Gripper Product Operation Manual

Joint-type Gripper

EtherCAT Version

Preface

Thank you for purchasing and using the Raybot Joint-type Gripper.

This manual introduces the usage methods, precautions, and other information of the joint-type gripper. Please ensure that relevant operators, debugging personnel, and maintenance personnel read this manual carefully before operation.

If you need to learn about other product information from our company, please feel free to contact us.

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Revision History

Date	Version	Description
20260306	V1.0	Initial version, writing operation and instruction related descriptions
20260729	V2.0	Added CSP mode and PP mode function introduction and communication routines

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Precautions

Unboxing

1. Please unpack in hierarchical order. Violent unpacking by knocking is strictly prohibited.
2. Please check against the packing list whether the gripper name is correct, accessories are complete, and whether there is any damage to the surface of the equipment and its accessories. If there are any problems, do not install and contact us immediately.

Testing

1. Do not plug or unplug power cables and communication cables while powered. Ensure the power indicator light is off before wiring and maintenance of the equipment.
2. It is strictly forbidden to disassemble any device or accessory of the equipment while powered, otherwise there is a risk of electric shock.
3. The gripper housing not being grounded may cause charge accumulation on the housing, affecting normal operation of the gripper, or even causing injury to the human body. Wiring cables must meet corresponding wire diameter and shielding requirements. The shielding layer of shielded cables must be reliably grounded.
4. Please conduct risk assessment before use and take appropriate measures to ensure personal safety and equipment safety.
5. Set appropriate position limits, speed limits, current limits, etc. Exceeding limits may damage the gripper or even threaten personal safety.
6. To prevent accidental accidents, please perform no-load trial operation of the gripper.
7. The gripper is a precision device. Do not use hammers or other tools to strike the gripper forcefully. Please handle with care to prevent damage such as cracks caused by the gripper falling from the table.
8. During gripper operation, the surface may become very hot. Please pay attention to protection. Avoid prolonged contact when surface temperature exceeds 40°C to prevent low-temperature burns. When surface temperature exceeds 85°C, avoid contact to prevent mild burns.

Storage

1. Please strictly follow the manual requirements for transportation and storage temperature and humidity. Avoid direct sunlight, strong magnetic fields, strong electric fields, strong vibration, etc. Recommended temperature: -20°C~60°C, relative humidity ⩽85% (no condensation).
2. Avoid storing the gripper for more than 3 months. If storage time is too long, please take more stringent protective measures and necessary inspection and maintenance.
3. Please pack the gripper strictly before transportation. It is strictly forbidden to transport it mixed with equipment that may affect it.

After-sales Policy

This product strictly implements the following after-sales services in accordance with the "Consumer Rights Protection Law of the People's Republic of China" and the "Product Quality Law of the People's Republic of China":

- For users who purchase this product, if product quality problems occur within 7 days, they can enjoy return and exchange services. When returning/exchanging, valid purchase vouchers and returned invoices must be provided, and the returned product must have complete functions, no appearance damage, and complete accessories.
- For users who purchase this product, they enjoy free warranty service within one year from the date of receipt. Warranty service will not be provided for man-made damage, man-made disassembly, etc. If testing confirms that the gripper needs replacement parts, the merchant and customer need to negotiate whether to purchase additional repair parts.
- From the date of receipt, within 7 to 15 days, if product quality problems occur and are confirmed, exchange service can be enjoyed. When exchanging, valid purchase vouchers and returned invoices must be provided, and the returned product must have complete functions, no appearance damage, and complete accessories.
- The following situations are not covered by warranty:

> 1. Gripper burned due to not installing and connecting other control equipment as required by the user manual.
> 2. Using beyond the specifications or standards shown in the user manual (such as incorrect gripper parameter settings).
> 3. Storage methods or working environments exceed the specified range in the user manual (such as pollution, salt damage, condensation, etc.).
> 4. Product damage caused by abnormal working conditions (such as dropping, impact, liquid intrusion, violent impact, etc.).
> 5. Product damage caused by force majeure factors (natural disasters, fire, flood, etc.).
> 6. User's own disassembly of the product causing damage to the gripper.
> 7. Exceeding the warranty period provided by the after-sales policy.
> 8. Unable to provide valid purchase vouchers.

