Dexterous Hands
User Manual for RH56F1

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Basic Instructions

- Thank you for choosing and purchasing the RH56F1 Series Dexterous Hand product. We are always committed to providing you with reliable products and services. Your satisfaction is our primary goal.
- This manual primarily introduces the product information for the RH56F1 Series Dexterous Hand.
- Please read this manual thoroughly before using the product and perform subsequent operations only with a full understanding of the content.

Version Change Record

Revision Date	Release Version	Change Content
2025-6	**V1.0**	**First Release**

Manual Acquisition Channels

- Printed manual

Please consult the supplier or office where you purchased the product to request a copy.

- Electronic manual

Log on to the official website of Inspire-Robots at https://www.inspire-robots.com.

Disclaimer

- The Company makes every effort to ensure the information in this manual is as accurate and up-to-date as possible. However, the manual is not guaranteed to be free from technical inaccuracies or typographical errors.
- If the manual content is updated, revisions will be made in subsequent versions. We reserve the right to make such modifications without prior notice to users.

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Safety Precautions

- Before using this product, be sure to read this section carefully and operate the product only after fully understanding the instructions regarding its operation, safety, and precautions. Please install and operate the product correctly and with utmost attention to safety.
- Potential hazards associated with product operation are primarily outlined in the "Safety Precautions" section. These are clearly marked with the following safety labels: "DANGER", "WARNING", and "CAUTION". For all other matters, adhere to standard electrical operating procedures.

Safety Level Definitions

DANGER Indicates that failure to comply with specified procedures will result in death or severe physical injury.

WARNING Indicates that failure to comply with specified procedures could result in death or serious physical injury.

CAUTION Indicates that failure to comply with specified procedures could result in minor physical injury or device damage.

Safety Precautions

- For clarity of presentation, some product illustrations in this manual may depict the unit with covers or safety shields removed. During product operation, all covers and safety shields must be properly installed and operational procedures must be followed as specified in this manual.
- The product illustrations in this manual are for illustrative purposes only and may exhibit slight variations from the product you ordered. Please refer to the actual product received.

Precautions for Unpacking and Acceptance
WARNING ● If you find loose screws, damage, corrosion, or other issues with the product and its accessories upon unpacking, do not proceed with installation! ● If, during unpacking, you find any moisture inside the product, missing components, or damaged parts, do not proceed with installation! ● If a careful check against the packing list reveals a discrepancy with the product name, do not proceed with installation!
CAUTION ● Before unpacking, inspect the external shipping package for any damage, including damage,

soaking, moisture, or deformation!

- Unpack the product layer by layer according to the sequence. Avoid violent striking!
- When unpacking, inspect the exterior of the device and all accessories for any physical damage, corrosion, or impact marks!
- After unpacking, check the contents against the packing list to verify that the device and its accessories, as well as documentation are all complete!

If any issues are found with the items listed above, please contact the product supplier or office promptly.

Storage and Transportation Precautions

- Please strictly follow the required storage and transportation conditions to avoid potential damage to the product!
- Avoid storage or transportation in environments subject to water splash, rain, direct sunlight, strong electric fields, strong magnetic fields, or severe vibration!
- Limit storage duration to a maximum of three months. If extended storage is necessary, please implement enhanced protective measures and conduct necessary inspections!
- The product must be securely packaged before vehicle transportation. Enclosed containers are mandatory for long-distance transit!
- It is strictly prohibited to transport this product together with any devices or materials that may potentially affect or damage it!

Installation Precautions

- The product manual and safety precautions must be read thoroughly before installation!
- The product must not be installed in locations subject to strong electric fields or electromagnetic interference!
- When installing the product in an enclosed environment (such as inside a cabinet or chassis), it must be adequately cooled using a cooling device (e.g., a cooling fan or air conditioner) to meet environmental requirements. Failure to do so may cause product overheating or fire!
- It is strictly prohibited to modify this product!
- It is strictly prohibited to loosen the fastening bolts of any product components or parts!
- When this product is installed in a cabinet or terminal equipment, the cabinet or terminal equipment must provide corresponding protective devices such as fireproof enclosures, electrical protection enclosures, and mechanical protection enclosures. The protection level shall comply with relevant IEC standards and local laws and regulations!
- When installing equipment that generates strong electromagnetic interference (such as transformers), a shielding device must be installed to prevent malfunction of this product!

- The product must be mounted on a flame-retardant surface (e.g., metal). Keep flammable materials away from the product to avoid fire hazards!

- During installation, cover the top of the product with a cloth or paper to prevent metal chips, oil, water, and other contaminants from entering the product during drilling, which could cause product failure. After installation is completed, remove the covering to prevent it from blocking ventilation holes and affecting heat dissipation, which could lead to overheating of the product!

Wiring Precautions

- Only qualified personnel are permitted to perform installation, wiring, maintenance, inspection, or component replacement of the product!
- Before performing any wiring, ensure that the power supply to all related devices is completely disconnected. After disconnecting the power, capacitors inside the equipment retain residual voltage. Wait at least for the duration specified on the product's warning label before proceeding with wiring or any other operations. Measure the DC voltage of the main circuit to confirm it is at a safe voltage. Failure to do so carries a risk of electric shock!

- It is strictly prohibited to connect the input power supply to the signal, communication terminal, or output terminals of the device or product, as this may cause device damage or even fire!
- Please use connectors and cables approved by our marketing or technical support personnel to prevent malfunctions caused by non-compliant connectors and cables!
- All cables used for wiring must comply with the requirements for wire gauge and shielding. The shielding layer of shielded cables must be reliably grounded at one end!
- The equipment and product must be properly grounded. Failure to do so may result in electrostatic damage to the product!
- During wiring, exposed metal wires shall be avoided to prevent high-temperatures oxidation or short circuits!

- Please adhere to Electrostatic Discharge (ESD) protection procedures. Wear an anti-static wrist strap during wiring to avoid damaging the device or the internal circuits of the product!
- Ensure the power plug and all other connectors are securely connected to prevent operational issues caused by poor contact!
- When wiring the control circuit, use twisted-pair shielded cable, and connect the shield to the product's grounding terminal. Failure to do so may cause abnormal operation of the product!

Power-On Precautions

DANGER

- Before powering on, ensure that the product is installed correctly and all wiring connections are secure!
- Before powering on, ensure that the power supply meets the product requirements to prevent product damage or fire!

WARNING

- Before powering on, ensure that the power specifications are compatible with the device's ratings to avoid damage from overvoltage!
- After wiring and parameter configuration are completed, perform a test run to confirm the machine operates safely. Failure to do so may result in personal injury or device damage!
- Before energizing, ensure the rated voltage of the product matches the power supply voltage. Incorrect power supply voltage poses a risk of fire!

Abnormality Precautions

WARNING

- Do not disassemble the device by yourself. If a malfunction is confirmed or suspected, please contact our marketing or technical support personnel!

Decommissioning Precautions

WARNING

- Decommission the device and product in accordance with relevant national regulations and standards to prevent property loss or personal injury!
- Decommissioned device and product must be disposed of and recycled according to industrial waste treatment standards to avoid environmental pollution!

- Under any of the following conditions, immediately disconnect the power and contact our company.
- Water ingress into the device.
- Cracked housing or detached components.
- Abnormal operation or performance deviation.
- Unusual odor, smoke, or abnormal noise generated by the device.

Contents

Dexterous Hands
User Manual for RH56F1

1. Product Overview

1.1 Product Features

RH56F1 Series Dexterous Hand is a mechanical dexterous hand (hereinafter referred to as "Dexterous Hand") designed to integrate the micro linear servo actuator with small volume and large torque. These dexterous hands feature six micro linear servo actuators equipped with sensitive force sensors with its user interface supporting RS485, CANFD, and EtherCAT communication. By setting different thresholds, users can easily grasp objects of varying hardness; simple and efficient interface control instructions enable users to quickly operate the dexterous hand; its superior performance makes this dexterous hand suitable for applications in service robots, educational teaching aids, prosthetics, and other fields.

1.2 Structural size

The structural size of the dexterous hand is as shown in Table 1 below.

