Dexterous Hands RH56E2 series User Manual

Beijing Inspire-Robots Technology Co., Ltd. | June 2025

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Basic Instructions

- Thank you for choosing and purchasing the RH56E2 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 RH56E2 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	**V1.0.0**	**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.

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

CAUTION

- 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

WARNING

- 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!

CAUTION

- 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

DANGER

- 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!

WARNING

- 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!

CAUTION

- 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.

Table of Contents

RH56E2 Dexterous Hand User Manual

1 Product Overview

1.1 Key Features

RH56E2 Series Dexterous Hand is a mechanical dexterous hand (hereinafter referred to as "Dexterous Hand") designed to integrate Micro linear servo actuator with small volume and large torque. These dexterous hands feature six Micro linear servo (actuators) equipped with sensitive force sensors. By setting different force control thresholds, precise grip force control can be achieved. High-precision tactile sensors are integrated into the fingertips, finger pads, and palm areas, providing real-time feedback on finger gripping information. User interfaces include Ethernet, RS485, and CAN2.0 communication ports. Concise and efficient interface control commands enable users to quickly manipulate the dexterous hands. Their superior performance makes them suitable for applications in service robots, educational tools, industrial automation, and other fields.

1.2 Performance Parameters

See Table 1:

Table 1 Performance parameters

Total number of joints	12
Degree of freedom (DOF)	6
Number of force sensors	6
Resolution of force sensor	0.1 N
Number of tactile sensors	5-17
Repeated fingertip positioning accuracy	±0.2mm
Five-finger gripping force	30 N
Operating voltage	24V
Quiescent current	0.2A @24V
Average current for no-load operation	1.2A @24V
Current for maximum gripping force	4.5A @24V
Communication interface	Modbus TCP + CAN2.0 or Modbus TCP + RS485

1.3 Electrical Connection

1.3.1 Pin Definitions

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 Figure 1, and the function definitions are as follows Table 2.

Table 2 Function Definitions

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

Figure 1 Wrist Connector Physical Diagram

The external cables of the dexterous hands are shown in Figure 3 below Figure 2, with the following function definitions Table 3:

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/CAN_H
Green	485_B/CAN_L
Red (thick)	VCC（24V）
Black (thick)	GND

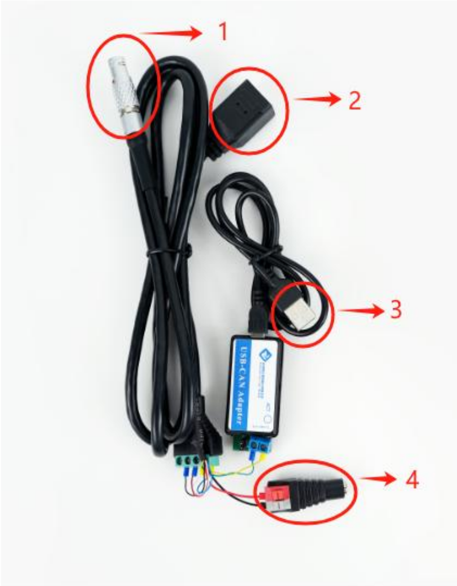


Figure 2 CAN Interface

Figure 3 RS485 Interface

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-CAN/RS485 Interface

4-Power Interface

1.3.2 Communication mode

When the RS485 interface is used, a particular conversion circuit can realize parallel connection of 254 dexterous hands to the same bus. When CAN interface is used, multiple dexterous hands (theoretically up to 16383 dexterous hands) can be connected to the same bus in parallel. For the purpose of communication control, the dexterous hands connected to the same bus should be configured with different ID. When using Modbus TCP control, the dexterous hands are controlled through IP addresses and port numbers. (Default IP address: 192.168.11.210, port number: 6000)

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.

2.2 Register reading/writing of RS485

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

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 length (unit: byte) of the register 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 below Table 4.

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	Length of the register to be read
byte[8]	Checksum	Checksum

The dexterous hand returns the following response frame to the read register instruction Table 5:

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 with 1546 (0x060A) as start address, and 12 bytes (0x0C) as length. The format of this instruction frame is shown below Table 6:

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]	0x0A	Low-order 8 bits in the start address of the register
byte[6]	0x06	High-order 8 bits in the start address of the register
byte[7]	0x0C	Length of the register to be read

byte[8]	0x32	Checksum

The dexterous hand returns the following response frame to this instruction Table 7:

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]	0x0A	Low-order 8 bits in the start address of the register
byte[6]	0x06	High-order 8 bits in the start address of the register
byte[7] byte[8]	0x6400	Converted to the integer data 100 (0x0064)
byte[9] byte[10]	0x6400	Converted to the integer data 100 (0x0064)
byte[11] byte[12]	0x6400	Converted to the integer data 100 (0x0064)
byte[13] byte[14]	0x6400	Converted to the integer data 100 (0x0064)
byte[15] byte[16]	0xD007	Converted to the integer data 2000 (0x07D0)
byte[17] byte[18]	0x0000	Converted to the integer data 0 (0x0000)
byte[19]	0x98	Checksum

From this response frame, we can obtain the actual values for DOF: 100, 100, 100, 100, 2000, and 0.

