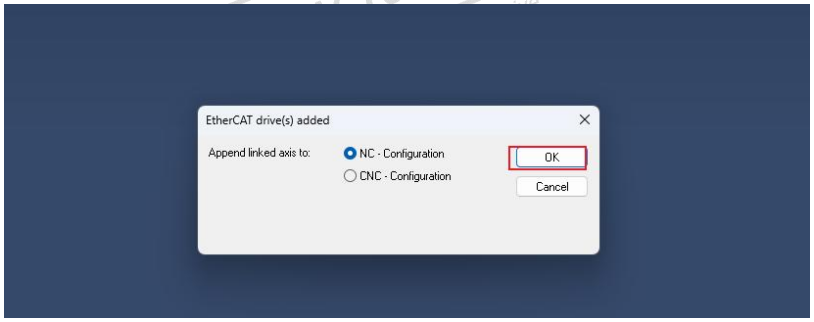

Figure 7-5 Connect Virtual Axes

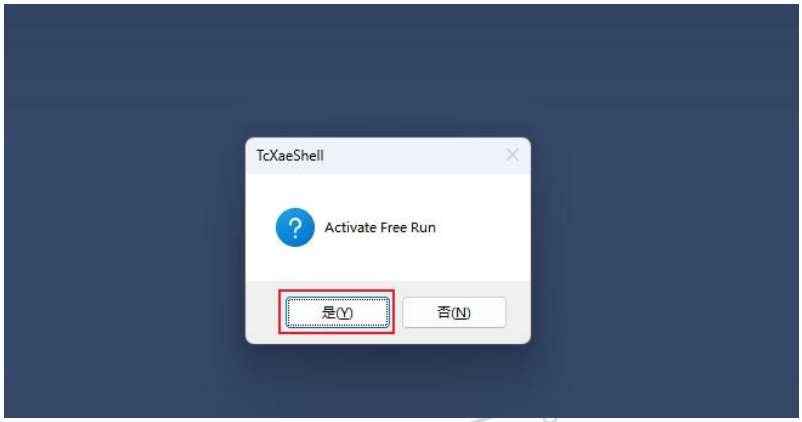

Figure 7-6 Activate Free Run

After the scan, the Solution Explorer 'TwinCAT Project6' appears the found device.

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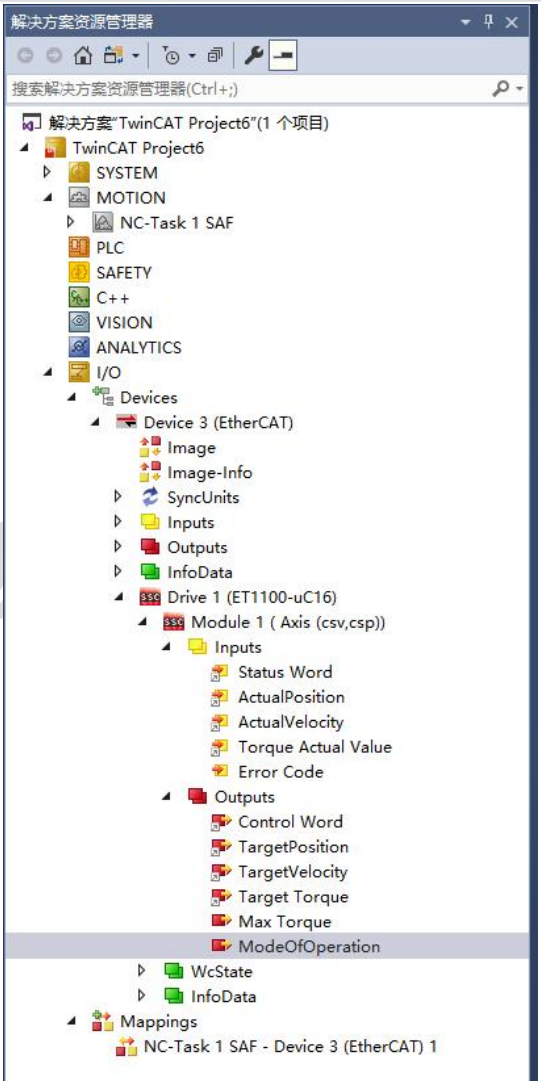

Figure 7-7 Solution Explorer Interface

Choose Drive 1 (ET1100-uC16)，enter the DC interface and change the Operation Mode to DC-Synchron.

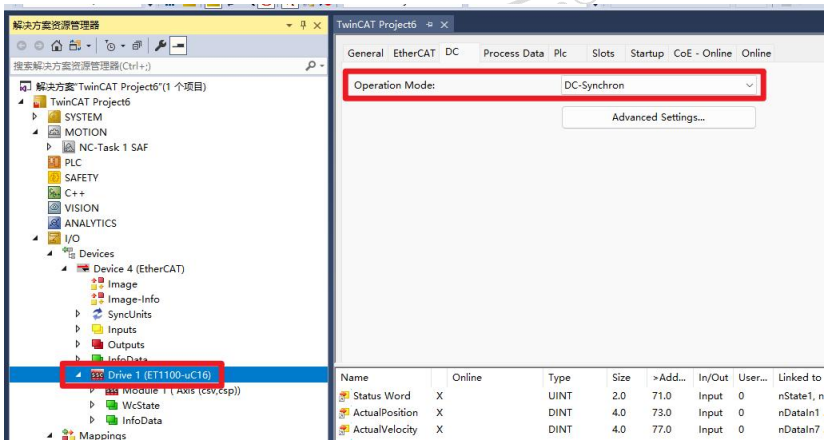

Figure 7-8 Enter the DC Interface

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Click the blue button as shown, restart TwinCAT。

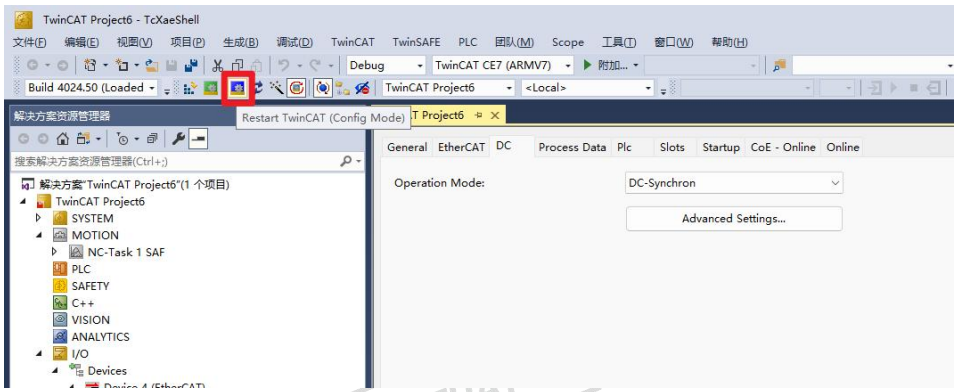

Figure 7-9 Restart TwinCAT

7.2. Position loop mode

Select ModeOfOperation in Module 1 and then select the Online interface. The Value written to ModeOfOperation is the setting of the operation mode of the motor, 8 representing the position mode, 9 the speed mode and 10 the current mode.