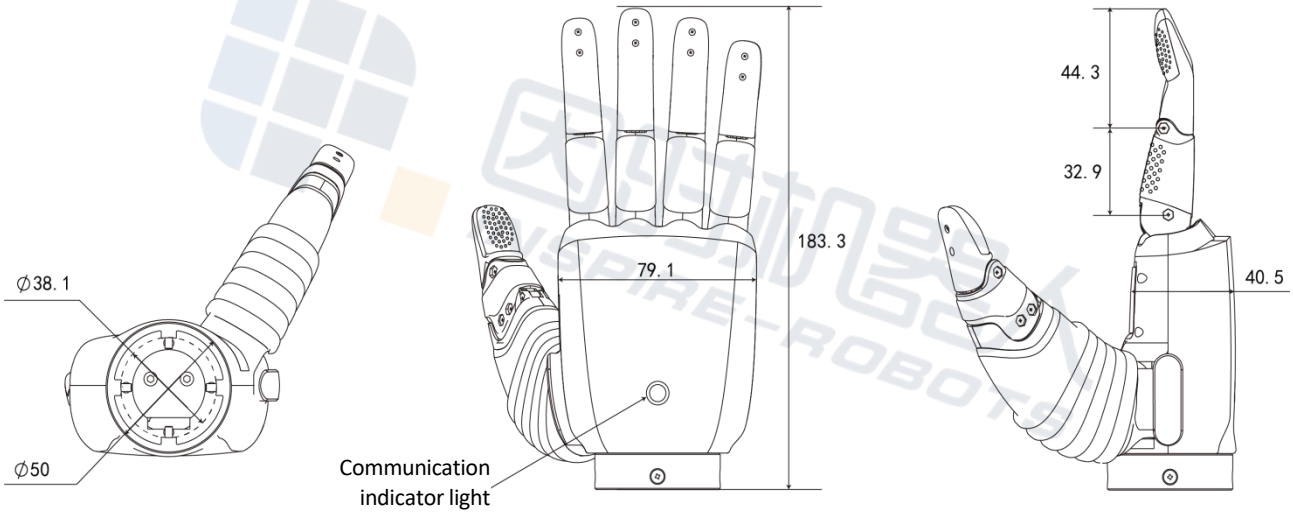


Figure 1 Diagram of structural size

1.3 Performance parameters

See Table 1. for the performance parameters of the dexterous hand.

Table 1 Performance parameters

Total number of joints	12
Degree of freedom (DOF)	6
Number of force sensors	6
Resolution of force sensor	0.1N
Repeated fingertip positioning accuracy	± 0.2mm

Four-finger gripping force	>10N
Thumb gripping force	>15N
Operating voltage	24-48V
Quiescent current	0.2 ± 0.015A@24V
Average current for no-load operation	1.0A @24V
Current for maximum gripping force	4.0A @24V
Communication interface	RS485+EtherCAT or CANFD + EtherCAT

1.4 Electric connection

1.4.1 Pin definition

The wrist of the dexterous hands uses a 1BZ1G08CLL00000 aviation plug interface (compatible with the Lemo FGG-1B-8P aviation plug interface). The physical image is shown below, and the function definitions are shown in Table 2 below.

Table 2 Function Definitions

S/N.	Definition
1	GND
2	VCC(24-48V)
3	485_A/CANFD_H
4	485_B/CANFD_L
5	TX+ (Data Send Positive)
6	TX- (Data Send Negative)
7	RX+ (Data Receive Positive)
8	RX- (Data Receive Negative)

Figure 2 Physical Diagram of Aviation Plug

The external cables of the dexterous hands are shown in Figure 3 below, with the function definitions shown in Table 3 below

Table 3 Function Definitions of Cables

Cable Description	Function Definition
White	TX+ (Data Send Positive)
Blue	TX- (Data Send Negative)
Red (thin)	RX+ (Data Receive Positive)
Black (thin)	RX- (Data Receive Negative)
Yellow	485_A/CANFD_H
Green	485_B/CANFD_L
Red (thick)	VCC (24-48V)
Black (thick)	GND

(Figure 3) Interface Description

Cable Interface Definitions: 1-Aviation Plug Interface: Connects to the dexterous hand's flange aviation plug

2-Network Interface: Connects to an Ethernet cable

3-CANFD/RS485 Interface

4-Power Interface

1.4.2 Communication mode

When the RS485 and CANFD interfaces are used, a particular conversion circuit can realize parallel connection of 254 dexterous hands to the same bus.

When the dexterous hand is using the EtherCAT interface, the bus control of multiple dexterous hands can be achieved based on the EtherCAT communication mechanism.

The communication instructions and registers of dexterous hands are open to the product users. Dexterous hands can be connected with users' PC (controller or general computer) via the aforesaid interface. The user can use a PC or an embedded controller to perform parameter configuration, motion control and other actions of dexterous hands via the aforesaid interface.

2. Communication Protocol

2.1 Summary of Communication Protocol

The main control unit (MCU) reads and writes the internal register of a dexterous hand to achieve state acquisition and control for the dexterous hand.

Read the register: The upper system reads the internal register values of a dexterous hand (readable in groups; groups refer to several registers with adjacent addresses); the upper system sends a read instruction to the dexterous hand (including the first address, length and other details of the register group); after the dexterous hand receives and successfully checks such data, it will return the data content of the corresponding register to the upper system.

Write the register: The upper system writes the corresponding data to the internal register of a dexterous hand (writable in groups); the upper system sends a write instruction to the dexterous hand (including the first address of the register group and the data content to be written); after the dexterous hand receives and successfully checks such data, it will return the acknowledgment signal to the upper system and execute corresponding operation.

2.2 Summary of RS485 Protocol

The RS485 interface is a serial data communication standard widely used in industrial and telecommunications fields, defined by the TIA/EIA-485 standard. It employs differential signal transmission (where the voltage difference between two lines, A and B, represents the data), significantly enhancing interference resistance and ensuring reliable communication over long distances and in high-noise environments.

The communication parameters of RS485 are 8 data bits, 1 stop bit, and no parity, 115200bps by default.

2.2.1 Reading a register of the dexterous hand

The instruction frame format for reading a register of the dexterous hand is shown below. "Address" is the start address of the register to be read. "Hands_ID" is the ID of the dexterous hand. "Address_L" is the low-order 8 bits of "Address". "Address_H" is the high-order 8 bits of "Address". "Register_Length" is the byte length (one register is composed of two bytes, unit: byte) of the data to be read. "Checksum" refers to the low-order bytes of the sum of all data before checksum except the response frame header, as shown in Table 4 below.

Table 4 Instruction frame format for register reading of RS485

	Value	Description

byte[0]	0xEB	Packet header
byte[1]	0x90	Packet header
byte[2]	Hands_ID	ID of the dexterous hand
byte[3]	0x04	Length of the frame data
byte[4]	0x11	Register reading
byte[5]	Address_L	Low-order 8 bits in the start address of the register
byte[6]	Address_H	High-order 8 bits in the start address of the register
byte[7]	Register_Length	Read the byte length of the data
byte[8]	Checksum	Checksum

The dexterous hand returns the following response frame to the read register instruction, as shown in Table 5 below:

Table 5 Instruction response frame format for register reading of RS485

	Value	**Description**
byte[0]	0x90	Packet header
byte[1]	0xEB	Packet header
byte[2]	Hands_ID	ID of the dexterous hand
byte[3]	Register_Length+3	Length of the frame data
byte[4]	0x11	This frame is the response to the read register instruction.
byte[5]	Address_L	Low-order 8 bits in the start address of the register
byte[6]	Address_H	High-order 8 bits in the start address of the register
byte[7] … byte[7+Register_Length-1]	Data[0] … Data[Register_Length-1]	Register value
byte[7+ Register_Length]	Checksum	Checksum

For example, the dexterous hand (ID=1) reads the actual angle for each degree of freedom (DOF). The actual angle for DOF is stored in the register group "ANGLE_ACT(m)", with 1064 (0x0428) as start

address, and 12 bytes (0x0C) as length. The format of this instruction frame is shown in Table 6 below:

Table 6 RS485 Example Read Register Frame Format

	Value	Description
byte[0]	0xEB	Packet header
byte[1]	0x90	Packet header
byte[2]	0x01	ID of the dexterous hand: 1
byte[3]	0x04	Length of the frame data
byte[4]	0x11	Register reading
byte[5]	0x28	Low-order 8 bits in the start address of the register
byte[6]	0x04	High-order 8 bits in the start address of the register
byte[7]	0x0C	Read the byte length of the data
byte[8]	0x4E	Checksum

The dexterous hand returns the following response frame to this instruction, as shown in Table 7 below:

Table 7 RS485 Example Response Frame Format

	Value	Description
byte[0]	0x90	Packet header
byte[1]	0xEB	Packet header
byte[2]	0x01	ID of the dexterous hand
byte[3]	0x0F	Length of the frame data: 12 + 3
byte[4]	0x11	This frame is the response to the read register instruction.
byte[5]	0x28	Low-order 8 bits in the start address of the register
byte[6]	0x04	High-order 8 bits in the start address of the register

byte[7] byte[8]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[9] byte[10]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[11] byte[12]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[13] byte[14]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[15] byte[16]	0x7805	Converted to the integer data 1400 (0x0578)
byte[17] byte[18]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[19]	0x61	Checksum

From this response frame, we can obtain the actual values for DOF: 1000, 1000, 1000, 1000, 1400, and 1000.