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 below Table 8. "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 Table 9:

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 below Table 10:

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]	0xED	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 100, 100, 100, 100, 2000, and 0. It is necessary to modify the write angle register group. The start address of this register group is 1486 (0x05CE), and its length is 12 bytes (0x0C). The instruction to be sent is listed below Table 11:

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]	0xCE	Low-order 8 bits in the start address of the register
byte[6]	0x05	High-order 8 bits in the start address of the register
byte[7]	0x6400	Converted to the integer

byte[8]		data 100 (0x0064)
byte[9] byte[10]	0x6400	Converted to the integer data 100 (0x0064)
byte[11] byte[12]	0x6400	Converted to the integer data 100 (0x0064)
byte[13] byte[14]	0x6400	Converted to the integer data 100 (0x0064)
byte[15] byte[16]	0xD007	Converted to the integer data 2000 (0x07D0)
byte[17] byte[18]	0x0000	Converted to the integer data 0 (0x0000)
byte[19]	0x5C	Checksum

The dexterous hand returns the following response frame to this instruction Table 12:

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]	0xCE	Low-order 8 bits in the start address of the register
byte[6]	0x05	High-order 8 bits in the start address of the register
byte[7]	0x01	
byte[8]	0xEB	Checksum

2.3 Register reading/writing of CAN

The default baud rate is 1000K. It 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 Table 13:

bit0-13: Hand_ID supports up to 16383 devices;

bit14-25: Start address of the register to be operated;

bit26-28: Read/write flag bits; 0 indicates reading a register of the dexterous hand; 1 indicates writing to a register of the dexterous hand; 4 indicates reading the wrist register of the dexterous hand; 5 indicates writing to the wrist register of the dexterous hand.

Bit29-31: Reserved flag bits

Table 13 CAN Register Operation Definitions

Identifier	bit 31-29	bit 26-28	bit14-25	bit 13-0
Meaning	Reserve	W/R 0:R - Reading a register of the dexterous hand 1:W - Writing to a register of the dexterous hand 4:R - Reading the wrist register of the dexterous hand 5:W - Writing to the wrist register of the dexterous hand	Register address	Hand_ID

2.3.1 Register reading

The identifier settings of register reading are as follows Table 14:

Table 14 CAN Read Register Identifier Settings

Identifier	bit 31-29	bit 26-28	bit14-25	bit 13-0
Meaning	Reserve	0	Address	Hand_ID

The data length is 1 byte.

Data content: Length of the register data to be read

After the dexterous hand receives and correctly analyzes the aforesaid instruction, it will return the following Table 15:

Identifier:

Table 15 CAN Read Register Response Settings

Identifier	bit 31-29	bit 26-28	bit14-25	bit 13-0
Meaning	Reserve	0	Address	Hand_ID

Data length: Length of the data to be returned to the register

Data content: Register data

For example, if we want to read the current actual angle of the index finger of the dexterous hand (ID=1), the following frame as shown in Table 16 should be sent to the CAN bus:

Identifier: The binary number is 0000 0001 1000 0100 0000 0000 0000 0001.

See Table 16:

Table 16 Example CAN Read Register Format

bit 31-29	bit 26-28	bit14-25	bit 13-0
0	0	The address of the index finger (read) is 1552; The binary number is 011000010000.	1

Data length: 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 following frame Table 17:

Identifier: The binary number is 0000 0001 1000 0100 0000 0000 0000 0001.

Table 17 Example CAN Read Register Response Frame Format

bit 31-29	bit 26-28	bit14-25	bit 13-0
0	0	The address of the index finger (read) is 1552; The binary number is 011000010000.	1

Data length: 2

Data content is as shown in Table 18 below. The current actual angle of the index finger 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).

See Table 18:

Table 18 CAN Read Register Response Data Content

byte0	byte1
0xF4	0x01

2.3.2 Register writing

The identifier settings of register writing are as follows Table 19:

Table 19 CAN Write Register Identifier Settings

Identifier	bit 31-29	bit 26-28	bit14-25	bit 13-0
Meaning	Reserve	1	Address	Hand_ID

Data length: Length of the data to be written to the register

Data content: Data to be written to the register

After the dexterous hand receives and correctly analyzes the aforesaid instruction, it will return the following Table 20:

Table 20 CAN Read Register Response Settings

Identifier	bit 31-29	bit 26-28	bit14-25	bit 13-0
Meaning	Reserve	1	Address	Hand_ID

Data length: 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 21 should be sent to the CAN bus:

Identifier: The binary number is 0000 0101 0111 0101 0000 0000 0000 0001.

See Table 21:

Table 21 Example CAN Write Register Response Frame Format

bit 31-29	bit 26-28	bit14-25	bit 13-0
0	1	The address of the index finger (write) is 1492; The binary number is 010111010100.	1

Data length: 2

Data content is as below Table 22. The current actual angle (write) 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 data content below:

Table 22 CAN Write Register Data Content

byte0	byte1
0x58	0x02

The dexterous hand returns the following frame Table 23:

Identifier: The binary number is 0000 0101 0111 0101 0000 0000 0000 0001.

Table 23 Example CAN Write Register Response Frame Format

bit 31-29	bit 26-28	bit14-25	bit 13-0
0	1	The address of the index finger (write) is 1492; The binary number is 01 0111 0101 00	1

Data length: 1

2.4 Summary of Modbus RTU Protocol

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

2.4.1 Read the holding register

Function code: 0x03, as below Table 24:

Table 24 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	0x6B	0x00	0x00	0x02	XXXX

Explanation: Read the holding register of Slave Station 1# (0x01), with start address = 0x006B, number of registers = 0x0002, and end address = 0x006B+2-1=0x006C; that is, read the holding register of Slave Station 17#, 0x006B-0x006C; there are totally two registers as below Table 25.