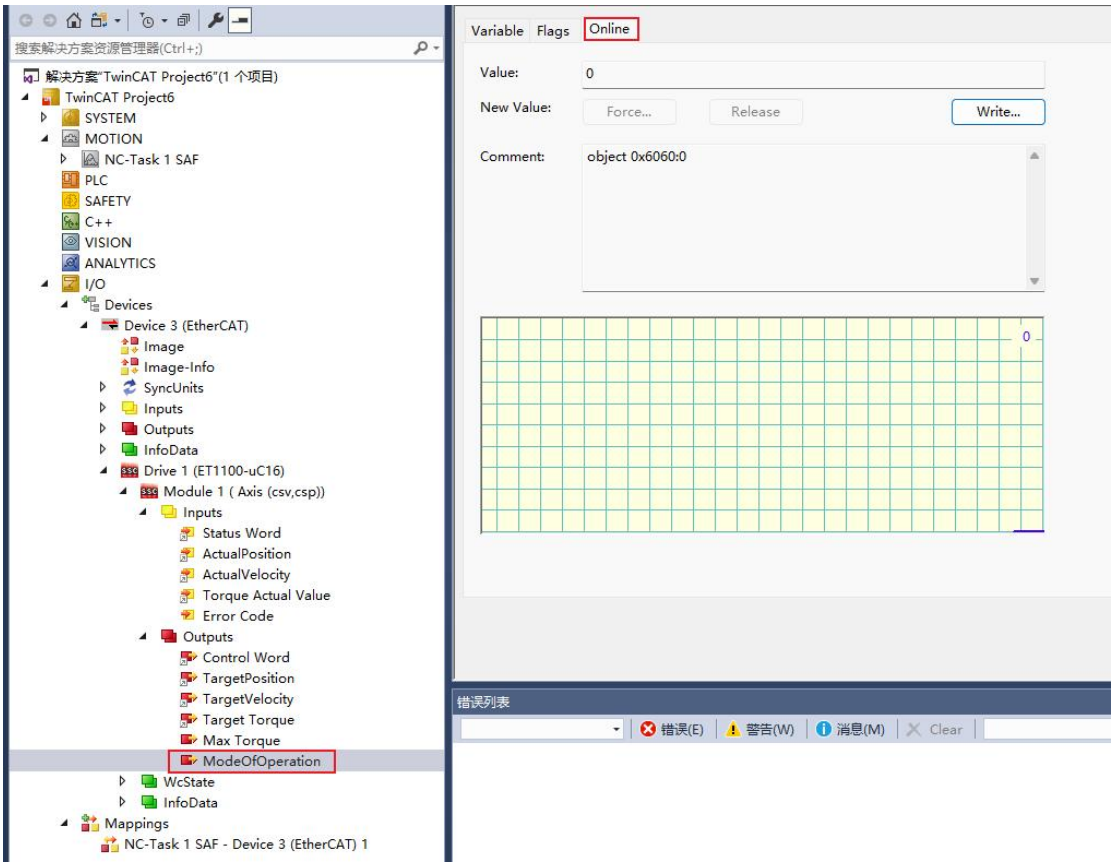

Figure 7-10 Position Mode Selection Interface

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Click Write, enter 8, and click ok to set the running mode to position mode.

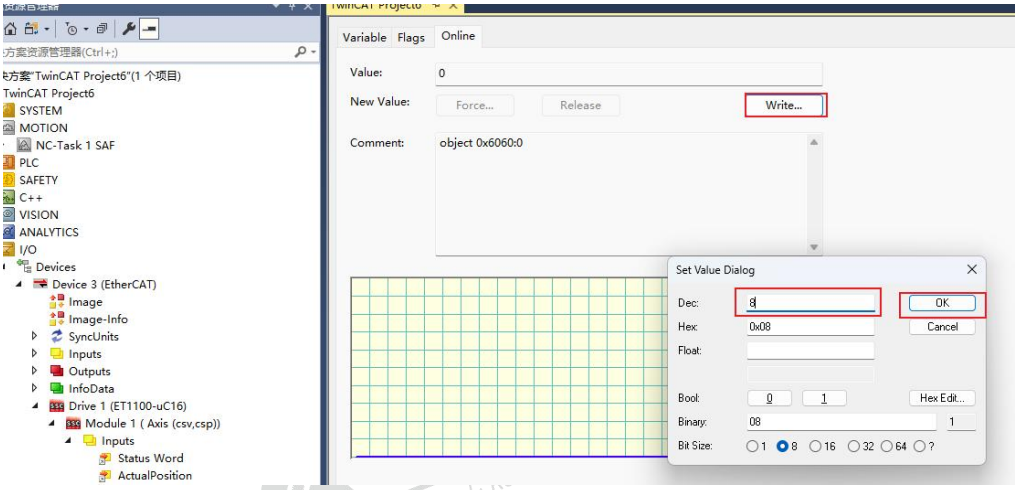

Figure 7-11 Set Position Mode

Click Max Torque, the maximum current in the operation process can be set in the Online interface of Max Torque. When the motor runs, the unit is: one thousandth of the rated current, and the default value of the rated current is 10A.