2.2.2 Writing to a register of the dexterous hand

The instruction frame format for writing to a register of the dexterous hand is shown in Table 8 below. "Data[0]- Data[Register_Length-1]" is the data to be written to the register.

Table 8 RS485 Write Register Command Frame Format

	Value	**Description**
byte[0]	0xEB	Packet header
byte[1]	0x90	Packet header
byte[2]	Hands_ID	ID of the dexterous hand
byte[3]	Register_Length+3	Length of the frame data
byte[4]	0x12	Write Register instruction flag
byte[5]	Address_L	Low-order 8 bits in the start address of the register
byte[6]	Address_H	High-order 8 bits in the start address of the register
byte[7] … byte[7+Register_Length-1]	Data[0] … Data[Register_Length-1]	Data to be written to the register
byte[7+ Register_Length]	checksum	Checksum

The dexterous hand returns the following response frame to the write register instruction, as shown in Table 9 below:

Table 9 RS485 Write Register Command Response Frame Format

	Value	Description
byte[0]	0x90	Packet header
byte[1]	0xEB	Packet header
byte[2]	Hands_ID	ID of the dexterous hand
byte[3]	4	Length of the frame data
byte[4]	0x12	This frame is the response to the write register instruction.
byte[5]	Address_L	Low-order 8 bits in the start address of the register
byte[6]	Address_H	High-order 8 bits in the start address of the register
byte[7]	1	
byte[8]	checksum	Checksum

For parameter saving (the register "SAVE" is set to 1), the result information frame will be returned one second after the dexterous hand returns the response frame. The content of the result information frame is shown in Table 10 below:

Table 10 RS485 Return Save Result Information Frame

	Value	Description
byte[0]	0x90	Packet header
byte[1]	0xEB	Packet header
byte[2]	Hands_ID	ID of the dexterous hand
byte[3]	4	Length of the frame data
byte[4]	0x12	This frame is the response to the write register instruction.
byte[5]	0xEC	Low-order 8 bits in the start address of the register "SAVE"
byte[6]	0x03	High-order 8 bits in the start address of the register "SAVE"
byte[7]	**	0x00 saving successful; 0xFF saving failure
byte[8]	checksum	Checksum

For example, the angles of a dexterous hand (ID=1) for degrees of freedom (DOF) are set to 1000, 1000, 1000, 1000, 1400, and 1000. It is necessary to modify the angle setting register group. The start

address of this register group is 1040 (0x0410), and its length is 12 bytes (0x0C). The instruction to be sent is shown in Table 11 below:

Table 11 RS485 Example Write Data Frame Format

	Value	Description
byte[0]	0xEB	Packet header
byte[1]	0x90	Packet header
byte[2]	0x01	ID of the dexterous hand
byte[3]	0x0F	Length of the frame data: 12 + 3
byte[4]	0x12	Write Register instruction flag
byte[5]	0x10	Low-order 8 bits in the start address of the register
byte[6]	0x04	High-order 8 bits in the start address of the register
byte[7] byte[8]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[9] byte[10]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[11] byte[12]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[13] byte[14]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[15] byte[16]	0x7805	Converted to the integer data 1400 (0x0578)
byte[17] byte[18]	0xE803	Converted to the integer data 1000 (0x03E8)
byte[19]	0x4A	Checksum

The dexterous hand returns the following response frame to this instruction, as shown in Table 12 below:

Table 12 RS485 Example Response Frame Format

	Value	Description
byte[0]	0x90	Packet header
byte[1]	0xEB	Packet header
byte[2]	0x01	ID of the dexterous hand
byte[3]	0x04	Length of the frame data
byte[4]	0x12	This frame is the response to the write register instruction.

byte[5]	0x10	Low-order 8 bits in the start address of the register
byte[6]	0x04	High-order 8 bits in the start address of the register
byte[7]	0x01	
byte[8]	0x2C	Checksum

2.3 Summary of Modbus_RTU Protocol

The Modbus_RTU protocol adopts the master-slave request/response communication mode. The protocol frame contains function codes, data fields, and cyclic redundancy check (CRC). This series actuator supports reading holding register (function code: 0x03), preset single register (function code: 0x06), and preset multiple registers (function code: 0x10).

2.3.1 Read the holding register (function code: 0x03).

Table 13 Modbus reads the holding register

Query frame format of master station	Slave station address	Function code	Starting register (high-order bytes)	Starting register (low-order bytes)	Number of registers (high-order bytes)	Number of registers (low-order bytes)	CRC
	0x01	0x03	0x03	0xE8	0x00	0x02	XXXX

Explanation: Read the holding register of Slave Station 1# (0x1), with start address = 0x03E8, number of registers = 0x0002, and end address =0x03E8+2-1=0x03E9; that is, read the holding register of Slave Station 1#, 0x03E8-0x03E9; there are totally two registers as shown in Table 14 below.

Table 14 Response frame of slave station Modbus

Response frame format of slave station	Slave station address	Function code	Byte count	0x006B register (high-order bytes)	0x006B register (low-order bytes)	0x006C register (high-order bytes)	0x006C register (low-order bytes)	CRC
	0x01	0x03	0x04	0x00	0x01	0x00	0x02	XXXX

Explanation: Return to the holding register of Slave Station 1# (0x01), 0x03E8-0x03E9; there are totally two registers. The value of 0x03E8 register is 0x0001, and that of 0x03E9 register is 0x0002.

2.3.2 Preset single register function code: 0x06

Table 15 Preset single register

Query frame format of	Slave station address	Function code	Starting register (high-orde	Starting register (low-order	Data content (high-orde	Data content (low-order	CRC

master			r bytes)	bytes)	r bytes)	bytes)	
station	0x01	0x06	0x03	0xE8	0x10	0x00	XXXX

Explanation: Set the holding register of Slave Station 1# (0x01), with register address = 0x03E8 and data content = 0x1000, as shown in Table 16

Table 16 Response frame of slave station Modbus

Response frame format of slave station	Slave station address	Function code	Starting register (high-order bytes)	Starting register (low-order bytes)	Data content (high-order bytes)	Data content (low-order bytes)	CRC
	0x01	0x06	0x03	0xE8	0x10	0x00	XXXX

2.3.3 Preset multiple registers function code: 0x10

Table 17 Preset multiple registers

Query frame format of master station	Slave station address	Function code	Starting register (high-order bytes)	Starting register (low-order bytes)	Number of registers (high-order bytes)	Number of registers (low-order bytes)	Byte count	Data (high-order bytes)	Data (low-order bytes)	Data (high-order bytes)	Data (low-order bytes)	CRC
	0x01	0x10	0x00	0x01	0x00	0x02	0x04	0x00	0x0A	0x01	0x02	XXXX

Explanation: Set the holding register of Slave Station 1# (0x01), with register start address = 0x0001, number of registers = 0x0002, byte count of data content = 0x04, 0x000A and 0x0102 as data content, as shown in Table 18:

Table 18 Response frame of slave station Modbus

Response frame format of slave station	Slave station address	Function code	Starting register (high-order bytes)	Starting register (low-order bytes)	Number of registers (high-order bytes)	Number of registers (low-order bytes)	CRC
	0x01	0x10	0x00	0x01	0x00	0x02	XXXX

2.4 Summary of CANFD Protocol

CAN FD is a high-performance communication protocol based on the traditional CAN bus, specifically designed to meet the demands of modern industrial equipment for higher bandwidth and greater data capacity.

CANFD default configuration: arbitration domain 1Mbps (80%), data domain 5Mbps (80%).

2.4.1 Explanation of CANFD Extended Frame Format

CANFD extended frame format adopts the extended identifier and data frame format. It does not use the standard identifier and remote frame. The extended identifier has 29 bits, which are defined from low-order to high-order bits as follows:

Bit0~7: dexterous hand ID, supports up to 254 devices;

Bit8~19: Start address of the register to be operated;

Bit20~27: Effective data length of data frame.