Table 25 Response frame of slave station Modbus

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

Explanation: Return to the holding register of Slave Station 1# (0x01), 0x006B-0x006C; there are totally two registers. The value of 0x006B register is 0x0001, and that of 0x0062 register is 0x0002.

2.4.2 Preset single register

Function code: 0x06, as below Table 26:

Table 26 Preset single register

Query frame format of master station	Slave station address	Functi on code	Starting register (high-order bytes)	Starting register (low-order bytes)	Data content (high-order bytes)	Data content (low-order bytes)	CRC
	0x01	0x06	0x00	0x6B	0x10	0x00	XXXX

Explanation: Set the holding register of Slave Station 1# (0x01), with register address = 0x006B and data content = 0x1000.

See Table 27:

Table 27 Response frame of slave station Modbus

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

2.4.3 Preset multiple registers

Function code: 0x10, as below Table 28:

Table 28 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
	0x11	0x10	0x00	0x01	0x00	0x02	0x04	0x00	0x0A	0x01	0x02	XX XX

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.

See Table 29:

Table 29 Response frame of slave station Modbus

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

2.5 Summary of Modbus TCP Protocol

The Ethernet conversion module adopts the Modbus TCP protocol, which is a Modbus protocol based on Ethernet TCP/IP introduced by Schneider company (It is a message transmission protocol at the application layer that utilizes a master/slave communication mode). For specific reference, see Table 30 below:

The data frame of Modbus TCP can be divided into two parts: MBAP and PDU below Figure 4.

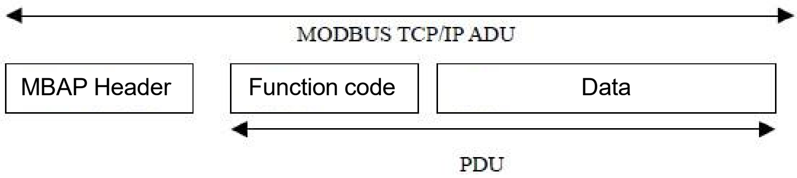


Figure 4 Data frame of Modbus TCP

MBAP Header:

Table 30 Modbus TCP protocol

Field	Length	Description	Client	Server
Transaction Identifier	2byte	Identifier for a MODBUS request/response transaction	Initiated by Client	Copied by Server from received request
Protocol Identifier	2byte	0 = MODBUS Protocol	Initiated by Client	Copied by Server from received request
Length	2byte	Number of the following bytes	Initiated by Client (for requests)	Initiated by Server (for responses)
Unit Identifier	1byte	Remote slave device identifier on a serial link or other bus	Initiated by Client	Copied by Server from received request

Note: The Length includes the Unit Identifier, Function Code, and the number of data bytes.

The Unit Identifier is set to 0xFF. For TCP, the Unit Identifier is not utilized (TCP relies on IP addressing for destination identification);

PDU Frame Structure:

The PDU comprises a Function Code and Data. The Function Code occupies 1 byte, while the Data length varies depending on the specific function in use.

Modbus offers a suite of 8 function codes below Table 31, among which we employ three: 03, 06, and 16.

Table 31 Modbus function code

Code	Chinese Name	Bit/Word Operation	Quantity of Operations
01	读线圈状态	Bit Operation	Single or Multiple
02	读离散输入状态	Bit Operation	Single or Multiple
03	读保持寄存器	Word Operation	Single or Multiple
04	读输入寄存器	Word Operation	Single or Multiple

05	写线圈状态	Bit Operation	Single
06	写单个保持寄存器	Word Operation	Single
15	写多个线圈	Bit Operation	Multiple
16	写多个保持寄存器	Word Operation	Multiple

2.5.1 Read Registers - Function Code 03 (0x03)

Request as below Table 32:

Table 32 0x03 request function code

Function code	1 byte	0x03
Start address	2 bytes	0x0000 to 0xFFFF
Number of registers	2 bytes	1 to 125 (0x7D)

Response as below Table 33:

Table 33 0x03 response function code

Function code	1 byte	0x03
Byte	1 byte	2*N
Number of registers	N*2 bytes	

Example below Table 34: This is an example of a request to read holding registers 108 to 110. The content of register 108 is represented as two hexadecimal byte values, 02 2B, or decimal 555. The contents of registers 109 and 110 are represented as hexadecimal 00 00 and 00 64, respectively, or decimal 0 and 100.

Table 34 Example of a request to read holding registers

Request		Response	
Field Name	Hexadecimal	Field Name	Hexadecimal
Function	03	Function	03
High start address	00	Byte	06
Low start address	6B	Register Value Hi (108)	02
High Register Number	00	Register Value Lo (108)	2B
Low Register Number	03	Register Value Hi (109)	00

	Register Value Lo (109)	00
	Register Value Hi (110)	00
	Register Value Lo (110)	64

2.5.2 Write Single Register - Function Code 06 (0x06)

Request as below Table 35:

Table 35 0x06 request function code

Function code	1 byte	0x06
Register address	2 bytes	0x0000 to 0xFFFF
Register Value	2 bytes	0x0000 to 0xFFFF

Response as below Table 36:

Table 36 0x06 response function code

Function code	1 byte	0x06
Register address	2 bytes	0x0000 to 0xFFFF
Register Value	N*2 bytes	0x0000 to 0xFFFF

Example below Table 37: This is an example of a request to write the hexadecimal value 00 03 to register 2.

