MICRO LINEAR SERVO ACTUATOR ELECTRICAL USER MANUAL (FORCE CONTROL)

(Applicable to LA, LAS, LAF and LASF Series)

Revision Description:

1. Speed mode, force control mode, voltage mode and speed & force control mode added; the communication protocol format adjusted;
2. Compatible with the communication protocol of the old version

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User Manual for Micro Linear Servo Actuator (Electrical)

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1 Product Overview

1.1 Product Introduction

The Micro Linear Servo Actuator (hereinafter referred to as the "Actuator") is a micro servo electric push rod, which is integrated with a micro motor, a reducer, a screw structure, a sensor and a drive control system. It can realize the precise servo control of any position within the stroke range. Because of the built-in absolute position sensor, the position information will not be lost after power failure and there is no need to return to zero position.

Features:

- Drive and control integrated design
- Small size, high power density and high repeatability
- Diversified interfaces:

Electrical interfaces: Serial Port LVTTL3.3V (Type-D) and Serial Port PWM (Type-P) are available. The actuator with Type-D interface has a configurable ID and multiple actuators with different ID can be controlled via serial buses. The actuator with Type-P interface is compatible with the standard actuator interface and supports PWM control signals of 50 Hz and 333 Hz.

Mechanical interfaces: There are abundant optional mechanical interface modes, which is convenient for users to install.

- Wide power supply range: DC 7 V to 9 V power supply is available and 8 V is recommended.
- Overheating and overcurrent protection

1.2 Product Series

LA Series: The center of rotation for the motor and the screw structure is in a straight line. It is featured by the slender overall configuration and a small cross-sectional area.

LAS Series: The center of rotation for the motor and the screw structure is not in a straight line and is arranged in parallel by gear transmission. It is featured by a shorter overall length and a slightly larger cross-sectional area.

LAXC Series: With the appearance identical to LA Series, the center of rotation for the motor and the screw structure is in a straight line; the screw has the planetary screw structure. It is featured by the slender overall configuration and a small cross-sectional area.

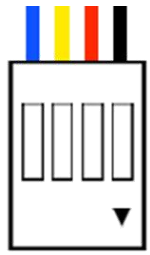
LAF Series: On the basis of LA series, a force sensor and corresponding signal acquisition and filtering algorithm are added to detect the force applied to the actuator.

LASF Series: On the basis of LAS series, a force sensor and corresponding signal acquisition and filtering algorithm are added to detect the force applied to the actuator.

Figure 1: Micro Linear Servo Actuators Series

1.3 Electrical Interface

Type-D interface is a standard 4-pin DuPont female connector with a 2.54 mm pitch. The definition is shown as follows:



Pin	Color	Definition	Voltage range
1	Black ■	GND	0 V
2	Red ■	VCC	7-9V
3	Yellow ■	R X	0-3.3 V
4	Blue ■	T X	0-3.3 V

Figure 2: Definition of Type-D Interface

Type-P interface is a standard 3-pin DuPont female connector with a 2.54 mm pitch. The definition is shown as follows:

Pin	Color	Definition	Voltage range
1	Yellow ■	PWM	0-3.3 V
2	Red ■	VCC	7-9V
3	Black ■	GND	0 V

Figure 3: Definition of Type-P Interface

Note: The power supply and control signals require common ground. Hot plugging is forbidden because it may damage hardware circuits.

2 Type-P Interface

Definition:

PWM	Pulse width modulation
PWM frequency	The count of signals changing from a high level to a low level and then back to the high level within one second
PWM period	PWM frequency
Pulse width	Duration of the high level in one PWM period
Duty cycle	Pulse width / PWM period

Type-P interface (i.e., PWM control interface) adopts the fixed signal cycle (supporting the PWM frequency of 50 Hz or 333 Hz). The pulse width is adjusted to control displacement. The PWM reference waveform is shown below:

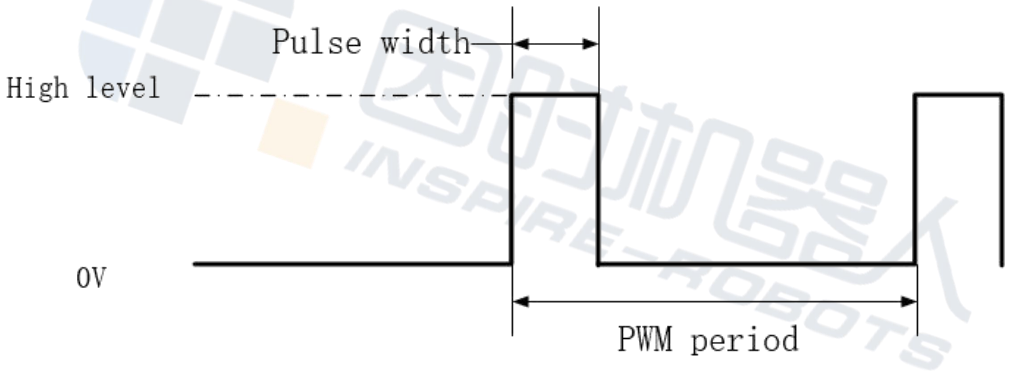


Figure 4: Periodic PWM Waveform

The linear relationship between pulse width and position of actuators is shown below:

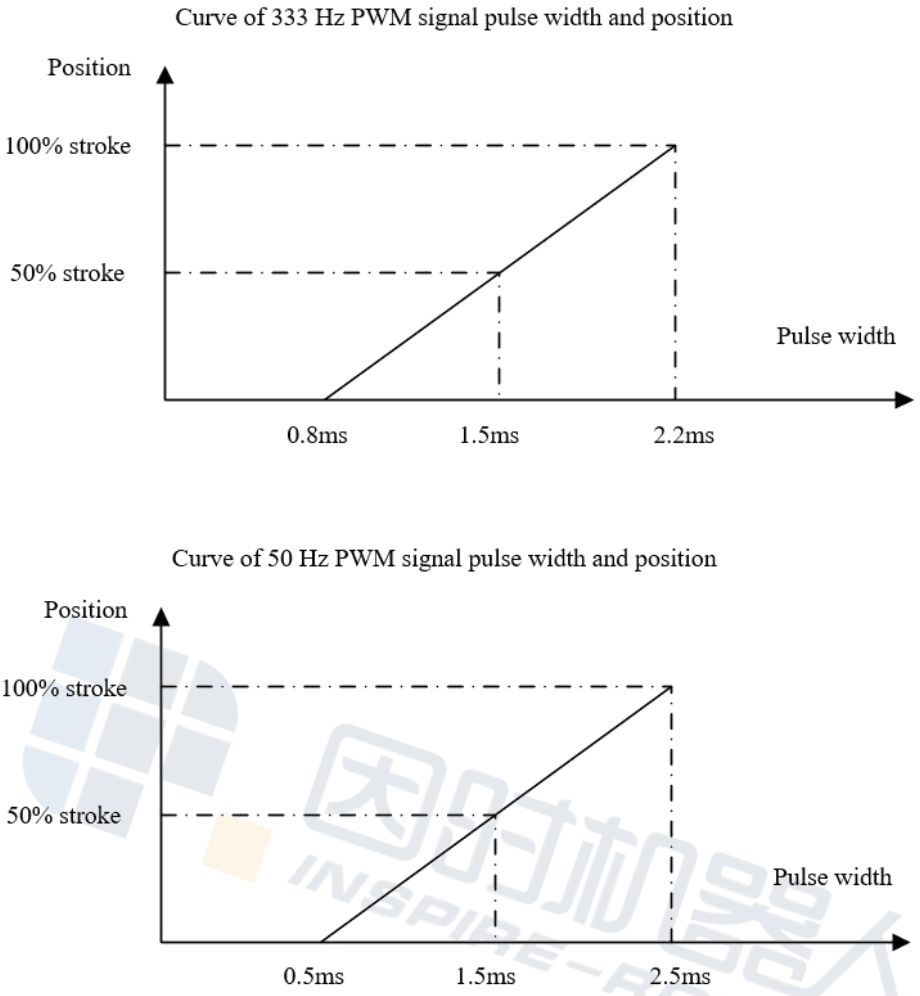


Figure 5: Curve of PWM Signal Pulse Width and Position

333Hz: Position = (5/7 * Pulse width – 4/7) * Stroke

50Hz: Position = (1/2 * Pulse width – 1/4) * Stroke

Note: As the pulse width of PWM signals can be adjusted once in one cycle at the highest speed, the shortest time interval of position adjustment should not be less than one PWM period.