In case of gripper failure, contact sales immediately to obtain solutions. Users must not disassemble or maintain the joint gripper for any reason, otherwise

warranty service will be terminated.

Gripper Overview

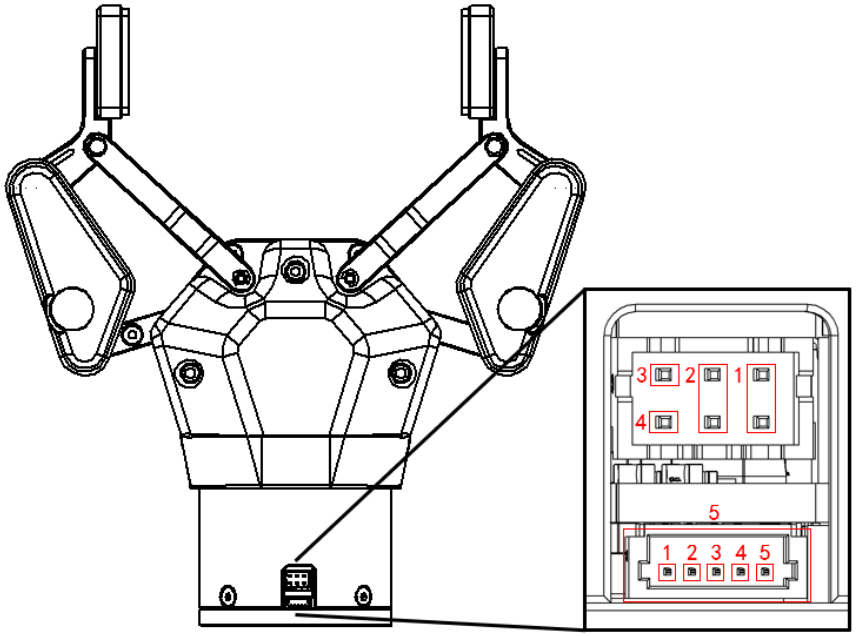
The joint-type gripper has two adaptive parallel mechanical joint fingers (hereinafter referred to as joint fingers). Each joint finger consists of multiple linkage mechanisms and a spring. This design simplifies the control method of gripping, allowing the joint fingers to automatically adapt to the shape of the objects they grip.

Force-position controllable: The gripper can program and adjust the gripping position and gripping force value. During gripper operation, the gripping force is related to the set value.

Multiple communication methods: The gripper body uses standard CAN2.0 communication protocol for control and EtherCAT communication protocol for control.

Gripping judgment: Gripping process uses a combination of force control and position control.

Interface Definition



No.	Interface Definition	Interface Description
1	DC+	24~48V Power Positive
2	DC-	24~48V Power Negative
3	CAN_L	CAN Network Signal
4	CAN_H	CAN Network Signal
5	1.R+ 2.R- 3.T+ 4.T-	EtherCAT Input Interface
6	1.R+ 2.R- 3.T+ 4.T-	EtherCAT Output Interface

EtherCAT System Composition

- EtherCAT is a fieldbus protocol for real-time Ethernet communication. It performs real-time data transmission and processing through data frames, achieving low latency and high bandwidth, while maintaining low cost and simple network structure.
- EtherCAT adopts a master-slave structure. Its system consists of one master device and multiple slave devices. The master sends control commands and data, and slaves receive and execute these commands and transmit output data in real-time, such as sensor data, actuator status, and control commands. Any computer with a network interface and embedded device with Ethernet control can serve as the master. For PC-side computers, the master controller mostly uses TwinCAT software developed by Beckhoff. Servo drives act as slaves, equipped with dedicated slave controllers. The communication network cable between master and slave must be Cat5e or above, communication rate is 100Mbit/s, and the maximum communication length between 2 nodes is 100 meters.

Wiring Method

EtherCAT communication uses twisted pair cables with individual shielding. The hardware connection method is shown in Figure 2-2.