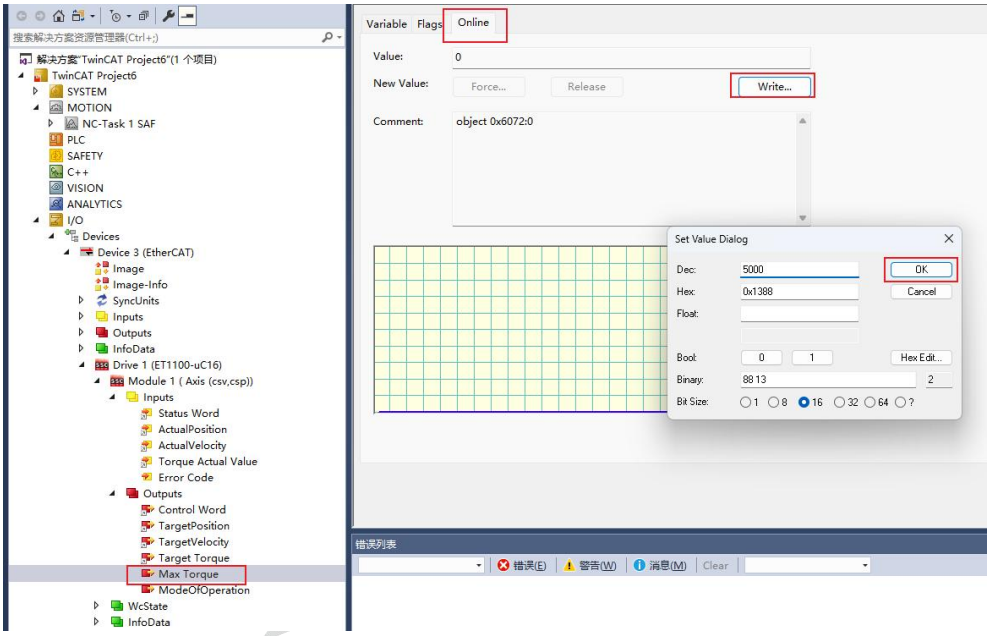

Figure 7-12 Set Maximum Phase Current

Click TartgetPosition to set the target position in the Online interface, the value range is-65535~65535,0 representing 0° , 65535-180° and -65535 is -180° .

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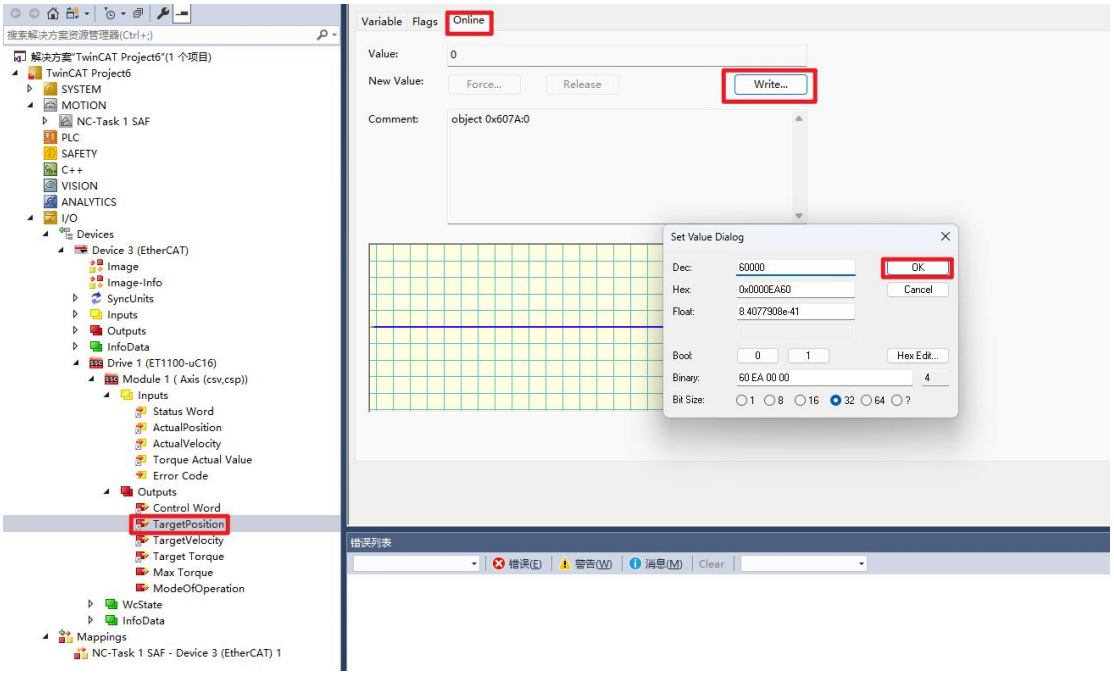

Figure 7-13 Set Target Position

Click ControlWord to write 15 for the start motor in the Online interface and write 0 for the stop motor.