3 Type-D Interface

3.1 UART Serial Bus

Type-D Interface adopts the UART serial bus communication mode with LVTTL 3.3 V level. Theoretically, it can support up 254 actuators mounted on one bus. Actuators mounted on the same bus need to be configured with different ID.

ID: The default ID is 0x01; 0xFF is the broadcast address. See 3.5.12 for ID configuration.

Baud rate: The default communication baud rate is 921600, which can also be configured as 115200, 57600 or 19200 as required. See 3.5.13 for baud rate configuration.

The UART serial bus adopts LVTTL 3.3 V level (VCC: 3.3 V; VOH≥2.4 V; VOL≤0.4 V; VIH≥2 V; VIL≤0.8 V).

All controllers meeting the aforesaid UART interface standards are applicable. Other communication interfaces (if any) can also be connected with the actuators through the interface conversion module. Common controller connections are as follows:

1. General computer (PC) with USB interface

The computer and actuators can be connected by a USB to LVTTL 3.3 V serial port converter.

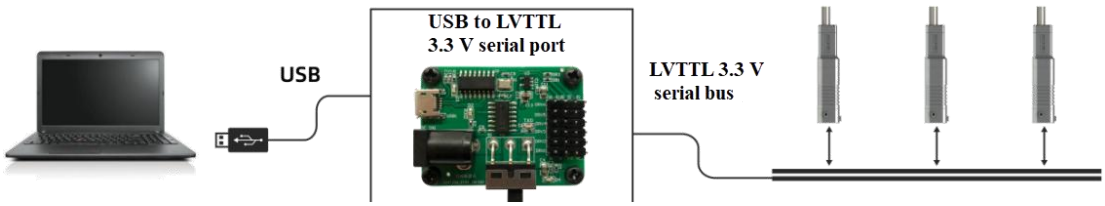


Figure 6: Connection between PC and Actuators

After the hardware is connected, internal parameters of actuators can be read and configured through the debugging software of PC and actuators can also be controlled.

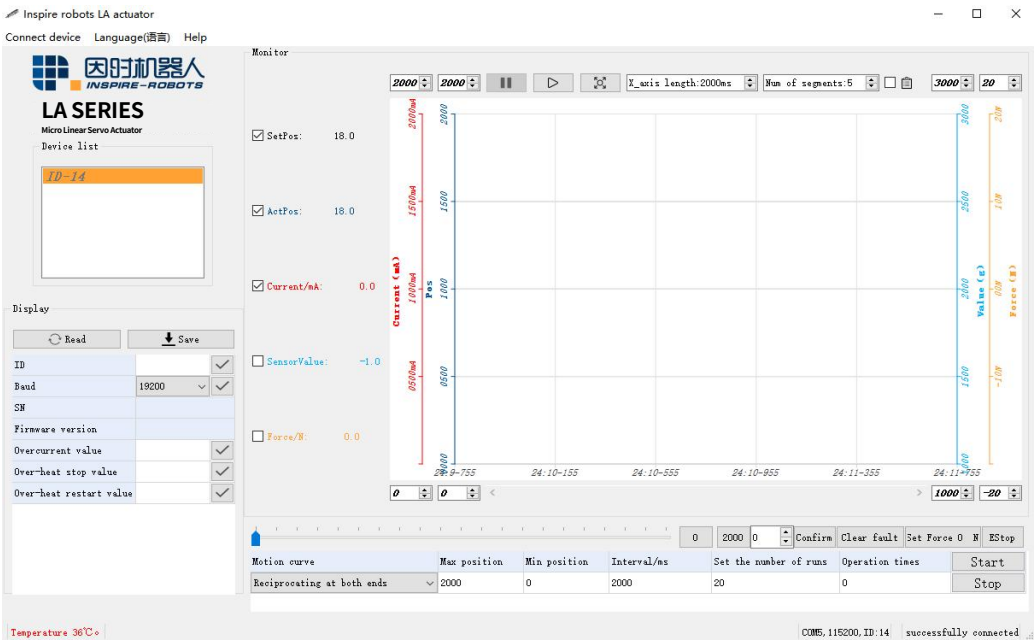


Figure 7: Debugging Software of PC for Push Rod

2. MCU with LVTTL 3.3 V serial port

All MCU meeting the interface specification can be connected with actuators.