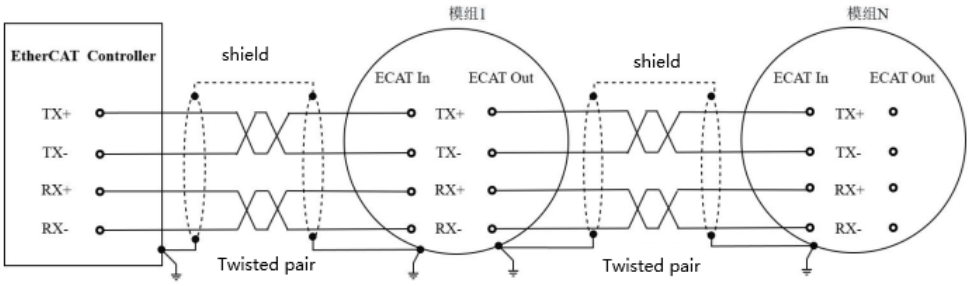


Figure 2-2

Object Dictionary

1. **0x6040 Control Word**

- Can set gripper status.
- 0x0F sets gripper to enabled state.
- 0x00 sets gripper to disabled state.

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
UINT16	0x0000	0xFFFF	0x00	RW	YES	Immediately	RxPDO

2. **0x6041 Status Word**

- Read gripper status.
- 0x0231 Ready to switch on
- 0x0237 Switched on
- 0x1237 Operation enabled
- 0x1231 Quick stop

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
UINT16	0x0000	0xFFFF	0x00	RO	NO	\	TxPDO

3. **0x6060 Modes of Operation**

- Can set gripper operating mode. The following are the 3 modes of the gripper.
- 0x00 is stop state, default at power-on.
- 0x06 is gripper zero-point initialization mode. In this mode, the gripper re-calibrates the zero position. Do not control the gripper during initialization. Initialization takes about 1-5 seconds. Please control after initialization completes.
- 0x08 is gripper torque-stroke mode. The gripper needs to set torque, speed, and stroke three parameters, and the gripper will operate according to the set parameters.

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
INT16	0x0000	0x000A	0x0000	RW	YES	Immediately	RxPDO

4. **0x6061 Modes of Operation Display**

- Read gripper operating mode.
- 0x00 is stop state, 0x06 is gripper zero-point initialization mode, 0x08 is gripper torque-stroke mode.

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
INT16	0x0008	0x000A	0x0000	RO	NO	\	TxPDO

5. **0x6064 Position Actual Value**

- Read gripper motor output shaft position data, displayed in ten-thousandths of the maximum positive angle. (Example: Maximum positive angle is 1200°, read data is 1000, 1200×1000×0.0001=120°, indicating the gripper motor output shaft rotated 120 degrees)

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT32	0x00000000	0x7FFFFFFF	0x80000000	RO	NO	0.01%	\	TxPDO

6. **0x6067 Torque Actual Value (Current)**

- Read gripper motor instantaneous torque current, unit is A.

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT16	0x0000	0x7FFF	0x8000	RO	NO	A	\	TxPDO

7. **0x606C Velocity Actual Value**

- Read gripper motor instantaneous velocity, unit is rpm/min.

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT32	0x00000000	0x7FFFFFFF	0x80000000	RO	NO	rpm/min	\	TxPDO

8. **0x603F Error Code**

- Read gripper error status, error flag System_errorState. (uint16_t type, each bit represents different gripper status)

- When multiple errors occur simultaneously, error status bits are accumulated and displayed. (Example: 0x0016 indicates 0x0002+0x0004+0x0010 sum, meaning the gripper has stall, undervoltage, and phase overcurrent errors simultaneously.)

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
UINT16	0x0000	0x7FFF	0x8000	RO	NO	\	TxPDO

System_errorState Status Table:

System_errorState Value	Status Description
0x0002	Gripper Stall
0x0004	Undervoltage
0x0008	Overvoltage
0x0010	Phase Overcurrent
0x0040	Power Limit Exceeded
0x0080	Calibration Parameter Write Error
0x0100	Overspeed
0x0800	Drive Board MOS Overtemperature
0x1000	Gripper Overtemperature
0x2000	Encoder Calibration Error

9. **0x607B Gripper Gripping Status**

- Read gripper operating status, default value is 0x0000
- When gripping an object, feedback status is 0x0001. When object drops after gripping, feedback status is 0x0002. The premise for feedback of object drop is that gripping status 0x0001 was detected.
- 0x0003 is homing completion flag.