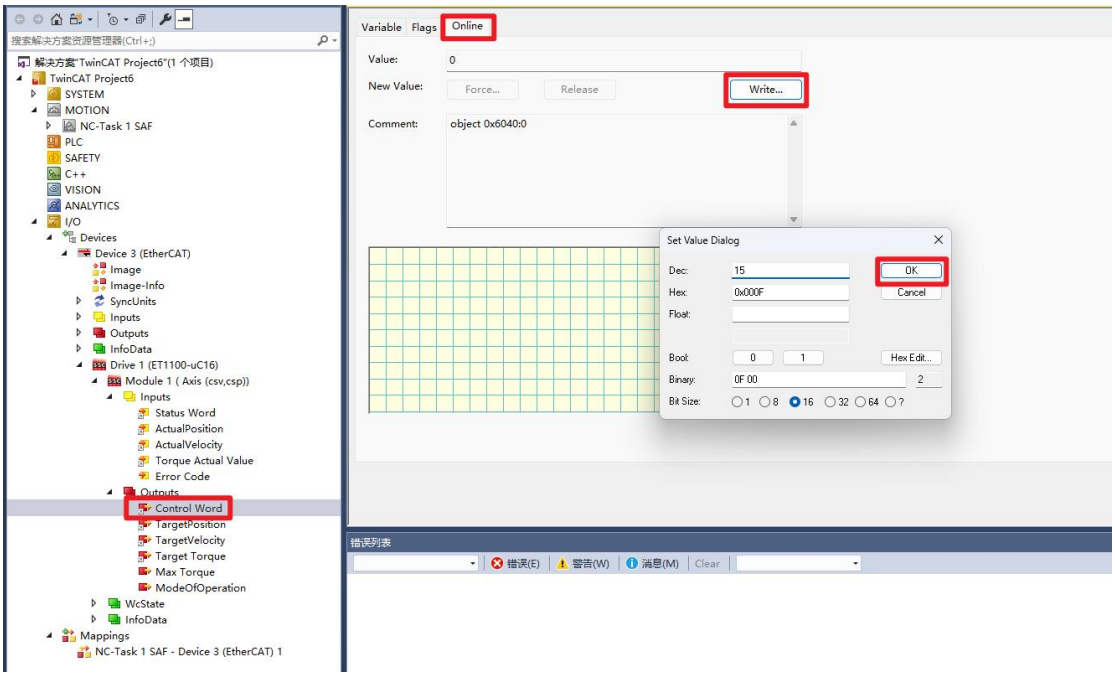

Figure 7-14 Start/Stop Motor

After starting the motor, check whether the motor has reached the specified

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position in the Online interface of ActualPosition.

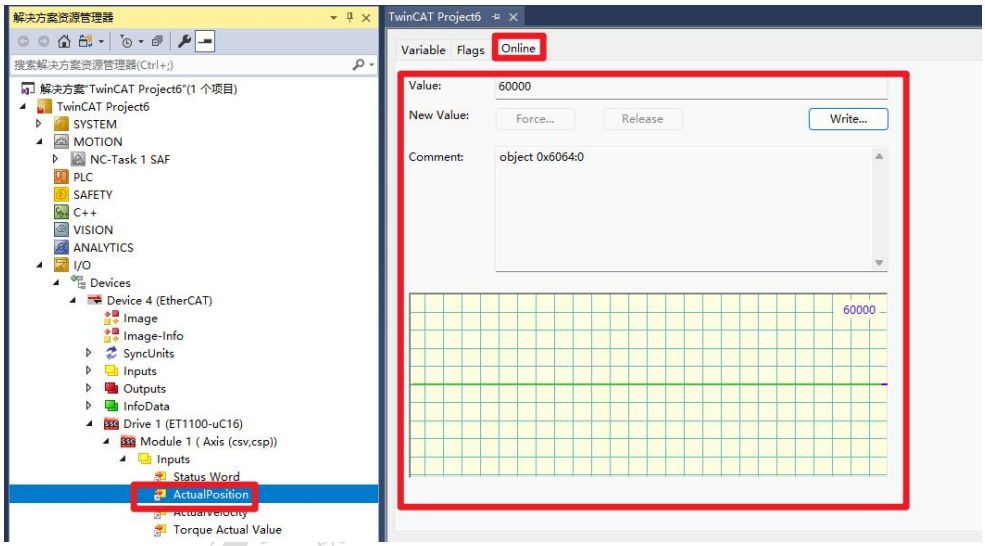

Figure 7-15 Check if the Motor Has Reached the Specified Position

7.3. Speed loop mode

Select ModeOfOperation in Module 1 and then select the Online interface. The Value written to ModeOfOperation is the setting of the operation mode of the motor, 8 representing the position mode, 9 the speed mode and 10 the current mode.

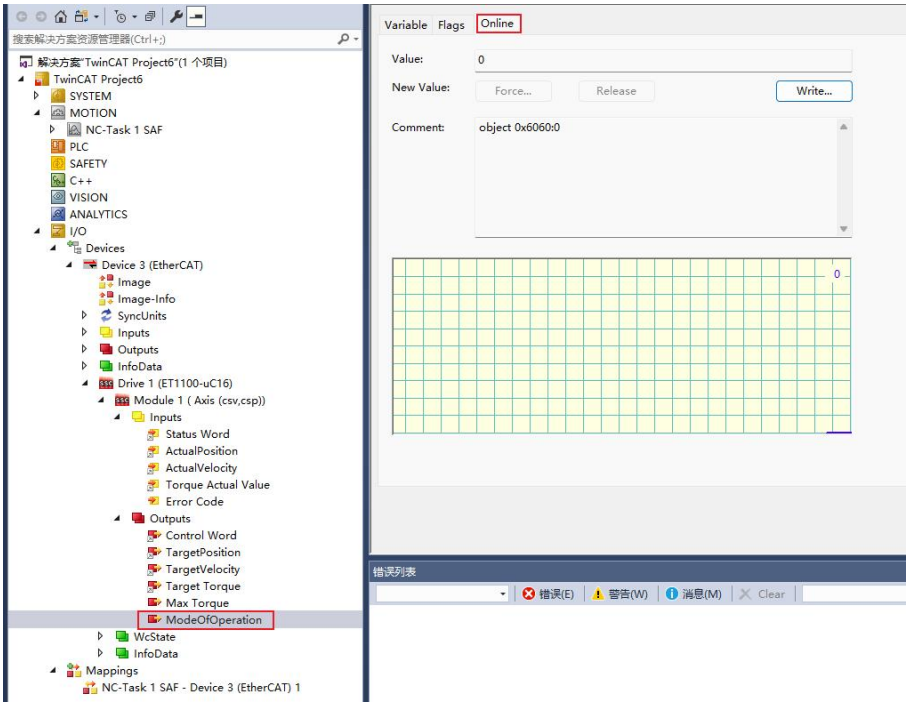

Figure 7-16 Interface for Setting Motor Operation Mode

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Click Write, enter 9, and click ok to set the running mode to speed mode.