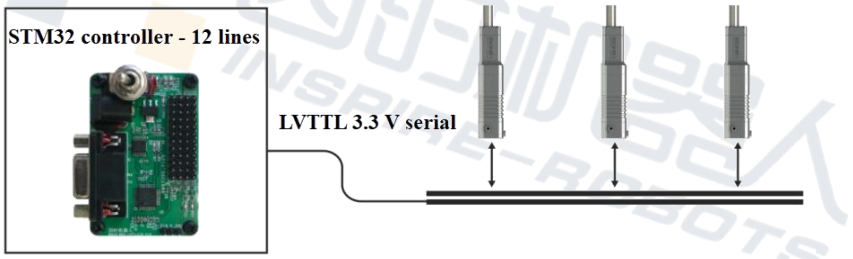


Figure 8: Connection between MCU and Actuators

3. PLC (programmable logic controller) with RS485

The PLC and actuators can be connected by a RS485 to LVTTL 3.3 V serial port converter.

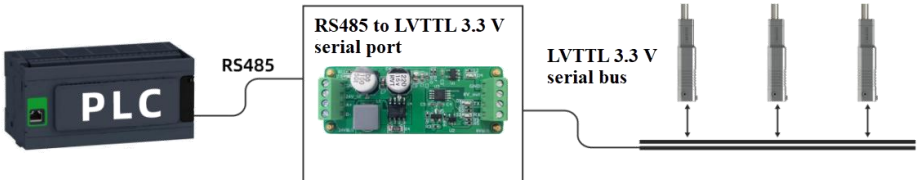


Figure 9: Connection between PLC and Actuators

4. Other interfaces

For RS232, analog control (voltage, current), pulse signal and other control interfaces, please consult the customer service staff for solutions.

3.2 Summary of UART Communication Protocol

3.2.1 Communication mechanism

Q&A communication is used between the controller and actuators. The controller sends the instruction frame; after receiving the instruction frame, actuators will return the response frame after resolution.

A controller is allowed to connect and control multiple actuators, so each actuator needs to be configured with a different ID as unique identifier. The data volume of the instruction frame sent by the controller includes the ID information. The actuators can completely receive the instruction frame only if the ID matches, and will return the corresponding response frame after processing the instruction.

The unit of the instruction frame is byte. A single byte consists of 10 bits, including a start bit, 8 data bits and 1 stop bit, no parity.

3.2.2 Format of basic frame

<table>
<tr><th rowspan="2">Frame type</th><th colspan="2" rowspan="2">Frame header (FH)
(2 bytes)</th><th rowspan="2">Data length
(1 bytes)</th><th rowspan="2">ID (1 byte)</th><th colspan="3">Data segment</th><th rowspan="2">Checksum
(1 bytes)</th></tr>
<tr><th>Instruction type
(1 bytes)</th><th>Register address
(2 bytes)</th><th>Data
(N bytes)</th></tr>
<tr><td>Instruction frame</td><td>0x55</td><td>0xAA</td><td rowspan="2">L</td><td rowspan="2">ID</td><td rowspan="2">CMD</td><td rowspan="2">RegisterAddr</td><td rowspan="2">Data</td><td rowspan="2">Check Sum</td></tr>
<tr><td>Response frame</td><td>0xAA</td><td>0x55</td></tr>
</table>

Frame header (FH): 0x55 0xAA for the instruction frame; 0xAA 0x55 for the response frame

Data length: number of bytes in the data segment, L = N + 3

ID: The ID range is from 0x01 to 0xFE, i.e., 1 to 254. The default ID is 0x01. 0xFF is the broadcast address. If the controller sends the instruction frame with ID of 0xFF, all actuators on the bus will receive it, without returning the response frame. The ID of the response frame is the ID of actuators that send it.

Data segment: Little endian is used for instruction type, register address, number of registers, data, etc. When the data length is larger than one byte, low-order bytes appear at the front of the data segment, while high-order bytes are kept behind the data segment.

Checksum: 8 low-order bytes of the sum of all data before checksum in the frame except the frame head

3.2.3 Interval between instructions

Due to control task interruption, the response time of the response frame is from 120 us to 800 us. The recommended interval between two adjacent instruction frames sent is not less than 1 ms.

3.3 Instruction type

Instruction type	Function description	Values	Length of data segment (unit: byte)
CMD_RD_STATUS	Read the actuator status information.	0x30	1
CMD_RD_REGISTER	Register reading	0x31	3
CMD_WR_REGISTER	Register writing	0x32	3+n*2 Where "n" is the number of registered to be written

Note: Each register occupies 2 bytes; little endian is used; low-order bytes appear at the front of the data segment, while high-order bytes are kept behind the data segment.