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
UINT16	0x0000	0x0002	0x0000	RO	NO	\	TxPDO

10. **0x607A Target Position**

- Set gripper motor output shaft stroke data, displayed in ten-thousandths of the maximum positive angle. (Example: Maximum positive angle is 1200°, set data is 1000, 1000×0.0001×1200=120°, indicating the gripper motor output shaft rotates to 120 degrees)

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT32	0x00000000	0x7FFFFFFF	0x80000000	RW	NO	0.01%	Immediately	RxPDO

11. **0x60FF Target Velocity**

- Set gripper motor maximum input speed, operating at thousandths of rated speed. (Example: Rated speed is 2000rpm/min, set data is 1000, 1000×0.001×2000=2000rpm/min, indicating gripper motor input maximum speed is 2000rpm/min)

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT32	0x00000000	0x7FFFFFFF	0x80000000	RW	NO	0.1%	Immediately	RxPDO

12. **0x6072 Max Torque (Current)**

- Set gripper motor maximum operating torque current, operating at thousandths of rated current. (Example: Rated current is 10A, set data is 200, 200×0.001×10=2A, indicating gripper motor input maximum operating torque current is 2A)

Data Type	Default	Max	Min	Access	Backup	Unit	Update	PDO Mapping
INT16	0x0000	0x7FFF	0x8000	RW	NO	0.1%	Immediately	RxPDO

13. **0x6060 Modes of Operation (Extended Modes)**

- 0x01 is Profile Position Mode (PP mode). The gripper supports point-to-point positioning, requiring configuration of target position, profile velocity, and acceleration/deceleration.
- 0x08 is Cyclic Synchronous Position Mode (CSP mode). The gripper follows master's cyclic position commands, suitable for multi-axis synchronous interpolation.

Data Type	Default	Max	Min	Access	Backup	Update	PDO Mapping
INT16	0x0008	0x000A	0x0000	RW	YES	Immediately	RxPDO

CSP Mode (Cyclic Synchronous Position Mode, Mode Code 0x08)

CSP mode is the cyclic synchronous position mode defined by the EtherCAT protocol. The master sends target positions to the slave in each communication cycle (e.g., 1ms). The slave updates the position loop after the sync signal (SYNC0) triggers, achieving high-precision multi-axis interpolation synchronization. Suitable for multi-gripper coordination, trajectory interpolation, force-position hybrid control, and other scenarios.

CSP Mode Related Object Dictionary

Index	Sub-index	Name	Type	Access	Description
0x6060	0x00	Modes of Operation	SINT	RW	Set to 0x08 (CSP mode)
0x6061	0x00	Modes of Operation Display	SINT	RO	Read back confirmed as 0x08
0x607A	0x00	Target Position	DINT	RW	Master cyclic target position (user units)
0x6064	0x00	Position Actual Value	DINT	RO	Encoder feedback actual position
0x606C	0x00	Velocity Actual Value	DINT	RO	Actual velocity feedback
0x6077	0x00	Torque Actual Value	INT	RO	Actual torque feedback
0x6040	0x00	Control Word	UINT	RW	State machine control
0x6041	0x00	Status Word	UINT	RO	Status feedback
0x60B1	0x00	Velocity Offset (Feedforward)	DINT	RW	Velocity feedforward (optional)
0x60B2	0x00	Torque Offset (Feedforward)	INT	RW	Torque feedforward (optional)

CSP Mode Control Word (0x6040) Key Bits

Bit	Name	Description
0	Switch On	State machine transition bit
1	Enable Voltage	State machine transition bit
2	Quick Stop	1=Activate quick stop
3	Enable Operation	1=Enable servo operation
4-6	Mode Specific	Reserved/Manufacturer specific in CSP mode
7	Fault Reset	0->1 Rising edge resets fault
8	Halt	1=Halt motion (pause following in CSP)
9-15	Manufacturer Specific	-

CSP Mode Status Word (0x6041) Key Bits

Bit	Name	Description
0	Ready to Switch On	Ready to switch on
1	Switched On	Switched on
2	Operation Enabled	Operation enabled (servo running)
3	Fault	Fault state
4	Voltage Enabled	Voltage enabled
5	Quick Stop	Quick stop active
6	Switch On Disabled	Switch on disabled
7	Warning	Warning present
8	Manufacturer Specific	-
9	Remote	Remote (controlled by master)
10	Target Reached	1=Position reached (following error within window)
11	Internal Limit Active	Soft limit triggered
12	Set-point Acknowledge	In CSP, 1=slave not following master target
13	Homing Attained	Homing attained
14-15	Manufacturer Specific	-