Bit28: Read/write flag bits; 0 indicates reading a register of the dexterous hand; 1 indicates writing to a register of the dexterous hand, as shown in Table 19:

Table 19 Explanation of CANFD Extended Frame ID Format

Identifier	**Bit 28**	**Bit 27-20**	**Bit 19-8**	**Bit 7-0**
Meaning	0: R - Reading a register of the dexterous hand 1: W - Writing to a register of the dexterous hand	Effective data length of data frame	Register address	Hand_ID

2.4.2 CANFD reading a register of the dexterous hand

The identifier settings of register reading are as shown in Table 20 below:

Table 20 Identifier settings of register reading

Identifier	**Bit 28**	**Bit 27-20**	**Bit 19-8**	**Bit 7-0**
Meaning	Read register flag	Effective data length of data frame	Address	Hand_ID

Effective data length of data frame portion: 1.

Data content of data frame: Length of the register data to be read.

After the dexterous hand receives and correctly analyzes the aforesaid instruction, it will return the following frame:

The identifier is as shown in Table 21 below:

Table 21 Read Register Response Identifier

Identifier	**Bit 28**	**Bit 27-20**	**Bit 19-8**	**Bit 7-0**
Meaning	Read register flag	Effective data length of data frame	Address	Hand_ID

Data content of data frame: Read the register data of corresponding byte length.

For example, if we want to read the current actual angle of the index finger of the dexterous hand (ID=1), the following frames as shown in Table 22 should be sent to the CANFD bus:

Identifier: The binary number is 0000 0000 0001 0100 0010 1010 0000 0001

Table 22 Example of Read Data Identifier

Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
0	1	The address of the actual angle of the index finger is 1066; The binary number is 010000101010.	1

Effective data length of data frame portion: 1

Data content: 2; the current actual angle of the index finger is an integer data; the data length is 2 bytes.

The dexterous hand returns the frame as shown in Table 23 below:

Identifier: The binary number is 0000 0000 0010 0100 0010 1010 0000 0001

Table 23 Example of Response Data Identifier

Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
0	2	The address of the actual angle of the index finger is 1066; The binary number is 010000101010.	1

Effective data length of data frame portion: 2

Data content of the data frame is as below: The current actual angle of the index finger is an integer, which is an integer. The following data should be converted to integers (low-order bytes are followed by high-order bytes). After high-order and low-order bytes are exchanged, the hexadecimal number is 0x01F4, and the decimal number is 500 (the current actual angle of the index finger is 500), as shown in Table 24 below.

Table 24 Response Data

byte0	byte1
0xF4	0x01

2.4.3 CANFD writing a register of the dexterous hand

The identifier settings of register writing are as shown in Table 25 below:

Table 25 Description of Write Register Identifier

Identifier	Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
Meaning	Write register flag	Effective data length of data frame	Address	Hand_ID

Effective data length of data frame portion: Length of the data to be written to the register.

Data content of the data frame: Data to be written to the register

After the dexterous hand receives and correctly analyzes the aforesaid instruction, it will return the following frame, as shown in Table 26:

Table 26 Write Register Response Identifier

Identifier	Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
Meaning	Write register flag	Effective data length of data frame	Address	Hand_ID

Effective data length of data frame portion: 1

Data content of data frame portion: 1

For example, if we want to set the angle of the index finger of the dexterous hand (ID=1) to 600, the following frame as shown in Table 27 should be sent to the CANFD bus:

Identifier: The binary number is 0001 0000 0010 0100 0001 0010 0000 0001

Table 27 Example of Write Data Identifier

Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
1	Effective data length of data frame	The set angle of the index finger is 1042; The binary number is 010000010010.	1

Effective data length of data frame portion: 2

Data content of the data frame portion is as below. The current set angle of the index finger is an integer. It is necessary to split the integer data into high-order and low-order bytes and then exchange these bytes; that is, 600 (0x0258) is converted to the following data content, as shown in Table 28 below:

Table 28 Example of Data Frame of Write Data

byte0	byte1
0x58	0x02

The dexterous hand returns the frame as shown in Table 29 below:

Identifier: The binary number is 0001 0000 0001 0100 0001 0010 0000 0001

Table 29 Example of Write Data Response Identifier

Bit 28	Bit 27-20	Bit 19-8	Bit 7-0
1	1	The set angle of the index finger is 1042; The binary number is 010000010010.	1

Effective data length of data frame portion: 1

Data content of data frame portion: 1

2.5 Explanation of RS485, Modbus_RTU, CANFD registers

The register parameters of the dexterous hand which are open to the users are as shown in Table 30 below:

Table 30 Register address description

Address	Meaning	Length	Permission (read /

			write)
1000 (0x03E8)	ID	2byte	W/R
1001 (0x03E9)	Baud rate setting	2byte	W/R
1003 (0x03EB)	Error clearance	2byte	W/R
1004 (0x03EC)	Saving data in Flash	2byte	W/R
1005 (0x03ED)	Restoring factory defaults	2byte	W/R
1007 (0x03EF)	Force sensor calibration	2byte	W/R
1016 (0x03F8)	Current protection value of the actuator for each DOF	12byte	W/R
1022 (0x03FE)	Set value of power-on speed for each DOF	12byte	W/R
1028 (0x0404)	Set value of power-on force control threshold for each DOF	12byte	W/R
1034 (0x040A)	Set value of the actuator position for each DOF	12byte	W/R
1040 (0x0410)	Set value of the angle for each DOF	12byte	W/R
1046 (0x0416)	Set value of force control threshold for each DOF	12byte	W/R
1052 (0x041C)	Set value of the speed for each DOF	12byte	W/R
1058 (0x0422)	Actual value of the actuator position for each DOF	12byte	R
1064 (0x0428)	Actual angle for each degree of freedom (DOF)	12byte	R
1070 (0x042E)	Actual force applied to each finger	12byte	R
1076 (0x0434)	Current value of the actuator for each DOF	12byte	R

1082 (0x043A)	Error codes of the actuator for each DOF	12byte	R
1088 (0x0440)	Status information for each DOF	12byte	R
1094 (0x0446)	Actuator temperature for each DOF	12byte	R
1100 (0x044C)	Finger Motion Mode Settings	12byte	W/R
1130 (0x046A)	Pause (Write 1 to enable pause; other values are invalid)	2byte	W/R
1131 (0x046B)	Emergency Stop (Write 1 to enable emergency stop; writing other values disables emergency stop)	2byte	W/R
2160 (0x0870)	Motion sequence number setting	2byte	W/R
2162 (0x0872)	Motion sequence run flag	2byte	W/R

2.5.1 ID of the dexterous hand

Default value = 1; range: 1-254; it can be saved.

When several dexterous hands are connected on one bus, each of them should be assigned a ID.

2.5.2 Baud rate setting

Default value = 0; range: 0-3; it can be saved.

485 Interface:

0: Baud rate = 115200bps

1: Baud rate = 57600bps

2: Baud rate = 19200bps

3: Baud rate = 921600bps

CAN2.0/CANFD Interface:

CANFD Interface 0: Baud rate 1M (80%) 5M (80%)

CANFD Interface 1: Baud rate 1M (80%) 2M (80%)

CAN2.0 Interface 2: Baud rate 500Kbps

CAN2.0 Interface 3: Baud rate 1000Kbps

2.5.3 Error clearance

Default value = 0; range: 0-1; it cannot be saved.

After 1 is written, clearable errors (actuator errors such as locked-rotor, overcurrent, abnormal operation, or communication error) in the dexterous hand will be cleared.

Note: The over temperature error of the actuator is not clearable. When the temperature falls, such error will be cleared automatically.

2.5.4 Save parameters

Default value = 0; range: 0-1; it cannot be saved.

After 1 is written, the dexterous hand will write current parameters in the Flash. These parameters will not be lost after power failure.

2.5.5 Restoring factory defaults

Default value = 0; range: 0-1; it cannot be saved.

After 1 is written, parameters of the dexterous hand will be restored to factory default settings.

2.5.6 Force sensor calibration

When the user sets the parameter to 1, the dexterous hand initiates the force sensor calibration process with the calibration lasting for 6s. The process is as follows: first, fully spread all five fingers; then bend the four fingers (little finger, ring finger, middle finger, and index finger; next, spread the four fingers while bending the thumb; finally, extend the thumb.

Note: The dexterous hand must be maintained in no-load state during calibration, that is, fingers cannot touch any object.