Table 37 Example of a request to write holding registers

Request		Response	
Field Name	Hexadecimal	Field Name	Hexadecimal
Function	06	Function	06
Register Address Hi	00	Output Address Hi	00
Register address Lo	01	Output Address Lo	01
Register Value Hi	00	Output Value Hi	00
Register Value Lo	03	Output Value Lo	03

2.5.3 Write Multiple Registers - Function Code 16 (0x10).

Request as below Table 38:

Table 38 0x10 request function code

Function code	1 byte	0x10
Start address	2 bytes	0x0000 to 0xFFFF
Number of registers	2 bytes	0x0001 to 0x0078
Byte	1 byte	2*N
Register Value	N*2 bytes	

Response as below Table 39:

Table 39 0x10 response function code

Function code	1 byte	0x10
Start address	2 bytes	0x0000 to 0xFFFF
Number of registers	2 bytes	1 to 123 (0x7B)

Example below Table 40: This is a example of a request to write the hexadecimal values 00 0A and 01 02 to the first two registers starting from register 2.

Table 40 Example of a request to write two registers

Request		Response	
Field Name	Hexadecimal	Field Name	Hexadecimal
Function	10	Function	10
High start address	00	High start address	00
Low start address	01	Low start address	01
Number of Registers Hi	00	Number of Registers Hi	00
Number of Registers Lo	02	Number of Registers Lo	02
Byte	04		
Register Value Hi	00		
Register Value Lo	0A		
Register Value Hi	01		
Register Value Lo	02		

2.6 Register description

The register parameters of the dexterous hand which are open to the users are listed below Table 41:

Table 41 User-Accessible Register Parameters

Address	Meaning	Length	Permission (read / write)
1000	ID of the dexterous hand	1byte	W/R
1002	Baud rate setting	1byte	W/R
1004	Error clearance	1byte	W/R
1005	Saving data in Flash	1byte	W/R
1006	Restoring factory defaults	1byte	W/R
1009	Force sensor calibration	1byte	W/R
1032	Set value of power-on speed for each DOF	6short(12byte)	W/R
1044	Set value of power-on force control threshold for each DOF	6short(12byte)	W/R
1474	Set value of the actuator position for each DOF	6short(12byte)	W/R
1486	Set value of the angle for each DOF	6short(12byte)	W/R
1498	Set value of force control threshold for each DOF	6short(12byte)	W/R
1522	Set value of the speed for each DOF	6short(12byte)	W/R
1534	Actual value of the actuator position for each DOF	6short(12byte)	R
1546	Actual angle for each degree of freedom (DOF)	6short(12byte)	R
1582	Actual force applied to each finger	6short(12byte)	R
1594	Actuator current value for each DOF	6short(12byte)	R
1606	Error codes of the actuator for each DOF	6byte	R
1612	Status information for each DOF	6byte	R
1618	Actuator temperature for	6byte	R

	each DOF		
1625	Finger Motion Mode Settings	6Byte	W/R
1700	IP Address First Octet, Default: 192, Range: 0-255, Effective after Re-powering	1byte	W/R
1701	IP Address Second Octet, Default: 168, Range: 0-255, Effective after Re-powering	1byte	W/R
1702	IP Address Third Octet, Default: 11, Range: 0-255, Effective after Re-powering	1byte	W/R
1703	IP Address Fourth Octet, Default: 210, Range: 0-255, Effective after Re-powering	1byte	W/R

2.6.1 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.

2.6.2 Baud rate setting

RS485 Interface: default value = 0; range: 0-3; it cannot be saved.

0: Baud rate = 115200

1: Baud rate = 57600

2: Baud rate = 19200

3: Baud rate = 921600

CAN Interface: default value = 0; range: 0-1; it cannot be saved.

0: Baud rate = 1000K

1: Baud rate = 500K

2.6.3 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.

2.6.4 Save parameters to FLASH

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.

2.6.5 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.

2.6.6 Force sensor calibration

When the user sets the parameter to 1, the dexterous hand initiates the force sensor calibration process.

Note: The dexterous hand must be maintained in a palm open state during calibration and fingers cannot touch any object.

2.6.7 Target gesture sequence number

Default value = 0xFF; range: 1- 40; it cannot be saved.

When the user modifies this register value, the dexterous hand will make a gesture corresponding the serial number.

1-13 gestures are fixed (saved before product delivery), i.e., holding open, two fingers touching each other, fist clenching, etc.

14-40 gestures are user-defined (the data is stored in the register "USER_DEF_ANGLE (K, m)") and can be modified and saved by the user.

2.6.8 Set value of power-on 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 below Table 42. These parameters can be saved after power failure.