CSP Mode PDO Mapping Recommendations

RxPDO (0x1600) - Standard Control (Torque-Stroke Mode / CSP Mode Common)

Sub-index	Mapping Object	Name	Bit Width
1	0x6040:00	Control Word	16 bit
2	0x607A:00	Target Position	32 bit
3	0x60FF:00	Target Velocity	32 bit
4	0x6071:00	Target Torque	16 bit
5	0x6072:00	Max Torque	16 bit
6	0x6060:00	Modes of Operation	8 bit
7	0x2FFD:00	Padding Byte	8 bit
Total			128 bit = 16 Bytes

TxPDO (0x1A00) - Slave -> Master

Sub-index	Mapping Object	Name	Bit Width
1	0x6041:00	Status Word	16 bit
2	0x6064:00	Position Actual Value	32 bit
3	0x606C:00	Velocity Actual Value	32 bit
4	0x6077:00	Torque Actual Value	16 bit
5	0x603F:00	Error Code	16 bit
6	0x607B:00	Holding Status	16 bit
7	0x6061:00	Modes of Operation Display	8 bit
8	0x2FFE:00	Padding Byte 2	8 bit
Total			128 bit = 16 Bytes

CSP Mode Communication Routine (TwinCAT / EtherCAT Master Example)

Initialization Phase (PreOP -> SafeOP -> OP)

1. **PreOP Phase**: Configure PDO mapping (0x1600, 0x1A00), sync manager parameters (0x1C32, 0x1C33), interpolation cycle (0x60C2).
2. **SafeOP Phase**: Set operation mode 0x6060 = 0x08, wait for 0x6061 to read back as 0x08.
3. **State Machine Enable Sequence** (write 0x6040):
   - 0x0F (Enable Operation)
4. **OP State Cyclic Communication**: Master writes 0x607A target position each cycle (e.g., 1ms). Slave updates position loop after sync signal (SYNC0) triggers,

feeds back 0x6064 position actual value, 0x606C velocity actual value, 0x6077 torque actual value.

Position Command Generation Example (Master Side Pseudo-code, 1ms Cycle)

```
// Master cyclic task (1ms)
void CyclicTask_1ms() {
    static int32_t target_pos = 0;
    static int32_t target_vel = 0;
    static int16_t target_trq = 0;

    // Example: Trapezoidal velocity profile move to 50000 position units
    if (target_pos < 50000) {
        target_vel = 10000;  // Target velocity 10000 units/s
        target_trq = 300;    // Target torque 30% of rated
        target_pos += target_vel / 1000;  // 1ms cycle position increment
        if (target_pos > 50000) target_pos = 50000;
    }

    // Write PDO data (Standard Control Channel 0x1600)
    pdoOutputs[0x6040] = 0x0F;       // Control word: Enable operation
    pdoOutputs[0x607A] = target_pos;  // Target position
    pdoOutputs[0x60FF] = target_vel;  // Target velocity
    pdoOutputs[0x6071] = target_trq;  // Target torque
    pdoOutputs[0x6072] = 1000;       // Max torque 100% rated
    pdoOutputs[0x6060] = 0x08;       // CSP mode

    // Read PDO feedback
    int32_t actual_pos = pdoInputs[0x6064];
    int32_t actual_vel = pdoInputs[0x606C];
    int16_t actual_trq = pdoInputs[0x6077];
    uint16_t status_word = pdoInputs[0x6041];

    // Check in-position: Status word Bit10=1 and position error < window
    bool in_position = (status_word & 0x0400) != 0;
}
```

PP Mode (Profile Position Mode, Mode Code 0x01)

PP mode is a point-to-point positioning mode. The master only needs to set target position, profile velocity, and acceleration/deceleration. The drive internally generates trapezoidal or S-curve velocity profile trajectories to complete point-to-point positioning. Suitable for scenarios not requiring strict multi-axis synchronization, only single-axis point-to-point positioning.