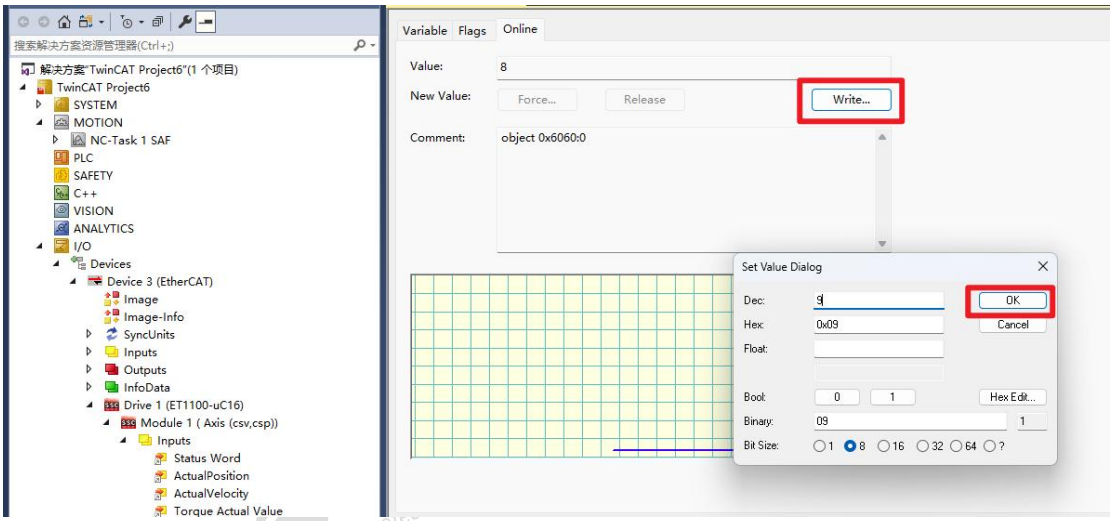

Figure 7-17 Set Speed Mode

Click Max Torque, the maximum current in the operation process can be set in the Online interface of Max Torque. When the motor runs, the unit is: one thousandth of the rated current, and the default value of the rated current is 10A.

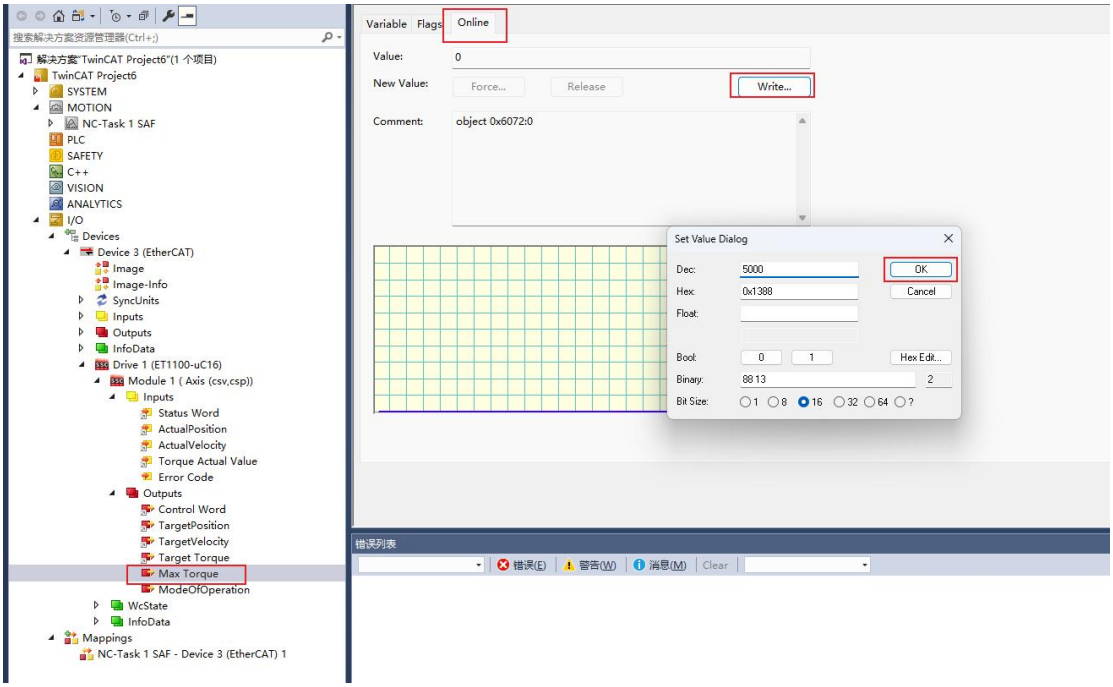

Figure 7-18 Set Maximum Phase Current

Click TartgetVelocity to set the output target speed in the Online interface in pulse /

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second. If the input value is X, the RPM is (X * 60 / 131072) RPM.

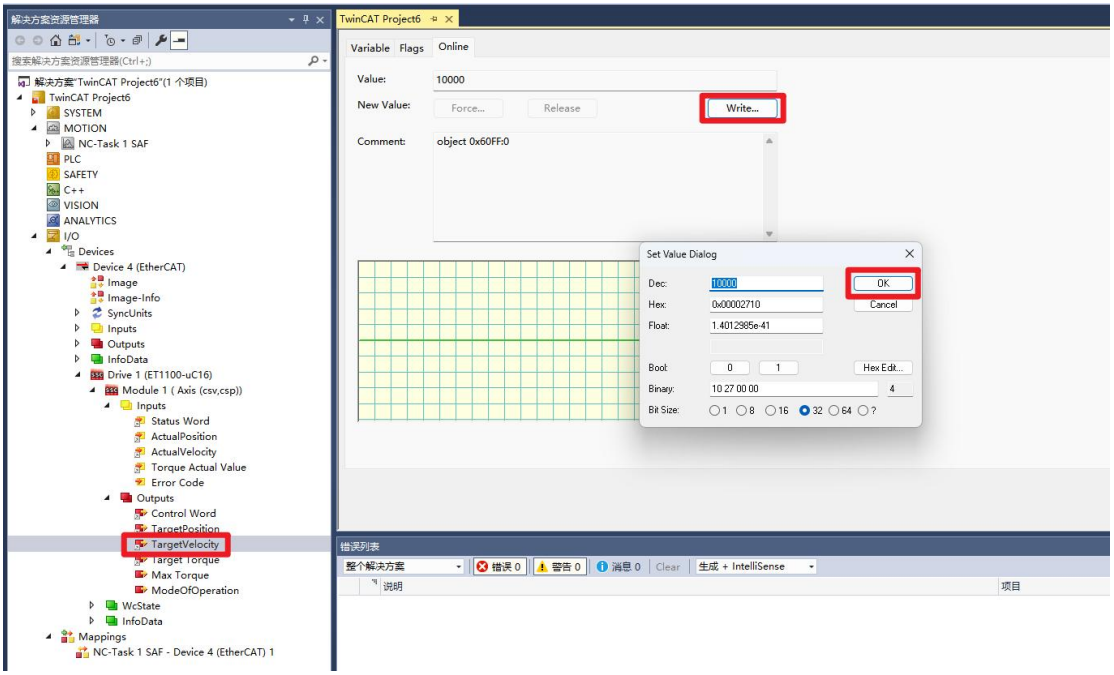

Figure 7-19 Set Target Speed for Output

Click ControlWord to write 15 for the start motor in the Online interface and write 0 for the stop motor.