Table 42 Set value of power-on speed for each DOF

Address	Description	Data type	Range
1032-1033	Initial power-on speed of the little finger	short	0-1000
1034-1035	Initial power-on speed of the ring finger	short	0-1000
1036-1037	Initial power-on speed of the middle finger	short	0-1000
1038-1039	Initial power-on speed of the index finger	short	0-1000

1040-1041	Initial power-on speed of thumb bending	short	0-1000
1042-1043	Initial power-on speed of thumb rotation	short	0-1000

Speed = 1000: This means that it will take 600ms for the fingers in the no-load state to move from a maximum angle to the minimum angle. If there is a heavy load, the actual speed will be somewhat lower than this value.

2.6.9 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 below Table 43. These parameters can be saved after power failure.

Table 43 Set value of power-on force control threshold for each DOF

Address	Description	Data type	Range
1044-1045	Initial power-on force control of the little finger	short	0-3000
1046-1047	Initial power-on force control of the ring finger	short	0-3000
1048-1049	Initial power-on force control of the middle finger	short	0-3000
1050-1051	Initial power-on force control of the index finger	short	0-3000
1052-1053	Initial power-on force control of thumb bending	short	0-3000
1054-1055	Initial power-on force control of thumb rotation	short	0-3000

This register value indicates the gripping force provided by the fingertip of the corresponding finger. For example, when power-on force control threshold of the ring finger is set to 800, it means that the fingertip of the ring finger is allowed to provide the gripping force of 800 g. (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.)

2.6.10 Set value of the actuator position for each DOF

This register group consists of six registers corresponding to the set value of the actuator position of the dexterous hand for 6 DOF, with details as below Table 44. These parameters cannot be saved.

Table 44 Set value of the actuator position for each DOF

Address	Description	Data type	Range
1474-1475	Position setting of the little finger actuator	short	0-2000
1476-1477	Position setting of the ring finger actuator	short	0-2000
1478-1479	Position setting of the middle finger actuator	short	0-2000
1480-1481	Position setting of the index finger actuator	short	0-2000
1482-1483	Position setting of the thumb bending actuator	short	0-2000
1484-1485	Position setting of the thumb rotation actuator	short	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.

2.6.11 Set value of the angle for each DOF

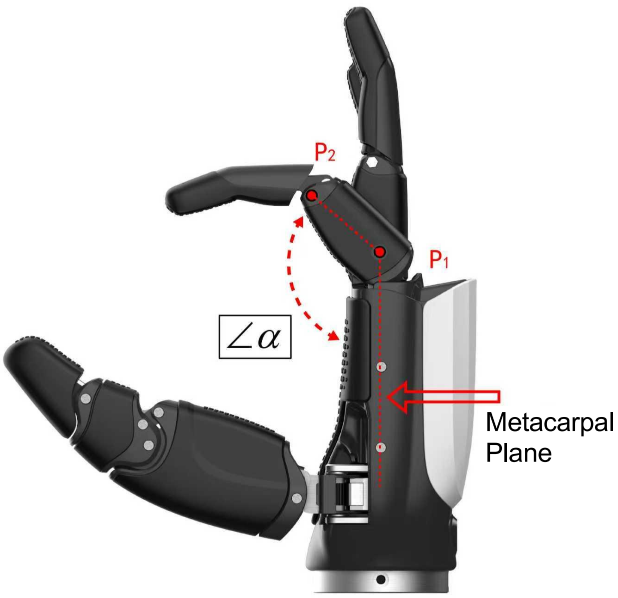
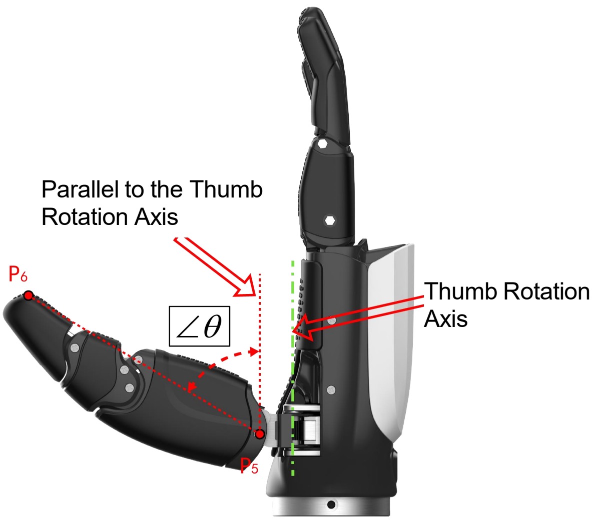
This register group consists of six registers corresponding to the set value of the angle of the dexterous hand for 6 DOF, with details as below Table 45. When the angle value for a degree of freedom (DOF) is set to the data within 0- 1000, the corresponding finger will take an immediate action. If the angle value is set to -1, the corresponding finger will make no response. For example, after the angle values of six write angle registers of the set value of the angle for each DOF are set to 500, 500, -1, 0, 500 and 500 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 "500"; the index finger will move to an angle corresponding to "0"; and the middle finger will not move (i.e., it will be maintained in the current position without action).

Table 45 Set value of the angle for each DOF

Address	Description	Data type	Range
1486-1487	Initial power-on angle of the little finger	short	-1, 0-1000
1488-1489	Initial power-on angle of	short	-1,0-1000

	the ring finger		
1490-1491	Initial power-on angle of the middle finger	short	-1,0-1000
1492-1493	Initial power-on angle of the index finger	short	-1,0-1000
1494-1495	Initial power-on angle of thumb bending	short	-1,0-1000
1496-1497	Initial power-on angle of thumb rotation	short	-1,0-1000

The definition of angle and the range of motion for each DOF are described as follows Figure 5.