2.5.7 Current protection value of the actuator for each DOF

This register group consists of six registers corresponding to the current protection value of of the dexterous hand for 6 DOF. When the current exceeds this value during finger motion, the finger will stop working, and the finger status register will indicate that the finger has stopped due to current protection. The details are as shown in Table 31 below. These parameters can be saved after power failure (unit: mA).

Table 31 Current protection value of the actuator for each DOF

Address	Description	Data type	Range
1016	Current protection value for the little finger	INT16	0-1500
1017	Current protection value for the ring finger	INT16	0-1500
1018	Current protection value for the middle finger	INT16	0-1500
1019	Current protection value for the index finger	INT16	0-1500
1020	Current protection value for bending of the thumb	INT16	0-1500

1021	Current protection value for rotation of the thumb	INT16	0-1500

2.5.8 Set value of power-on speed for each DOF

This register group consists of six registers corresponding to the set value of the power-on speed of the dexterous hand for 6 DOF, with details as shown in Table 32 below. These parameters can be saved after power failure, without range dimension.

Table 32 Set value of power-on speed for each DOF

Address	Description	Data type	Range
1022	Initial power-on speed of the little finger	INT16	0-4000
1023	Initial power-on speed of the ring finger	INT16	0-4000
1024	Initial power-on speed of the middle finger	INT16	0-4000
1025	Initial power-on speed of the index finger	INT16	0-4000
1026	Initial power-on speed of thumb bending	INT16	0-4000
1027	Initial power-on speed of thumb rotation	INT16	0-4000

Speed = 2000: This means that it will take 1000ms for the fingers in the no-load state to move from a large angle to the minimum angle. If there is a heavy load, the actual speed will be somewhat lower than this value.

2.5.9 Set value of power-on force control threshold for each DOF

This register group consists of six registers corresponding to the set value of the power-on force control threshold of the dexterous hand for 6 DOF, with details as shown in Table 33 below. These parameters can be saved after power failure (unit: g).

Table 33 Set value of power-on force control threshold for each DOF

Address	Description	Data type	Range
1028	Initial power-on force control of the little finger	INT16	0-1000
1029	Initial power-on force control of the ring finger	INT16	0-1000
1030	Initial power-on force control of the middle finger	INT16	0-1000

1031	Initial power-on force control of the index finger	INT16	0-1000
1032	Initial power-on force control of thumb bending	INT16	0-1500
1033	Initial power-on force control of thumb rotation	INT16	0-1500

This register value indicates the gripping force provided by the fingertip of the corresponding finger. For example, when the initial power-on force control of the ring finger is set to 200, it means that the fingertip of the ring finger is allowed to provide the gripping force of 200g. (If the portion of a finger that touches an object is not the fingertip, the available gripping force will be different. Its magnitude is related to the length of the arm of force. The shorter the arm of force is, the greater the gripping force will be.)

2.5.10 Set value of the actuator position for each DOF

This register group consists of six registers corresponding to the set position of the actuator of the dexterous hand for 6 DOF, with details as shown in Table 34 below. These parameters cannot be saved, without range dimension.

Table 34 Set value of the actuator position for each DOF

Address	Description	Data type	Range
1034	Setting of the actuator position for the little finger	INT16	0-2000
1035	Setting of the actuator position for the ring finger	INT16	0-2000
1036	Setting of the actuator position for the middle finger	INT16	0-2000
1037	Setting of the actuator position for the index finger	INT16	0-2000
1038	Setting of the actuator position for bending of the thumb	INT16	0-2000
1039	Setting of the actuator position for rotation of the thumb	INT16	0-2000

0: Minimum actuator stroke, corresponding to the maximum finger angle (i.e., holding fingers open);

2000: Maximum actuator stroke, corresponding to the minimum finger angle (i.e., bending fingers);

-1: The actuator does not take any action.

It is not recommended to set the finger position angle by setting this register group.

2.5.11 Set value of the angle for each DOF

This register group consists of six registers corresponding to the set value of the angle of the dexterous hand for 6 DOF, with details as shown in Table 35 below. These parameters cannot be saved after power failure. When the angle value for a degree of freedom (DOF) is set to the data in the range shown in the table below, the corresponding finger will take an immediate action. If the angle value is set to -1, the corresponding finger will make no response. For example, after the angle values of six write angle registers are set to 1200, 1200, -1, 1500, 1200, and 1200 respectively, the little and ring fingers and the thumb will be bent, and the thumb will rotate by 4 DOF and move to an angle corresponding to "1200"; the index finger will move to an angle corresponding to "1200"; and the middle finger will not move (i.e., it will be maintained in the current position without action), unit: 0.1°, the joint angle corresponding to 1200 is 120°.

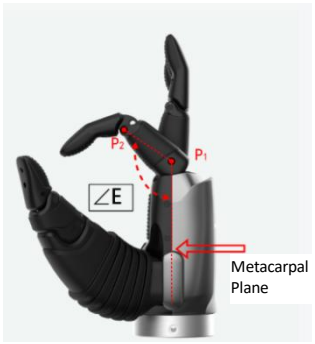
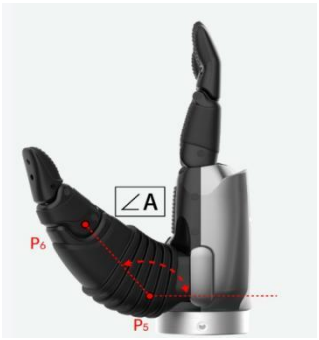
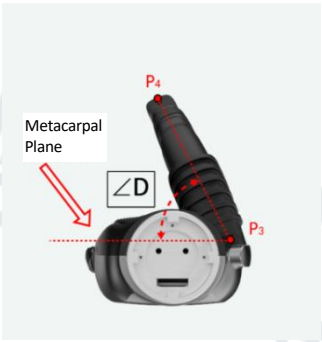
Table 35 Set value of the angle for each DOF

Address	Description	Data type	Range
1040	Angle setting of the little finger	INT16	-1,900-1740
1041	Angle setting of the ring finger	INT16	-1,900-1740
1042	Angle setting of the middle finger	INT16	-1,900-1740
1043	Angle setting of the index finger	INT16	-1,900-1740
1044	Bending angle setting of the thumb	INT16	-1,1100-1350
1045	Rotation angle setting of the thumb	INT16	-1,600-1800

The definition of angle and the range of motion for each DOF are described in Table 36 below.

Table 36 Definitions of angle and the range of motion for each DOF

Angle	Legend description	Range

Little finger Ring finger Middle finger Index finger		90°-174°
Bending angle of the thumb		110°-135°
Rotation angle of the thumb		60°-180°

2.5.12 Set value of force control threshold for each DOF

This register group consists of six registers corresponding to the set value of the force control threshold of the dexterous hand for 6 DOF, with details in the table below. These parameters cannot be saved after power failure. The user can set this register group to control the gripping force of fingers. For example, set force control threshold for the index finger to 100, and set the current actual angle of the index finger to 1720 (i.e., fully open). After the user sets the set angle of the index finger to 900, the index finger will bend towards the palm. Once it is detected that the actual force applied to the index finger during bending reaches 100, the index finger will stop moving; otherwise, the index finger will move to the preset angle, unit: g, with details as shown in Table 37 below.

Table 37 Set value of force control threshold for each DOF

Address	Description	Data type	Range
1046	Set value of force control for the little finger	INT16	0-1000
1047	Set value of force control for the ring finger	INT16	0-1000

1048	Set value of force control for the middle finger	INT16	0-1000
1049	Set value of force control for the index finger	INT16	0-1000
1050	Set value of bending force control for the thumb	INT16	0-1000
1051	Set value of rotation force control for the thumb	INT16	0-1000

This register value indicates the force fed back by the finger end of the corresponding finger.For example, when the force control threshold for the ring finger is set to 200, it means that the fingertip of the ring finger is allowed to provide the gripping force of 200g. (If the portion of a finger that touches an object is not the fingertip, the available gripping force will be different. Its magnitude is related to the length of the arm of force. The shorter the arm of force is, the greater the gripping force will be.)

2.5.13 Set value of the speed for each DOF

This register group consists of six registers corresponding to the set value of the speed of the dexterous hand for 6 DOF, with details as shown in Table 38 below. These parameters cannot be saved after power failure, without range dimension.

Table 38 Set value of the speed for each DOF

Address	Description	Data type	Range
1052	Set value of the speed for the little finger	INT16	0-4000
1053	Set value of the speed for the ring finger	INT16	0-4000
1054	Set value of the speed for the middle finger	INT16	0-4000
1055	Set value of the speed for the index finger	INT16	0-4000
1056	Set value of the speed for thumb bending	INT16	0-4000
1057	Set value of the speed for thumb rotation	INT16	0-4000

Speed = 2000: This means that it will take 1000ms for the fingers in the no-load state to move from a large angle to the minimum angle. If there is a heavy load, the actual speed will be somewhat lower than this value.