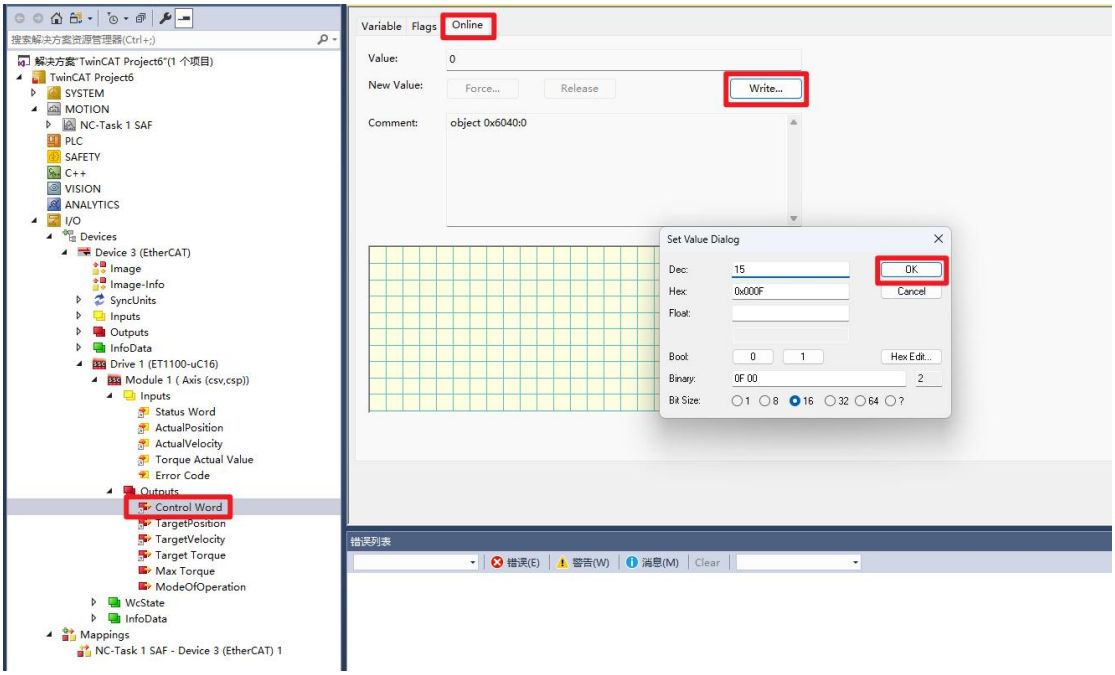

Figure 7-20 Start/Stop Motor

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After starting the motor, the motor can reached the specified speed in the Online interface of ActualVelocity.

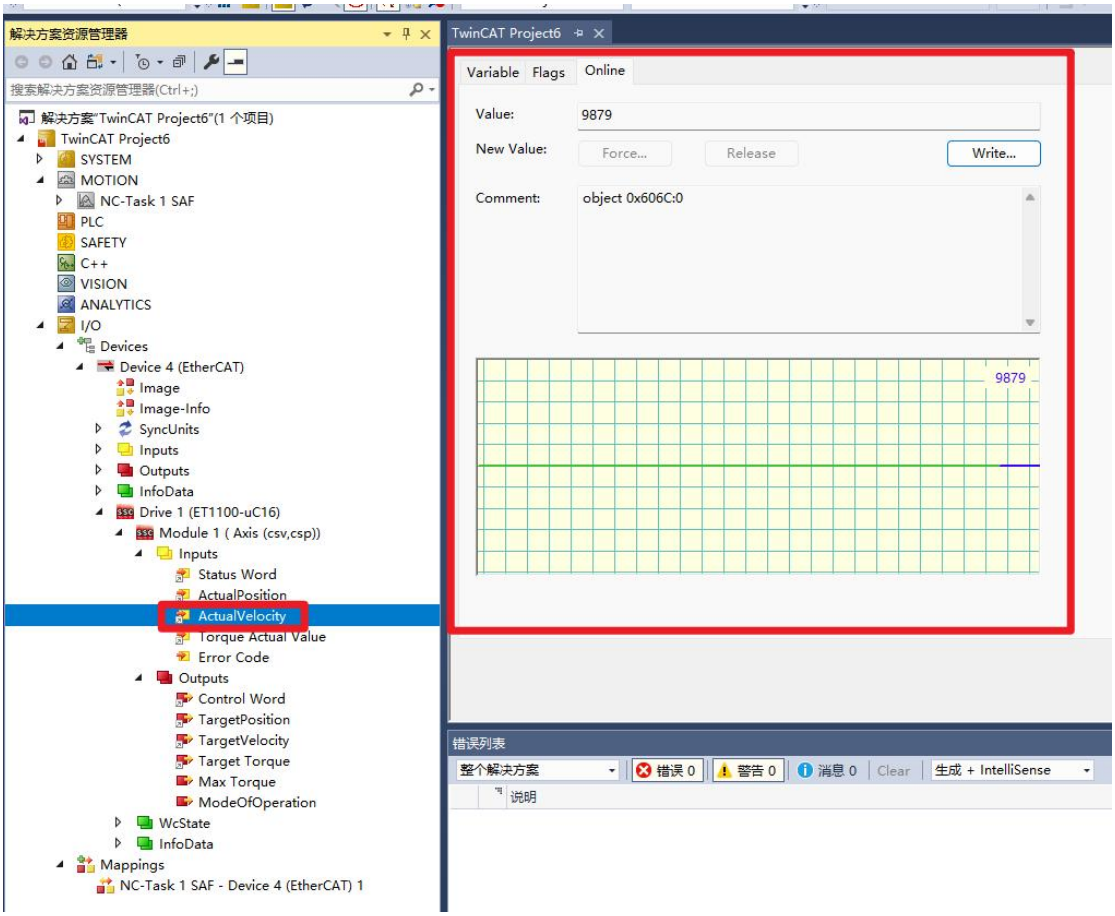

Figure 7-21 Check if the Motor Has Reached the Specified Speed

7.4. Current loop mode

Select ModeOfOperation in Module 1 and then select the Online interface. The Value written to ModeOfOperation is the setting of the operation mode of the motor, 8 representing the position mode, 9 the speed mode and 10 the current mode.