Angle	Legend description	Range
Little finger Ring finger Middle finger Index finger		91.5°-170°
Bending angle of the thumb		28.5°-64°

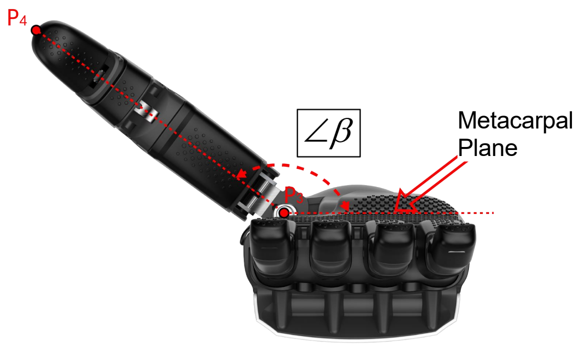
Rotation angle of the thumb		75°-170°

Figure 5 The angle for DOF and the range of motion

2.6.12 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 as below Table 46. The user can set this register group to control the gripping force of fingers. For example, set force control for the index finger to 300, and set the current actual angle of the index finger to 1000 (i.e., fully open). After the user sets the angle of the index finger to 0, the index finger will bend towards the palm. Once it is detected that the actual force applied to the index finger during bending reaches 300, the index finger will stop moving; otherwise, the index finger will move to the preset angle.

Table 46 Set value of force control threshold for each DOF

Address	Description	Data type	Range
1498-1499	Set value of force control for the little finger	short	0-3000
1500-1501	Set value of force control for the ring finger	short	0-3000
1502-1503	Set value of force control for the middle finger	short	0-3000
1504-1505	Set value of force control for the index finger	short	0-3000
1506-1507	Set value of bending force control for the thumb	short	0-3000
1508-1509	Set value of rotation force control for the thumb	short	0-3000

This register value indicates the gripping force provided by the fingertip of the corresponding finger. For example, when the force control for the ring finger is set to 800, it means that the fingertip of the ring finger is allowed to provide the gripping force of 800 g. (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.)

2.6.13 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 below Table 47. These parameters can be saved after power failure.

Table 47 Set value of the speed for each DOF

Address	Description	Data type	Range
1522-1523	Set value of the speed for the little finger	short	0-1000
1524-1525	Set value of the speed for the ring finger	short	0-1000
1526-1527	Set value of the speed for the middle finger	short	0-1000
1528-1529	Set value of the speed for the index finger	short	0-1000
1530-1531	Set value of the speed for thumb bending	short	0-1000
1532-1533	Set value of the speed for thumb rotation	short	0-1000

Speed = 1000: This means that it will take 600ms 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.

2.6.14 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 below Table 48. These parameters can be read only.

Table 48 Actual value of the actuator position for each DOF

Address	Description	Data type	Range
1534-1535	Actual position value of the little finger	short	0-2000
1536-1537	Actual position value of the ring finger	short	0-2000

1538-1539	Actual position value of the middle finger	short	0-2000
1540-1541	Actual position value of the index finger	short	0-2000
1542-1543	Actual position value of the thumb bending	short	0-2000
1544-1545	Actual position value of the thumb rotation	short	0-2000

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

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

2.6.15 Actual angle for each degree of freedom (DOF)

This register group consists of six registers corresponding to the actual angle of the dexterous hand for 6 DOF, with details as below Table 49. For the definition of angle for each DOF, refer to 2.6.11 the description of the register group for the set value of the angle for each DOF These parameters can be read only.

Table 49 Actual angle for each degree of freedom (DOF)

Address	Description	Data type	Range
1546-1547	Actual angle of the little finger	short	0-1000
1548-1549	Actual angle of the ring finger	short	0-1000
1550-1551	Actual angle of the middle finger	short	0-1000
1552-1553	Actual angle of the index finger	short	0-1000
1556-1557	Actual angle of thumb rotation	short	0-1000

2.6.16 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, unit: g, with details as below Table 50. These parameters can be read only.

Table 50 Actual force applied to each finger

Address	Description	Data type	Range
1582-1583	Actual force applied	short	-4000-4000

	to the little finger		
1584-1585	Actual force applied to the ring finger	short	-4000-4000
1586-1587	Actual force applied to the middle finger	short	-4000-4000
1588-1589	Actual force applied to the index finger	short	-4000-4000
1590-1591	Actual bending force applied to the thumb	short	-4000-4000
1592-1593	Actual rotation force applied to the thumb	short	-4000-4000

2.6.17 Actuator current value for each DOF

This register group consists of six registers corresponding to the current value of six actuators of the dexterous hand, with details as below Table 51. These parameters can be read only.

Table 51 Actuator current value for each DOF

Address	Description	Data type	Range	Unit
1594-1595	Current value of the actuator for the little finger	short	0-2000	mA
1596-1597	Current value of the actuator for the ring finger	short	0-2000	mA
1598-1599	Current value of the actuator for the middle finger	short	0-2000	mA
1600-1601	Current value of the actuator for the index finger	short	0-2000	mA
1602-1603	Current value of the actuator for the thumb bending	short	0-2000	mA
1604-1605	Current value of the actuator for the thumb	short	0-2000	mA

	rotation			

2.6.18 Error codes of each actuator

This register group consists of six registers corresponding to error codes of six actuators of the dexterous hand, with details in the table below Table 52. These parameters can be read only.