2.5.14 Actual value of the actuator position for each DOF

This register group consists of six registers corresponding to the current actual position of the actuator of the dexterous hand for 6 DOF, with details as shown in Table 39 below. These parameters can be read only, without range dimension.

Table 39 Actual value of the actuator position for each DOF

Address	Description	Data type	Range
1058	Actual position value of the actuator for the little finger	INT16	0-2000
1059	Actual position value of the actuator for the ring finger	INT16	0-2000
1060	Actual position value of the actuator for the middle finger	INT16	0-2000
1061	Actual position value of the actuator for the index finger	INT16	0-2000
1062	Actual position value of the actuator for bending of the thumb	INT16	0-2000
1063	Actual position value of the actuator for rotation of the thumb	INT16	0-2000

0: Minimum actuator stroke, corresponding to the maximum finger angle.

2000: Maximum actuator stroke, corresponding to the minimum finger angle.

2.5.15 Actual angle for each degree of freedom (DOF)

This register group consists of six registers corresponding to the current actual angle of the dexterous hand for 6 DOF, with details as shown in Table 40 below. These parameters can be read only, unit: 0.1 °.

Table 40 Actual angle value for each DOF

Address	Description	Data type	Range
1064	Actual angle of the little finger	INT16	900-1720
1065	Actual angle of the ring finger	INT16	900-1720
1066	Actual angle of the middle finger	INT16	900-1720
1067	Actual angle of the index finger	INT16	900-1720

1068	Actual angle of thumb bending	INT16	1200-1450
1069	Actual angle of thumb rotation	INT16	500-1700

2.5.16 Actual force applied to each finger

This register group consists of six registers corresponding to the actual force applied to six fingers of the dexterous hand, with details as shown in Table 41 below. These parameters can be read only, unit: g.

Table 41 Actual force applied to each finger

Address	Description	Data type	Range
1070	Actual force applied to the little finger	INT16	-1000-1000
1071	Actual force applied to the ring finger	INT16	-1000-1000
1072	Actual force applied to the middle finger	INT16	-1000-1000
1073	Actual force applied to the index finger	INT16	-1000-1000
1074	Actual bending force applied to the thumb	INT16	-1000-1500
1075	Actual rotation force applied to the thumb	INT16	-1000-1500

2.5.17 Current value of the actuator for each DOF

This register group consists of six registers corresponding to the current value applied to six actuators of the dexterous hand, with details as shown in Table 42 below. These parameters can be read only.

Table 42 Current value of the actuator for each DOF

Address	Description	Data type	Range	Unit
1076	Current value of the actuator for the little finger	INT16	0-1500	mA
1077	Current value of the actuator for the ring finger	INT16	0-1500	mA
1078	Current value of the actuator for the middle finger	INT16	0-1500	mA
1079	Current value of the actuator for the index finger	INT16	0-1500	mA

1080	Current value of the actuator for bending of the thumb	INT16	0-1500	mA
1081	Current value of the actuator for the thumb rotation	INT16	0-1500	mA

2.5.18 Error codes of each actuator

This register group consists of six registers corresponding to the error code applied to six actuators of the dexterous hand, with details as shown in Table 43 below. These parameters can be read only.

Table 43 Error codes of each actuator

Address	Description	Data type
1082	Error code of the actuator for the little finger	INT16
1083	Error code of the actuator for the ring finger	INT16
1084	Error code of the actuator for the middle finger	INT16
1085	Error code of the actuator for the index finger	INT16
1086	Error code of the actuator for bending of the thumb	INT16
1087	Error code of the actuator for the thumb rotation	INT16

The implication of error codes is as shown in Table 44 below. For example, if the error code of the index finger is 0x06 (00000110 in the binary system), it means that over temperature and overcurrent errors occur in the actuator of the index finger.

Table 44 Description of error codes

	Description
Bit0	Locked-rotor error
Bit1	Over temperature error
Bit2	Overcurrent error
Bit3	Abnormal operation of the motor
Bit4	Communication error

2.5.19 Status information for each DOF

This register group consists of six registers corresponding to the status information of the dexterous hand for 6 DOF, with details as shown in Table 45 below. These parameters can be read only.

Table 45 Status information for each DOF

Address	Description	Data type
1088	Status information of little finger	INT16
1089	Status information of ring finger	INT16
1090	Status information of middle finger	INT16
1091	Status information of index finger	INT16
1092	Status information of thumb bending	INT16
1093	Status information of thumb rotation	INT16

The meaning of the status code is as shown in Table 46 below:

Table 46 Description of status code

Status code	Description
0	Releasing
1	Gripping
2	Position in-place stop
3	Force control in-place stop
5	Current protection stop
6	Locked-rotor stop of the actuator
7	Fault stop of the actuator

2.5.20 Temperature of each actuator

This register group consists of six registers corresponding to the temperature value applied to six actuators of the dexterous hand, with details as shown in Table 47 below. These parameters can be read only.

Table 47 Temperature of each actuator

Address	Description	Data type	Range	Unit
1094	Temperature value of the actuator for the little finger	INT16	0-100	℃
1095	Temperature value of the actuator for the ring finger	INT16	0-100	℃
1096	Temperature value of the actuator for the middle finger	INT16	0-100	℃

1097	Temperature value of the actuator for the index finger	INT16	0-100	℃
1098	Temperature value of the actuator for bending of the thumb	INT16	0-100	℃
1099	Temperature value of the actuator for rotation of the thumb	INT16	0-100	℃

2.5.21 Finger Motion Mode

This register group consists of six registers corresponding to the operation mode of six fingers of the dexterous hand, with details as shown in Table 48 below.

Introduction of Finger Operation Mode:

0: Speed-Force Protection Mode: Control finger movement based on set position, speed, and force, and finger motion stops upon reaching the set force or position

1: Force Closed-loop Mode: Perform force closed-loop control based on set force, and the finger follows the set force to control

2: Impedance Control. Dynamically adjust the balance between contact force and position deviation when grasping or operating objects to prevent object damage or failure caused by rigid contact.

Table 48 Finger Motion Mode

Address	Description	Range	Data type
1100	Motion mode of little finger	0-2	INT16
1101	Motion mode of ring finger	0-2	INT16
1102	Motion mode of middle finger	0-2	INT16
1103	Motion mode of index finger	0-2	INT16
1104	Motion mode of thumb bending	0-2	INT16
1105	Motion mode of thumb rotation	0-2	INT16

2.5.22 Explanation of each finger tactile format

The fingers are equipped with capacitive tactile sensors. These sensors provide data on the normal force, tangential force, and tangential force direction at the fingertip. The relationship between the data and the actual force is: if the data obtained is 1024, the actual force value is 10.24N. The tangential force direction is 0-359°.The direction increases clockwise from the fingertip (0-359°) as shown in Figure 4, If the acquired tangential force data is 0xFFFF, the angle is invalid. The details of data address and content are as shown in Table 49 below.

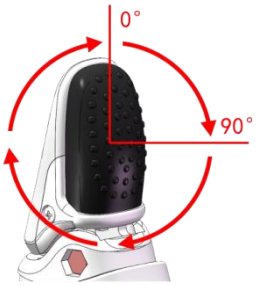


Figure 4 Tangential Force Direction Diagram

Table 49 Explanation of finger tactile format

Address	Meaning	Data type	Resolution	Permission (read / write)
3000	Tactile normal force data for little finger	UINT16	0.01N	R
3001	Tactile tangential force data for little finger	UINT16	0.01N	R
3002	Tactile tangential force direction for little finger	UINT16	Degree	R
3003	Tactile proximity value of little finger is low-order 16-bit	UINT16	24-bit	R
3004	Tactile proximity value of little finger is high-order 16-bit	UINT16		
3005	Tactile normal force data for ring finger	UINT16	0.01N	R
3006	Tactile tangential force data for ring finger	UINT16	0.01N	R
3007	Tactile tangential force direction for ring finger	UINT16	Degree	R
3008	Tactile proximity value of ring finger is low-order 16-bit	UINT16	24-bit	R
3009	Tactile proximity value of ring finger is high-order 16-bit	UINT16		
3010	Tactile normal force data for middle finger	UINT16	0.01N	R
3011	Tactile tangential force data for middle finger	UINT16	0.01N	R