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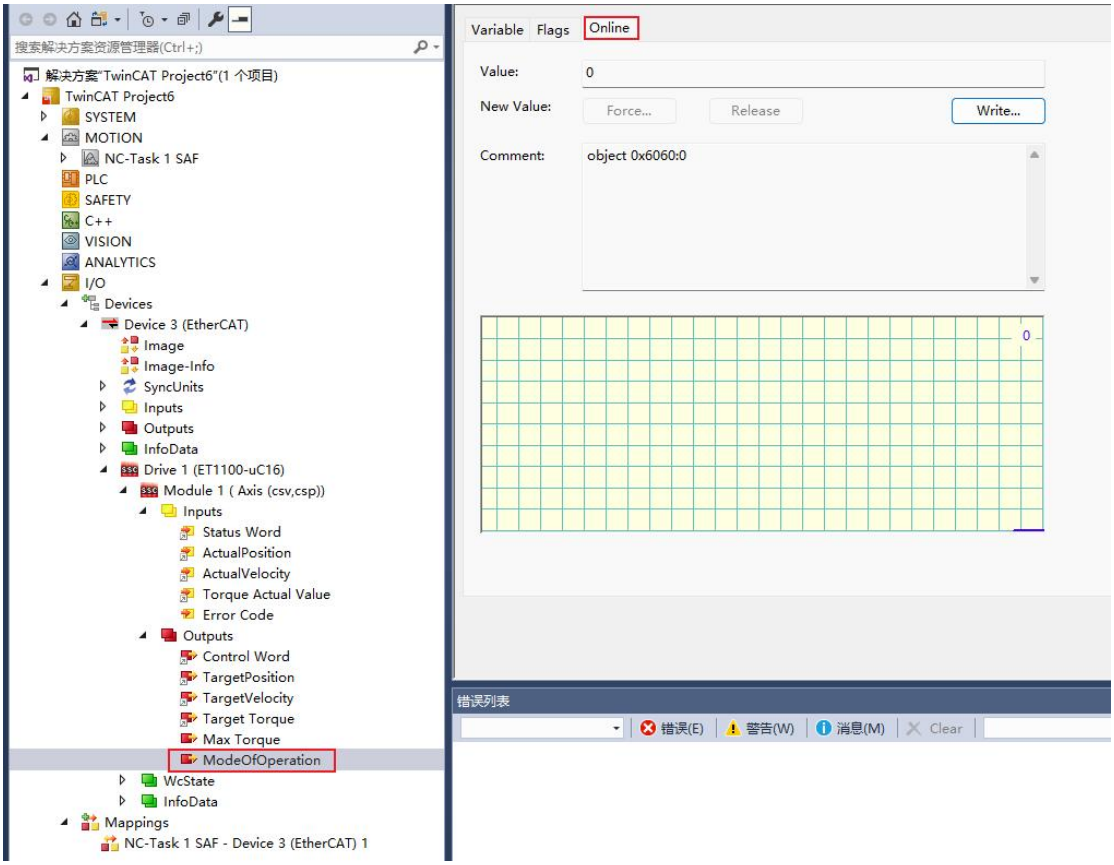

Figure 7-22 Interface for Setting Motor Operation Mode

Click Write, enter 10, and click ok to set the operation mode to the current mode.

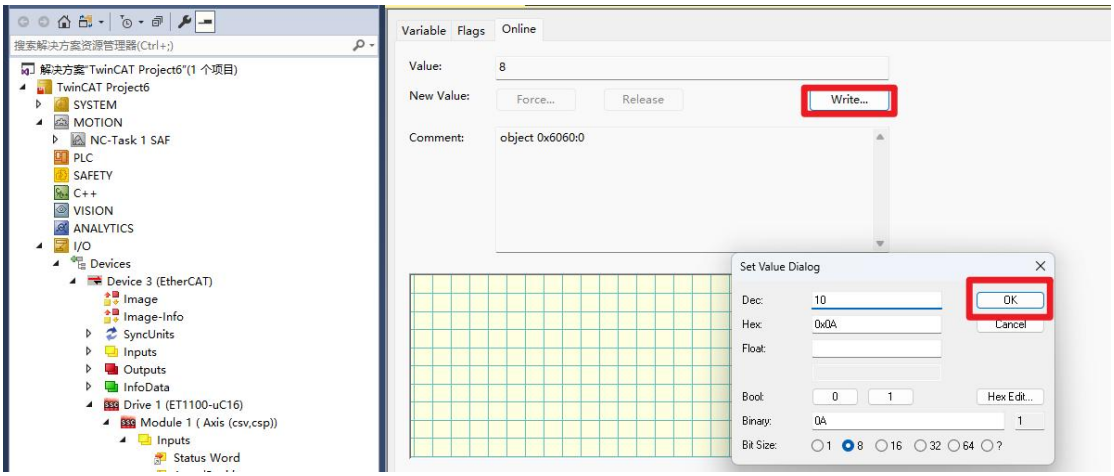

Figure 7-23 Set Current Mode

Click Max Torque, the maximum current in the operation process can be set in the Online interface of Max Torque. When the motor runs, the unit is: one thousandth of the

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rated current, and the default value of the rated current is 10A.