Table 52 Error codes of each actuator

Address	Description	Data type
1606	Error code of the actuator for the little finger	byte
1607	Error code of the actuator for the ring finger	byte
1608	Error code of the actuator for the middle finger	byte
1609	Error code of the actuator for the index finger	byte
1610	Error code of the actuator for the thumb bending	byte
1611	Error code of the actuator for the thumb rotation	byte

The implication of error codes is listed below Table 53. For example, if the error code is 0x06 (00000110 in the binary system), it means that over temperature and overcurrent errors occur in the actuator of the index finger.

Table 53 Example of error codes

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

2.6.19 Temperature of each actuator

This register group consists of six temperature values of six actuators of the dexterous hand, with details as below Table 54. These parameters can be read only.

Table 54 Temperature of each actuator

Address	Description	Data type	Range	Unit
1618	Temperature value of the actuator for the little finger	byte	0-100	℃
1619	Temperature value of the actuator for the ring finger	byte	0-100	℃
1620	Temperature value of the actuator for the middle finger	byte	0-100	℃
1621	Temperature value of the actuator for the index finger	byte	0-100	℃
1622	Temperature value of the actuator for the thumb bending	byte	0-100	℃
1623	Temperature value of the actuator for the thumb rotation	byte	0-100	℃

2.6.20 Finger Motion Mode Settings

This register group consists of six registers corresponding to the operation modes of different fingers of the dexterous hand.

For Finger Operation Mode, see below Table 55:

Set value 0: The finger operates in Speed-Force Protection Mode. The finger will stop moving when it reaches the preset angle or when the actual force exceeds the set force.

Set value 1: The finger operates in Force Closed-Loop Control mode based on the set force value. It will maintain this control until the actual force stabilizes within a specified range of the set value, at which point motion stops. If the actual force changes, the finger will resume force closed-loop control to track these variations

Table 55 Finger Motion Mode Settings

Address	Description	Data type	Range
1625	Little Finger Motion Mode Settings 0: Speed-Force Protection Mode 1: Force Control Mode	byte	0-1
1626	Ring Finger Motion Mode Settings 0: Speed-Force Protection Mode 1: Force Control Mode	byte	0-1
1627	Middle Finger Motion Mode Settings 0: Speed-Force Protection Mode 1: Force Control Mode	byte	0-1
1628	Index Finger Motion Mode Settings 0: Speed-Force Protection Mode 1: Force Control Mode	byte	0-1
1629	Thumb Flexion Motion Mode Settings 0: Speed-Force Protection Mode 1: Force Control Mode	byte	0-1
1630	Thumb Rotation Motion Mode Settings 0: Speed-Force	byte	0-1

	Protection Mode 1: Force Control Mode		

2.6.21 Explanation of Tactile Sensor Data Format

RH56DFTP-0L/0R and RH56DFTP-2L/2R dexterous hands utilize piezoresistive tactile sensors. The RH56DFTP-0L/0R-C1 and RH56DFTP-2L/2R-C1 models employ capacitive tactile sensors. Different models of the dexterous hand are equipped with different types of tactile sensors. Please pay attention to the specific model when in use.

The tactile distribution of RH56DFTP-0L/0R, RH56DFTP-2L/2R dexterous hands is illustrated below Figure 6 (with the light yellow sections indicating the locations of the tactile sensors).

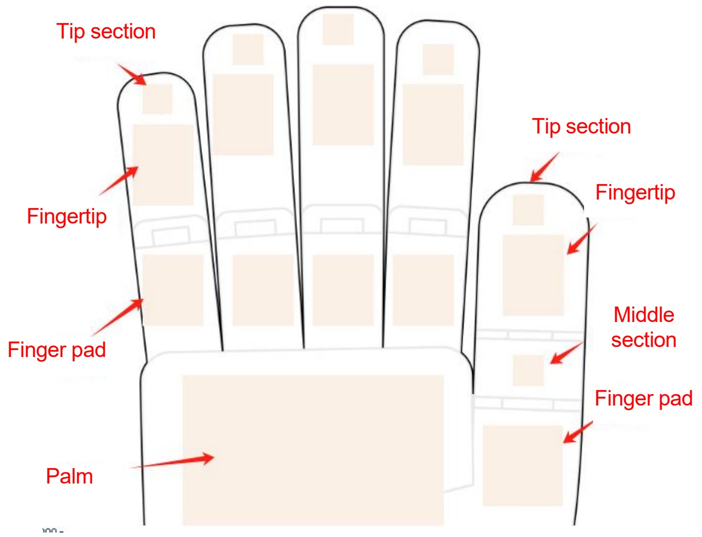


Figure 6 Piezoresistive Tactile Sensor Distribution Map

Table 56 Piezoresistive Tactile Sensor Data Format

Address	Meaning	Row and column count	Length	Permission (read / write)
3000-3017	Tactile data for little finger tip	3*3	18byte	R
3018-3209	Tactile data for little finger nail	12*8	192byte	R
3210-3369	Tactile data for little finger pad	10*8	160byte	R
3370-3387	Tactile data for ring finger tip	3*3	18byte	R
3388-3579	Tactile data for ring finger nail	12*8	192byte	R