3012	Tactile tangential force direction for middle finger	UINT16	Degree	R
3013	Tactile proximity value of middle finger is low-order 16-bit	UINT16	24-bit	R
3014	Tactile proximity value of middle finger is high-order 16-bit	UINT16		
3015	Tactile normal force data for index finger	UINT16	0.01N	R
3016	Tactile tangential force data for index finger	UINT16	0.01N	R
3017	Tactile tangential force direction for index finger	UINT16	Degree	R
3018	Tactile proximity value of index finger is low-order16-bit	UINT16	24-bit	R
3019	Tactile proximity value of index finger is high-order 16-bit	UINT16		
3020	Tactile normal force data for thumb	UINT16	0.01N	R
3021	Tactile tangential force data for thumb	UINT16	0.01N	R
3022	Tactile tangential force direction for thumb	UINT16	Degree	R
3023	Tactile proximity value of thumb is low-order 16-bit	UINT16	24-bit	R
3024	Tactile proximity value of thumb is high-order 16-bit	UINT16		
3025	Tactile normal force data for palm (right)	UINT16	0.01N	R
3026	Tactile tangential force data for palm (right)	UINT16	0.01N	R
3027	Tactile tangential force direction for palm (right)	UINT16	Degree	R
3028	Tactile normal force data for palm (middle)	UINT16	0.01N	R
3029	Tactile tangential force data for palm (middle)	UINT16	0.01N	R

3030	Tactile tangential force direction for palm (middle)	UINT16	Degree	R
3031	Tactile normal force data for palm (left)	UINT16	0.01N	R
3032	Tactile tangential force data for palm (left)	UINT16	0.01N	R
3033	Tactile tangential force direction for palm (left)	UINT16	Degree	R

2.6 EtherCAT Protocol Overview

The I/O mode of the EtherCAT bus is an efficient data exchange mechanism based on real-time Ethernet. Its core lies in achieving ultra-low latency input/output control through distributed clock synchronization and Process Data Objects (PDO). Currently, EtherCAT only supports the I/O protocol and does not support the CIA402 protocol or DC mode.

2.6.1 Introduction to the PDO Object Dictionary

Table 50 PDO Object Dictionary

Address	Name	Meaning	Data type	Permission (read / write)
0x6000：01	POSACT1	Actual position of the actuator for the little finger	INT16	R
0x6000：02	POSACT2	Actual position of the actuator for the ring finger	INT16	R
0x6000：03	POSACT3	Actual position of the actuator for the middle finger	INT16	R
0x6000：04	POSACT4	Actual position of the actuator for the index finger	INT16	R
0x6000：05	POSACT5	Actual position of the actuator for bending of the thumb	INT16	R
0x6000：06	POSACT6	Actual position of the actuator for sidesway of the thumb	INT16	R
0x6000：07	ANGLEACT1	Actual angle of the little finger	INT16	R
0x6000：08	ANGLEACT2	Actual angle of the ring finger	INT16	R
0x6000：09	ANGLEACT3	Actual angle of the middle finger	INT16	R
0x6000：0A	ANGLEACT4	Actual angle of the index finger	INT16	R
0x6000：0B	ANGLEACT5	Actual angle of thumb bending	INT16	R
0x6000：0C	ANGLEACT6	Actual angle of the actuator for	INT16	R

		sidesway of the thumb		
0x6000：0D	FORCEACT1	Actual force applied to the little finger	INT16	R
0x6000：0E	FORCEACT2	Actual force for sidesway of the ring finger	INT16	R
0x6000：0F	FORCEACT3	Actual force for sidesway of the middle finger	INT16	R
0x6000：10	FORCEACT4	Actual force for sidesway of the index finger	INT16	R
0x6000：11	FORCEACT5	Actual force for bending of the thumb	INT16	R
0x6000：12	FORCEACT6	Actual force for sidesway of the thumb	INT16	R
0x6000：13	CURACT1	Actual current applied to the little finger	INT16	R
0x6000：14	CURACT2	Actual current for sidesway of the ring finger	INT16	R
0x6000：15	CURACT3	Actual current for sidesway of the middle finger	INT16	R
0x6000：16	CURACT4	Actual current for sidesway of the index finger	INT16	R
0x6000：17	CURACT5	Actual current for bending of the thumb	INT16	R
0x6000：18	CURACT6	Actual current for sidesway of the thumb	INT16	R
0x6000：19	ERROR1	Error code of the little finger	INT16	R
0x6000：1A	ERROR2	Error code of the ring finger	INT16	R
0x6000：1B	ERROR3	Error code of the middle finger	INT16	R
0x6000：1C	ERROR4	Error code of the index finger	INT16	R
0x6000：1D	ERROR5	Error code for bending of the thumb	INT16	R
0x6000：1E	ERROR6	Error code for sidesway of the thumb	INT16	R
0x6000：1F	STATUS1	Status information of little finger	INT16	R
0x6000：20	STATUS2	Status information of ring finger	INT16	R
0x6000：21	STATUS3	Status information of middle finger	INT16	R
0x6000：22	STATUS4	Status information of index finger	INT16	R
0x6000：23	STATUS5	Status information of thumb bending	INT16	R
0x6000：24	STATUS6	Status information for sidesway of the thumb	INT16	R

0x6000：25	TEMP1	Temperature of the little finger	INT16	R
0x6000：26	TEMP2	Temperature of the ring finger	INT16	R
0x6000：27	TEMP3	Temperature of the middle finger	INT16	R
0x6000：28	TEMP4	Temperature of the index finger	INT16	R
0x6000：29	TEMP5	Temperature for bending of the thumb	INT16	R
0x6000：2A	TEMP6	Temperature for sidesway of the thumb	INT16	R
0x6000：2B	NormalForce1	Normal force value for little finger	INT16	R
0x6000：2C	TangentialForce1	Tangential force value for little finger	INT16	R
0x6000：2D	Direction1	Tangential force direction for little finger	INT16	R
0x6000：2E	ProximityValue_L1	Proximity sense value for little finger	INT16	R
0x6000：2F	ProximityValue_H1		INT16	R
0x6000：30	NormalForce2	Normal force value for ring finger	INT16	R
0x6000：31	TangentialForce2	Tangential force value for ring finger	INT16	R
0x6000：32	Direction2	Tangential force direction for ring finger	INT16	R
0x6000：33	ProximityValue_L2	Proximity sense value for ring finger	INT16	R
0x6000：34	ProximityValue_H2		INT16	R
0x6000: 35	NormalForce3	Normal force value for middle finger	INT16	R
0x6000: 36	TangentialForce3	Tangential force value for middle finger	INT16	R
0x6000: 37	Direction3	Tangential force direction for middle finger	INT16	R
0x6000: 38	ProximityValue_L3	Proximity sense value for middle finger	INT16	R
0x6000: 39	ProximityValue_H3		INT16	R
0x6000: 3A	NormalForce4	Normal force value for index finger	INT16	R
0x6000: 3B	TangentialForce4	Tangential force value for index finger	INT16	R
0x6000: 3C	Direction4	Tangential force direction for index finger	INT16	R
0x6000: 3D	ProximityValue_L4	Proximity sense value for index finger	INT16	R
0x6000: 3E	ProximityValue_H4		INT16	R
0x6000: 3F	NormalForce5	Normal force value for thumb	INT16	R
0x6000: 40	TangentialForce5	Tangential force value for thumb	INT16	R