3.3.1 Read the actuator status information.

The format of the instruction frame is listed below:

Frame header (FH) (2 bytes)		Data length (1 bytes)	ID (1 byte)	Data segment			Checksum (1 bytes)
				Instruction type (1 bytes)	Register address (2 bytes)	Data (0 bytes)	
0x55	0xAA	0x03	ID	0x30	0x0000	Null	Check Sum

The format of the response frame is listed below:

<table>
<tr><td colspan="4">Frame header (FH)
(2 bytes)</td><td>Low-order byte</td><td>0xAA</td></tr>
<tr><td colspan="4"></td><td>High-order byte</td><td>0x55</td></tr>
<tr><td colspan="5">Data length (1 byte)</td><td>0x0F</td></tr>
<tr><td colspan="5">ID (1 byte)</td><td>ID</td></tr>
<tr><td rowspan="15">Data segment
(14 bytes)</td><td colspan="4">Instruction type (1 byte)</td><td>0x30</td></tr>
<tr><td colspan="4">Preserved (1 byte)</td><td>0x00</td></tr>
<tr><td colspan="4">Preserved (1 byte)</td><td>0x00</td></tr>
<tr><td rowspan="13">Actuator status information
(12 bytes)</td><td rowspan="2">Target position
(16 bits signed integer data)</td><td>Low-order byte</td><td>Target Position_L</td></tr>
<tr><td>High-order byte</td><td>Target Position_H</td></tr>
<tr><td rowspan="2">Actual position
(16 bits signed integer data)</td><td>Low-order byte</td><td>Current Position_L</td></tr>
<tr><td>High-order byte</td><td>Current Position_H</td></tr>
<tr><td rowspan="2">Actual current
(16 bits unsigned integer data)</td><td>Low-order byte</td><td>Current Current_L</td></tr>
<tr><td>High-order byte</td><td>Current Current_H</td></tr>
<tr><td rowspan="2">Force sensor value
(16 bits signed integer data)</td><td>Low-order byte</td><td>Force Sensor_L</td></tr>
<tr><td>High-order byte</td><td>Force Sensor_H</td></tr>
<tr><td rowspan="2">Original value of force sensor
(16 bits unsigned integer data)</td><td>Low-order byte</td><td>Force ADC_L</td></tr>
<tr><td>High-order byte</td><td>Force ADC_H</td></tr>
<tr><td colspan="2">Temperature (8 bits signed integer data)</td><td>Temperature</td></tr>
<tr><td colspan="2">Error code (8 bits unsigned integer data)</td><td>Error Code</td></tr>
<tr><td colspan="5">Checksum (1 byte)</td><td>Check Sum</td></tr>
</table>

3.3.2 Register reading

The format of the instruction frame is listed below:

<table>
<tr><td rowspan="3">Frame header (FH)
(2 bytes)</td><td rowspan="3">Data length
(1 bytes)</td><td rowspan="3">ID
(1 bytes)</td><td colspan="4">Data segment</td><td rowspan="3">Checksum
(1 bytes)</td></tr>
<tr><td rowspan="2">Instruction type
(1 bytes)</td><td colspan="2">Register address (2 bytes)</td><td rowspan="2">Number of registers
(1 bytes)</td></tr>
<tr><td>Low-order byte</td><td>High-order byte</td></tr>
</table>

0x55	0xAA	0x04	ID	0x31	Register Addr_L	Register Addr_H	n	Check Sum

The format of the response frame is listed below:

Frame header (FH) (2 bytes)			Low-order byte	0xAA
			High-order byte	0x55
Data length (1 byte)				3+2*n
ID (1 byte)				ID
Data segment (3+2*n bytes)	Instruction type (1 byte)			0x31
	Register address (2 bytes)		Low-order byte	RegisterAddr_L
			High-order byte	RegisterAddr_H
	N register data (2 * n bytes)	1st register	Low-order byte	0x**
			High-order byte	0x**
		...	Low-order byte	0x**
			High-order byte	0x**
		nth register	Low-order byte	0x**
			High-order byte	0x**
Checksum (1 byte)				Check Sum

3.3.3 Register writing

The format of the instruction frame is listed below:

Frame header (FH) (2 bytes)			Low-order byte	0x55
			High-order byte	0xAA
Data length (1 byte)				3+2*n
ID (1 byte)				ID
Data segment (3+2 * n bytes)	Instruction type (1 byte)			0x32
	Register address (2 bytes)		Low-order byte	RegisterAddr_L
			High-order byte	RegisterAddr_H
	N register data	1st register	Low-order byte	0x**

	(2 * n bytes)		High-order byte	0x**
		...	Low-order byte	0x**
			High-order byte	0x**
		nth register	Low-order byte	0x**
			High-order byte	0x**
Checksum (1 byte)				Check Sum

The format of the response frame is listed below:

Frame header (FH) (2 bytes)			Low-order byte	0xAA
			High-order byte	0x55
Data length (1 byte)				0x0F
ID (1 byte)				ID
Data segment (15 bytes)	Instruction type (1 byte)			0x32
	Register address (2 bytes)		Low-order byte	RegisterAddr_L
			High-order byte	RegisterAddr_H
	Actuator status information (12 bytes)	Target position (16 bits signed integer data)	Low-order byte	TargetPosition_L
			High-order byte	TargetPosition_H
		Actual position (16 bits signed integer data)	Low-order byte	CurrentPosition_L
			High-order byte	CurrentPosition_H
		Actual current (16 bits unsigned integer data)	Low-order byte	CurrentCurrent_L
			High-order byte	CurrentCurrent_H
		Force sensor value (16 bits signed integer data)	Low-order byte	ForceSensor_L
			High-order byte	ForceSensor_H
		Original value of force sensor	Low-order byte	ForceADC_L

		(16 bits unsigned integer data)	High-order byte	ForceADC_H
		Temperature (8 bits signed integer data)		Temperature
		Error code (8 bits unsigned integer data)		ErrorCode
Checksum (1 byte)				Check Sum

3.4 Register description

Address	Name	User permission
0x16	ID; range: 1-254	Read and write
0x17	Baud rate: 3-921600; 2-115200; 1-57600; 0-19200	Read and write
0x18	1 - Fault clearance command	Read and write
0x19	1 - Emergency stop command	Read and write
0x1A	1 - Dwell motion command	Read and write
0x1B	1 - Parameter recovery command	Read and write
0x1C	1 - Hold-over command	Read and write
0x1D	Permissions validation code	Read and write
0x1E	Over temperature protection (unit: ℃)	Read and write
0x1F	Recovery temperature value (unit: ℃)	Read and write
0x20	Overcurrent protection value (unit: mA)	Read and write
0x21	Maximum forward output value of motor; range: [0, 1000]	Read and write
0x22	Maximum reverse output value of motor; range: [0, 1000]	Read and write
0x23	Upper limit of stroke; range: [lower limit of stroke, 2000]	Read and write
0x24	Lower limit of stroke; range: [0,upper limit of stroke]	Read and write
0x25	Control mode: 0 - positioning mode; 1 - servo mode; 2 - speed mode; 3 - force control mode; 4 - voltage mode; 5 - speed & force control mode	Read and write
0x26	Output voltage of motor (valid in the voltage mode); range: [-1000, 1000]	Read and write
0x27	Target value of force control (valid in the force control mode); unit: g	Read and write
0x28	Target speed (valid in the speed mode); unit: step/s	Read and write
0x29	Target position (valid in the speed, positioning and servo modes); unit: [0, 2000]	Read and write

Address	Name	User permission
0x2A	Actual position; range: [0, 2000]	Read only
0x2B	Current value (unit: mA)	Read only
0x2C	Actual force value (unit: g)	Read only
0x2D	Original value of force sensor; range: [0, 4095]	Read only
0x2E	Actual temperature value (unit: ℃)	Read only
0x2F	Error code (bit0: locked-rotor; bit1: over temperature; bit2: overcurrent; bit3: abnormal operation of the motor; bit4: Flash parameter error or not saved)	Read only

Note: 1 step corresponds to 1/2000 of the full stroke. For example, for an actuator with the stroke of 10 mm, 1 step corresponds to 0.05 mm.