3580-3739	Tactile data for ring finger pad	10*8	160byte	R
3740-3757	Tactile data for middle finger tip	3*3	18byte	R
3758-3949	Tactile data for middle finger nail	12*8	192byte	R
3950-4109	Tactile data for middle finger pad	10*8	160byte	R
4110-4127	Tactile data for index finger tip	3*3	18byte	R
4128-4319	Tactile data for index finger nail	12*8	192byte	R
4320-4479	Tactile data for index finger pad	10*8	160byte	R
4480-4497	Tactile data for thumb tip	3*3	18byte	R
4498-4689	Tactile data for thumb nail	12*8	192byte	R
4690-4707	Tactile data for thumb middle section	3*3	18byte	R
4708-4899	Tactile data for thumb tip	12*8	192byte	R
4900-5123	Tactile data for palm	8*14	224byte	R

Each tactile point in the above Table 56 data is represented by a 16-bit integer (composed of two bytes in little-endian format, with the low byte first and the high byte second), with a value range of 0-4095.

For the fingers, the data points correspond to actual positions as follows: Data Point 1 corresponds to the first row, first column; Data Point 2 corresponds to the first row, second column; Data Point 3 corresponds to the first row, third column; Data Point 4 corresponds to the first row, fourth column; Data Point 5 corresponds to the first row, fifth column; Data Point 6 corresponds to the first row, sixth column; Data Point 7 corresponds to the first row, seventh column; Data Point 8 corresponds to the first row, eighth column; Data Point 9 corresponding to the second row, first column; Data Point 10 corresponding to the second row, second column; and so on.

For the palm, data points correspond to actual positions as follows: Data Point 1 corresponds to the eighth row, first column; Data Point 2 corresponds to the seventh row, first column; Data Point 3 corresponds to the sixth row, first column; Data Point 4 corresponds to the fifth row, first column; Data Point 5 corresponds to the fourth row, first column; Data Point 6 corresponds to the third row, first column; Data Point 7 corresponds to the second row, first column; Data Point 8 corresponds to the first row, first column; Data Point 9 corresponding to the eighth row, second column; Data Point 10 corresponding to the seventh row, second column; and so on.

The tactile distribution of RH56DFTP-0L/0R-C1, RH56DFTP-2L/2R-C1 dexterous hands is illustrated in Figure 7 (with the light yellow sections indicating the locations of the tactile sensors)

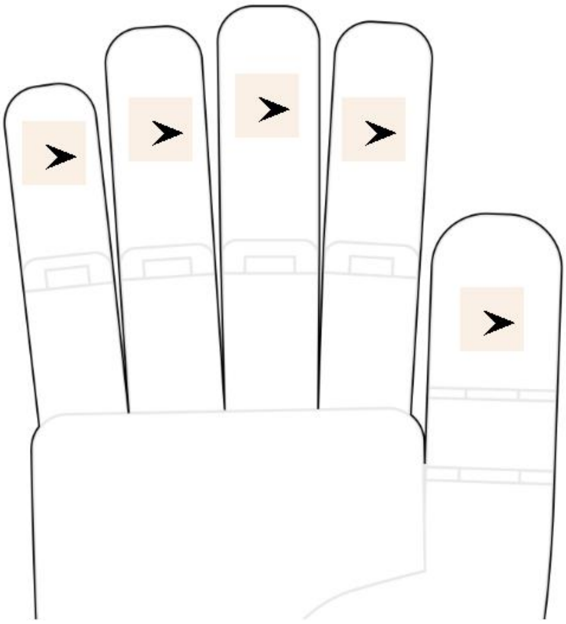


Figure 7 Capacitive Tactile Sensor Distribution Map

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 tangential force direction ranges from 0° to 359°, increasing clockwise from the fingertip's orientation (0-359°), as shown in Figure 8 below. If the acquired tangential force data is 0xFFFF, the angle is invalid. Table 57 describes the raw data format of the tactile sensors, and Table 58 provides the specific data addresses of the tactile data within the dexterous hand system.

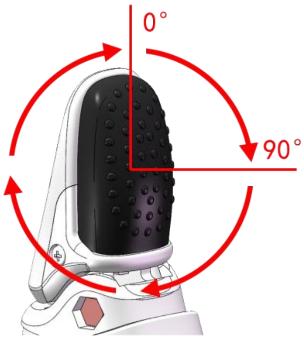


Figure 8 Tangential Force Direction Diagram

Table 57 Capacitive Tactile Sensor Data Format

	Raw Value	3D Force Data						Check	Reserved
		Normal Force	Normal Force Delta	Tangential Force	Tangential Force	Tangential Force	Proximity Sense Delta		

					Delta	Direction			
Byte	Number of channels*4	4	4	4	4	2	4	2	2
Data	32-bit little-endian	Float little-endian	32-bit little-endian	Float little-endian	32-bit little-endian	16-bit little-endian	32-bit little-endian	chk_l, chk_h	

The storage addresses for capacitive tactile data are shown in Table 58

Table 58 Capacitive Tactile Data Storage Address

Address	Meaning	Length	Permission (read / write)
3000-3057	Tactile data for little finger	58byte	R
3058-3115	Tactile data for ring finger	58byte	R
3116-3173	Tactile data for middle finger	58byte	R
3174-3231	Tactile data for index finger	58byte	R
3232-3290	Tactile data for thumb	58byte	R

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