Note: PP mode requires enabling 2 channels (PDO mapping channels) to work properly. Both RxPDO and TxPDO mappings must be configured simultaneously. It is recommended to activate both 0x1600 and 0x1602.

PP Mode Related Object Dictionary

Index	Sub-index	Name	Type	Access	Description
0x6060	0x00	Modes of Operation	SINT	RW	Set to 0x01 (PP mode)
0x6061	0x00	Modes of Operation Display	SINT	RO	Read back confirmed as 0x01
0x607A	0x00	Target Position	DINT	RW	Target position (user units)
0x6081	0x00	Profile Velocity	UDINT	RW	Maximum running velocity (user units/s)
0x6083	0x00	Profile Acceleration	UDINT	RW	Acceleration (user units/s²)
0x6084	0x00	Profile Deceleration	UDINT	RW	Deceleration (user units/s²)
0x6064	0x00	Position Actual Value	DINT	RO	Actual position feedback
0x606C	0x00	Velocity Actual Value	DINT	RO	Actual velocity feedback
0x6040	0x00	Control Word	UINT	RW	State machine control + New target position trigger
0x6041	0x00	Status Word	UINT	RO	Status feedback + Target reached/Set-point acknowledge

PP Mode Control Word (0x6040) Key Bits (PP Mode Specific)

Bit	Name	Description
4	New Set-point	0->1 Rising edge triggers new target position start (absolute/relative determined by Bit6)
5	Change Set Immediately	1=Immediately interrupt current motion and start new target; 0=Wait for current motion to complete
6	Absolute/Relative	1=Relative position; 0=Absolute position
8	Halt	1=Halt motion (deceleration stop)

PP Mode Status Word (0x6041) Key Bits (PP Mode Specific)

Bit	Name	Description
10	Target Reached	1=Position reached (position error within following error limit)
12	Set-point Acknowledge	1=Drive has received new target position (set after Bit4 rising edge)
13	Following Error	1=Following error exceeded

PP Mode PDO Mapping Recommendations

RxPDO (0x1600) - Standard Control Channel (Common with CSP/Torque-Stroke Mode)

Sub-index	Mapping Object	Name	Bit Width
1	0x6040:00	Control Word	16 bit
2	0x607A:00	Target Position	32 bit
3	0x60FF:00	Target Velocity	32 bit
4	0x6071:00	Target Torque	16 bit
5	0x6072:00	Max Torque	16 bit
6	0x6060:00	Modes of Operation	8 bit
7	0x2FFD:00	Padding Byte	8 bit
Total			128 bit = 16 Bytes

RxPDO (0x1602) - PP Mode Dedicated Channel (Must be activated simultaneously)

Sub-index	Mapping Object	Name	Bit Width
1	0x6040:00	Control Word	16 bit
2	0x607A:00	Target Position	32 bit
3	0x6081:00	Profile Velocity	32 bit
4	0x6083:00	Profile Acceleration	32 bit
5	0x6084:00	Profile Deceleration	32 bit
6	0x6060:00	Modes of Operation	8 bit
7	0x2FFD:00	Padding Byte	8 bit
Total			160 bit = 20 Bytes

TxPDO (0x1A00) - Slave -> Master

Sub-index	Mapping Object	Name	Bit Width
1	0x6041:00	Status Word	16 bit
2	0x6064:00	Position Actual Value	32 bit
3	0x606C:00	Velocity Actual Value	32 bit
4	0x6077:00	Torque Actual Value	16 bit
5	0x603F:00	Error Code	16 bit
6	0x607B:00	Gripping Status	16 bit
7	0x6061:00	Modes of Operation Display	8 bit
8	0x2FFE:00	Padding Byte 2	8 bit
Total			128 bit = 16 Bytes

PP Mode Communication Routine (Absolute Positioning Example)

Initialization

1. Set 0x6060 = 0x01, wait for 0x6061 = 0x01.
2. State machine enable: 0x0F -> 0x1F.
3. Set motion parameters:
   - 0x6081 = 300000 (GP2-53 recommended Profile velocity 300000 units/s,GP2-51 recommended Profile velocity 100000 units/s)
   - 0x6083 = 600000 (GP2-53 recommended Acceleration 600000 units/s^2,GP2-53 recommended Acceleration 200000 units/s^2)
   - 0x6084 = 600000 (GP2-53 recommended Deceleration 600000 units/s^2,GP2-53 recommended Deceleration 200000 units/s^2)