3.5 Examples of common instructions

3.5.1 Read the actuator status information.

Instruction frame		Response frame	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x01	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x30	CMD_RD_STATUS	0x30	CMD_RD_STATUS
0x32	Checksum	0x00	Preserved
		0x00	Preserved
		0x00	Target position (0 step)
		0x00	
		0x00	Actual position (0 step)
		0x00	
		0x00	Actual current (0 mA)

		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x5F	Checksum

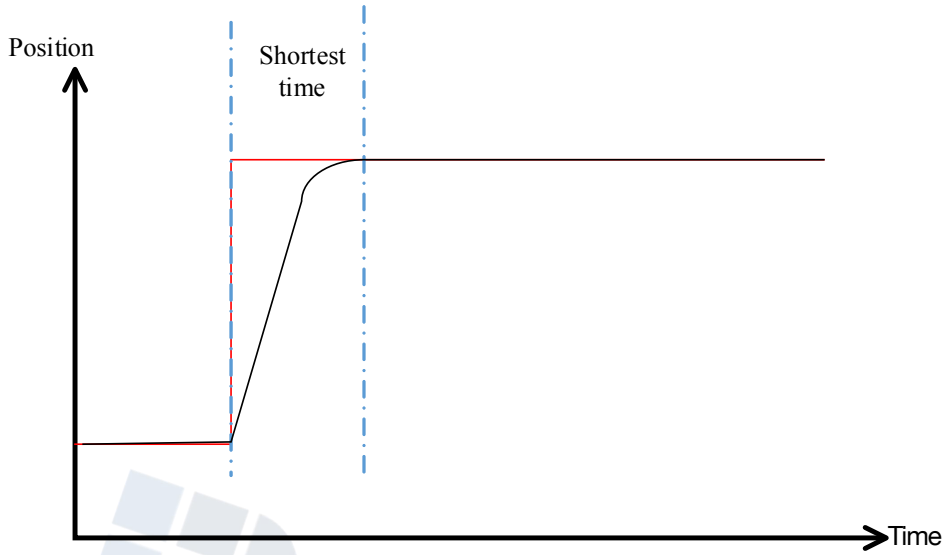
3.5.2 Read the over temperature protection value and the recovery temperature value.

The register address of the over temperature protection value is 0x1E and that of the recovery temperature value is 0x1F. Both addresses are adjacent and thus can be read through an instruction.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x04	Data length	0x07	Data length
0x01	ID	0x01	ID
0x31	CMD_RD_REGISTER	0x31	CMD_RD_REGISTER
0x1E	Register address of the over temperature protection value	0x1E	Register address of the over temperature protection value
0x00		0x00	
0x02	The number of registers already read is 2.	0x50	Over temperature protection value 80 ℃ (0x0050)
0x56	Checksum	0x00	
		0x3C	Recovery temperature value 60 ℃ (0x3C)
		0x00	
		0xE3	Checksum

3.5.3 Positioning mode

In this mode, an actuator performs automatic path planning to move to the target position in the shortest time and return the status information simultaneously.



Red: target position; Black: actual position

Method 1: First of all, set the control mode as the positioning mode, and modify the register 0x25 to 0.

Instruction frame		Response frame	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x00	0 Set the control mode as the positioning mode.	0x00	Target position (0 step)
0x00		0x00	

0x5D	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x87	Checksum

Then set the target position and modify the register 0x29 to 1000 steps.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x29	Register address of the target position	0x29	Register address of the target position
0x00		0x00	
0xE8	Target position (1000 steps) (0x03E8)	0xE8	Target position (1000 steps) (0x03E8)
0x03		0x03	
0x4C	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)