0x6000: 41	Direction5	Tangential force direction for thumb	INT16	R
0x6000: 42	ProximityValue_L5	Proximity sense value for thumb	INT16	R
0x6000: 43	ProximityValue_H5		INT16	R
0x6000: 44	Palm_NormalForce1	Normal force value for palm area 1	INT16	R
0x6000: 45	Palm_TangentialForc1	Tangential force value for palm area 1	INT16	R
0x6000: 46	Palm_Direction1	Tangential force direction for palm area 1	INT16	R
0x6000: 47	Palm_NormalForce2	Normal force value for palm area 2	INT16	R
0x6000: 48	Palm_TangentialForc2	Tangential force value for palm area 2	INT16	R
0x6000: 49	Palm_Directio2	Tangential force direction for palm area 2	INT16	R
0x6000: 4A	Palm_NormalForce3	Normal force value for palm area 3	INT16	R
0x6000: 4B	Palm_TangentialForc3	Tangential force value for palm area 3	INT16	R
0x6000: 4C	Palm_Directio3	Tangential force direction for palm area 3	INT16	R
0x7000：01	ENABLE_SET	Motion control enable	INT16	R/W
0x7000：02	ANGLESET1	Angle setting of the little finger	INT16	R/W
0x7000：03	ANGLESET2	Angle setting of the ring finger	INT16	R/W
0x7000：04	ANGLESET3	Angle setting of the middle finger	INT16	R/W
0x7000：05	ANGLESET4	Angle setting of the index finger	INT16	R/W
0x7000：06	ANGLESET5	Bending angle setting of the thumb	INT16	R/W
0x7000：07	ANGLESET6	Angle setting for sidesway of the thumb	INT16	R/W
0x7000：08	FORCESET1	Set force applied to the little finger	INT16	R/W
0x7000：09	FORCESET2	Set force applied to the ring finger	INT16	R/W
0x7000：0A	FORCESET3	Set force applied to the middle finger	INT16	R/W
0x7000：0B	FORCESET4	Set force applied to the index finger	INT16	R/W
0x7000：0C	FORCESET5	Set force for bending of the thumb	INT16	R/W
0x7000：0D	FORCESET6	Set force for sidesway of the thumb	INT16	R/W
0x7000：0E	SPEEDSET1	Set speed for the little finger	INT16	R/W
0x7000：0F	SPEEDSET2	Set speed for the ring finger	INT16	R/W
0x7000：10	SPEEDSET3	Set speed for the middle finger	INT16	R/W
0x7000：11	SPEEDSET4	Set speed for the index finger	INT16	R/W
0x7000：12	SPEEDSET5	Set speed for bending of the thumb	INT16	R/W
0x7000：13	SPEEDSET6	Set speed for sidesway of the thumb	INT16	R/W

2.6.2 Introduction to the SDO Object Dictionary

Table 51 SDO Object Dictionary

Address	Name	Meaning	Data type	Permission (read / write)
0x2000：01	HAND_ID	Device ID	INT16	R/W
0x2000：02	Redu_ratio	Baud rate of the device	INT16	R/W
0x2000：03	Clear_error	Clear fault	INT16	R/W
0x2000：04	Save	Save parameters	INT16	R/W
0x2000：05	Reset_para	Restoring factory defaults	INT16	R/W
0x2000：06	Gesture_force_clb	Force calibration of the dexterous hand	INT16	R/W
0x2000：07	Current_limi1	Limited current setting for the little finger	INT16	R/W
0x2000：08	Current_limi1	Limited current setting for the ring finger	INT16	R/W
0x2000：09	Current_limi2	Limited current setting for the middle finger	INT16	R/W
0x2000：0A	Current_limi3	Limited current setting for the index finger	INT16	R/W
0x2000：0B	Current_limi4	Limited current setting for bending of the thumb	INT16	R/W
0x2000：0C	Current_limi5	Limited current setting for sidesway of the thumb	INT16	R/W
0x2000：0D	Default_speed_set1	Power-on speed setting for the little finger	INT16	R/W
0x2000：0E	Default_speed_set2	Power-on speed setting for the ring finger	INT16	R/W
0x2000：0F	Default_speed_set3	Power-on speed setting for the middle finger	INT16	R/W
0x2000：10	Default_speed_set4	Power-on speed setting for the index finger	INT16	R/W
0x2000：11	Default_speed_set5	Power-on speed setting for bending of the thumb	INT16	R/W
0x2000：12	Default_speed_set6	Power-on speed setting for sidesway of the thumb	INT16	R/W

0x2000：13	Default_force_set1	Power-on force setting for the little finger	INT16	R/W
0x2000：14	Default_force_set2	Power-on force setting for the ring finger	INT16	R/W
0x2000：15	Default_force_set3	Power-on force setting for the middle finger	INT16	R/W
0x2000：16	Default_force_set4	Power-on force setting for the index finger	INT16	R/W
0x2000：17	Default_force_set5	Power-on force setting for bending of the thumb	INT16	R/W
0x2000：18	Default_force_set6	Power-on force setting for sidesway of the thumb	INT16	R/W
0x2000：19	Action_seq_index	Motion sequence number setting	INT16	R/W
0x2000：1A	Action_seq_run	Motion sequence execution flag	INT16	R/W
0x2000：1B	FINGER_MODE1	Motion mode setting of little finger	INT16	R/W
0x2000：1C	FINGER_MODE2	Motion mode setting of ring finger	INT16	R/W
0x2000：1D	FINGER_MODE3	Motion mode setting of middle finger	INT16	R/W
0x2000：1E	FINGER_MODE4	Motion mode setting of index finger	INT16	R/W
0x2000：1F	FINGER_MODE5	Motion mode setting of thumb bending	INT16	R/W
0x2000：20	FINGER_MODE6	Motion mode setting of thumb sidesway	INT16	R/W
0x2000：21	FINGER_PAUSE	Pause instruction	INT16	R/W
0x2000：22	FINGER_STOP	Emergency Stop instruction	INT16	R/W

3. Example of common instructions

Example 1 (modify ID)

Change the dexterous hand of ID=1 to ID=2

Instruction frame: EB 90 01 05 12 E8 03 02 00 06

Response frame: 90 EB 02 04 12 E8 03 01 04

In the instruction frame, “EB 90” is the packet header, “01” is the current dexterous hand ID, “04” is

the frame data length, “12” is the write register instruction flag, “E8 03” is the register address, ‘02’ is the data to be written to the register, and “04” is the checksum. In the response frame, “90 EB” is the packet header, “02” is the current dexterous hand ID, “04” is the frame data length, “12” is the write register instruction flag, “E8 03” is the register address, and “04” is the checksum.

The ID change takes effect immediately upon completion. Subsequent communication will use the new ID. To save this new ID after power failure, the “Save Parameters” operation must be performed.

Example 2 (modify baud rate)

Change the baud rate 115200 for the dexterous hand (ID=1) to 57600:

Instruction frame: EB 90 01 05 12 E9 03 01 00 05

Response frame: 90 EB 01 04 12 EA 03 01 05

The baud rate modification does not take effect immediately. With the “Save Parameters” operation, the modification will take effect after power cycling.

Example 3 (Error clearance)

Clear the fault information for the dexterous hand (ID=1). When the dexterous hand is subject to faults such as locked-rotor, overcurrent or abnormalities, normal operation can be restored by issuing a Clear Fault reset instruction:

Instruction frame: EB 90 01 05 12 EB 03 01 00 07

Response frame: 90 EB 01 04 12 EC 03 01 07

Example 4 (Save parameters)

When modifying parameters such as ID or baud rate, the dexterous hand will write parameters in the Flash, then these parameters will not be lost after power failure.

Instruction frame: EB 90 01 05 12 EC 03 01 00 08

Response frame: 90 EB 01 04 12 ED 03 01 08，90 EB 01 04 11 ED 03 00 06

The Save Parameters instruction will have two response frames.

Example 5 (Force sensor calibration)

Instruction frame: EB 90 01 05 12 F1 03 01 00 0B

Response frame: 90 EB 01 04 12 F1 03 01 0C，90 EB 01 04 11 02 00 00 18

When executing sensor calibration, a response frame will be received. A second response frame will be received upon completion of calibration. The dexterous hand must be maintained in no-load state during calibration.

Example 6 (Set the force control threshold value for each DOF)

Set the force control threshold of the dexterous hand (ID=1) for each DOF to 1000:

Instruction frame: EB 90 01 0F 12 16 04 E8 03 E8 03 E8 03 E8 03 E8 03 E8 03 BE

Response frame: 90 EB 01 04 12 16 04 01 32

The force control threshold takes effect immediately after setting and is not saved upon power cycling.

Example 7 (Set the speed for each DOF)

Set the speed of the dexterous hand (ID=1) for each DOF to 1000:

Instruction frame: EB 90 01 0F 12 1C 04 E8 03 E8 03 E8 03 E8 03 E8 03 E8 03 C4

Response frame: 90 EB 01 04 12 1C 04 01 38

The speed takes effect immediately after setting and is not saved upon power cycling.

Example 8 (Set the angle for each DOF)

Set the angle of the dexterous hand (ID=1) for each DOF to 1000:

Instruction frame: EB 90 01 0F 12 10 04 E8 03 E8 03 E8 03 E8 03 E8 03 E8 03 B8

Response frame: 90 EB 01 04 12 10 04 01 2C

Example 9 (Read the current angle position for each DOF)

Read the current angle position of the dexterous hand (ID=1) for each DOF:

Instruction frame: EB 90 01 04 11 28 04 0C 4E

Response frame: see examples in 2.2.1 herein