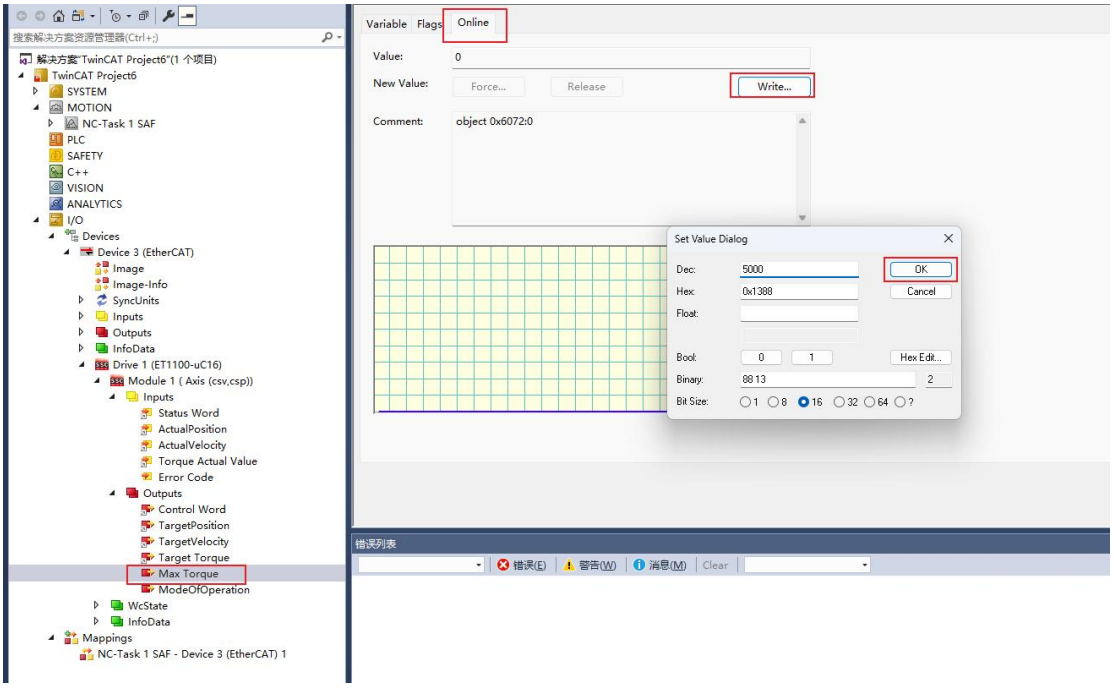

Figure 7-24 Set Maximum Phase Current

Click Tartget Torque, the target current can be set in the Online interface, the unit is: one thousandth of the rated current, the default value of the rated current is 10A, the motor will run with this current, but it will not exceed the maximum current set in 4.3.

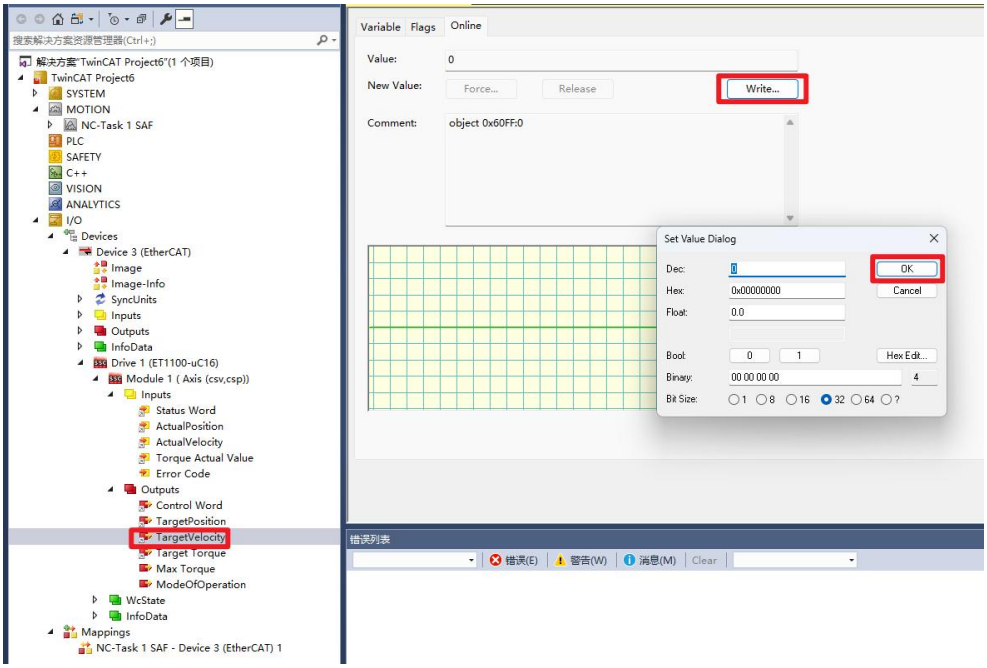

Figure 7-25 Set Target Current

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Click ControlWord to write 15 for the start motor in the Online interface and write 0 for the stop motor.

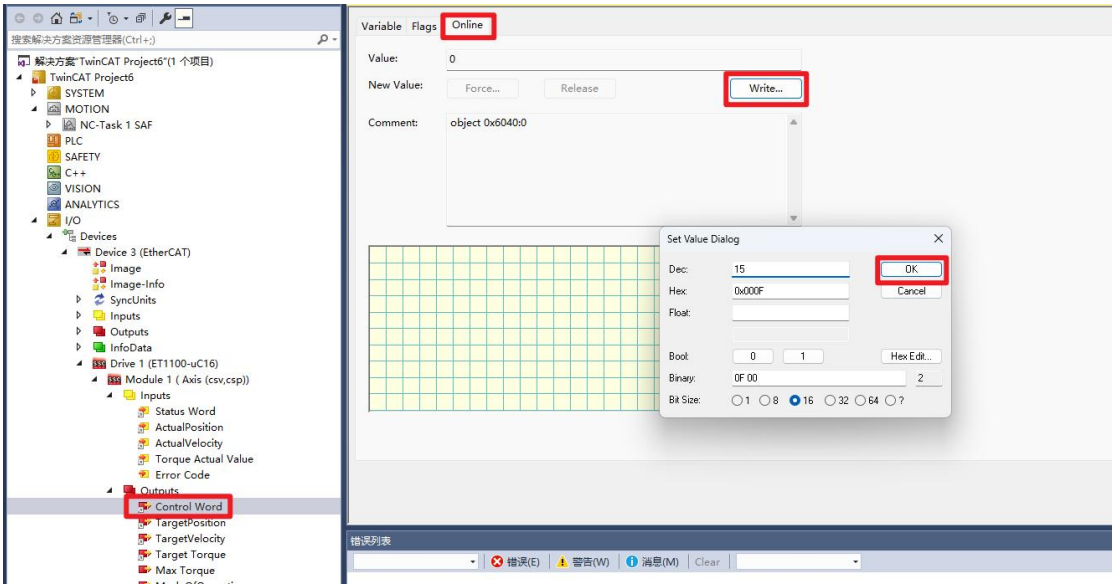

Figure 7-26 Start/Stop Motor

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