Single Absolute Position Move (Target Position 10000)

1. Write target position 0x607A
2. Control word Bit4 changes from 0 to 1 (e.g., 0x000F → 0x001F)
3. Drive starts trajectory planning and motion
4. After motion completes, StatusWord Bit10 = 1
5. To move to a new position, clear Bit4 to 0 first, then repeat the above steps

```
// 1. Write target position
pdoOutputs[0x607A] = 10000;

// 2. Trigger new set-point: Control word Bit4 0->1 rising edge
pdoOutputs[0x6040] = 0x1F;  // 0x0F -> 0x1F (Bit4=1)

// 3. Wait for Status word Bit10 (Target reached) = 1
while ((pdoInputs[0x6041] & 0x0400) == 0) {
    // Wait for motion to complete
}

// 4. Clear Bit4, prepare for next trigger
pdoOutputs[0x6040] = 0x0F;

// 5. Next target position, repeat steps 1-4
```

Relative Position Move (Relative to Current Position -2000)

1. Write target position 0x607A = 8000
2. Control word Bit6=1 (Relative mode), Bit4 0->1 to trigger
3. Wait for StatusWord Bit10 = 1
4. Clear Bit4 and Bit6

Relative Position Move (Relative to Current Position -2000)

```
// 1. 设置目标位置为相对增量
pdoOutputs[0x607A] = 8000;

// 2. 控制字 Bit6=1 (相对模式), Bit4=1 (新设定点上升沿)
// 当前 0x0F -> 设置 Bit4, Bit6 -> 0x5F
pdoOutputs[0x6040] = 0x5F;

// 3. 等待 Bit12=1 (设定点确认)
while ((pdoInputs[0x6041] & 0x1000) == 0);

// 4. 清除 Bit4 和 Bit6
pdoOutputs[0x6040] = 0x0F;
```

```
// 5. 等待 Bit10=1 (目标到达)
while ((pdoInputs[0x6041] & 0x0400) == 0);
```

PP Mode Halt/Resume

```
// Halt: Set Bit8=1
pdoOutputs[0x6040] |= 0x0100;  // Keep enable bits, set halt bit

// Resume: Clear Bit8=0
pdoOutputs[0x6040] &= ~0x0100;
```

Control Routines

CSP Mode Control Routine

1. After power-on, set 0x6060=6, 0x6072=300, 0x6040=15. Wait for gripper initialization. When 0x607B=0x03, initialization is complete.
2. Set 0x6060=8 to make gripper work in torque-stroke mode.
3. Read current gripper motor maximum positive angle proportion from 0x6064. Set target position 0x607A to this proportion.
4. Set stroke speed 0x60FF=1000. Gripper maximum speed runs at 100% of rated speed.
5. Set torque 0x6071=200. Gripper maximum torque set to 20% of rated current.
6. Set control word 0x6040=15 for enabled state.
7. Set control word 0x607A to corresponding values 0~10000. Gripper operates according to motor maximum positive angle proportion. 0 corresponds to finger closed state, 10000 corresponds to finger fully open state.

PP Mode Control Routine

1. After power-on, set 0x6060=6, 0x6072=300, 0x6040=15. Wait for gripper initialization. When 0x607B=0x03, initialization is complete.
2. Set 0x6060=1 to make gripper work in PP mode (Profile Position Mode).
3. Set motion parameters: 0x6081=20000 (Profile velocity), 0x6083=50000 (Acceleration), 0x6084=50000 (Deceleration).
4. State machine enable: 0x6040=0x0F-> 0x1F.
5. Configure PDO mapping: RxPDO (0x1600) Standard Control Mapping; RxPDO (0x1602) PP-specific Mapping (0x6040/0x607A/0x6081/0x6083/0x6084/0x6060); Must activate both 0x1600 and 0x1602 channels simultaneously.
6. Set target position 0x607A=50000 (Absolute position). Trigger control word Bit4 rising edge (0x0F->0x1F->0x0F).
7. Wait for Status word Bit12=1 (Set-point acknowledge), then wait for Bit10=1 (Target reached).
8. For relative moves, set control word Bit6=1 (Relative mode). Same process as above.