		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x76	Checksum

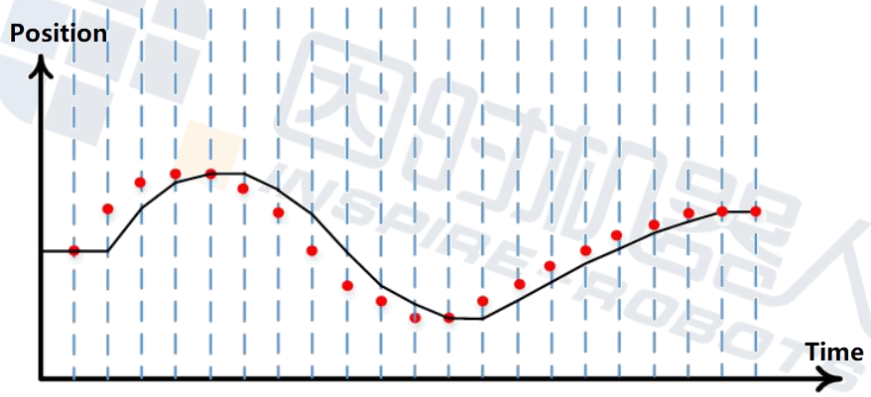
Method 2: Modify the register 0x25 (control mode) and the register 0x29 (target position) simultaneously.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x0D	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x00	0 Set the control mode as the positioning mode.	0xE8	Target position (1000 steps) (0x03E8)
0x00		0x03	
0x00	Register of the motor output voltage	0x00	Actual position (0 step)
0x00	Invalid in the positioning mode; set it to 0x0000.	0x00	
0x00	Register of the target value for force control	0x00	Current (0 mA)
0x00	Invalid in the positioning mode; set it to 0x0000.	0x00	
0x00	Register address of the target	0x00	Force sensor value (0 g)

0x00	speed Invalid in the positioning mode; set it to 0x0000.	0x00	
0xE8	Target position (1000 steps) (0x03E8)	0x00	Original value of force sensor (0)
0x03		0x00	
0x50	Checksum	0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x72	Checksum

3.5.4 Servo mode

In this mode, the controller needs to send the target position to the actuator at a fixed frequency (a value not lower than 50 Hz recommended); the actuator will perform position interpolation and follow the target position to have curvilinear motion.



Red: target position; Black: actual position

Method 1: First of all, set the control mode as the servo mode and modify the register 0x25 to 1.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID

0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x01	1 Set the control mode as the servo mode.	0x00	Target position (0 step)
0x00		0x00	
0x5E	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x86	Checksum

Then set the target position, and modify the register 0x29 to 1000 steps.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x29	Register address of the target position	0x29	Register address of the target position
0x00		0x00	

0xE8	Target position (1000 steps) (0x03E8)	0xE8	Target position (1000 steps) (0x03E8)
0x03		0x03	
0x4C	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x74	Checksum

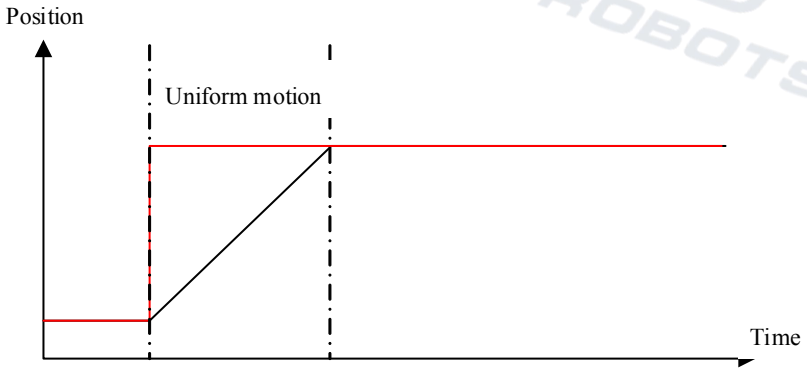
Method 2: Modify the register 0x25 (control mode) and the register 0x29 (target position) simultaneously.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x0D	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x01	1 Set the control mode as the servo mode.	0xE8	Target position (1000 steps) (0x03E8)
0x00		0x03	
0x00	Register of the motor output	0x00	Actual position (0 step)

0x00	voltage Invalid in the positioning mode; set it to 0x0000.	0x00	
0x00	Register of the target value for force control Invalid in the positioning mode; set it to 0x0000.	0x00	Current (0 mA)
0x00		0x00	
0x00	Register address of the target speed Invalid in the positioning mode; set it to 0x0000.	0x00	Force sensor value (0 g)
0x00		0x00	
0xE8	Target position (1000 steps) (0x03E8)	0x00	Original value of force sensor (0)
0x03		0x00	
0x51	Checksum	0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x72	Checksum

3.5.5 Speed mode

In this mode, the push rod will move to the target position at the preset constant target speed and then stop.



Red: target position; Black: actual position

Method 1: First of all, set the control mode as the speed mode and modify the register 0x25 to 2.

Instruction frame	**Response frame**

Values	Description	Values	Description
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x02	2 Set the control mode as the speed mode.	0x00	Target position (0 step)
0x00		0x00	
0x5F	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x87	Checksum

Then set the target speed and the target position and modify the register 0x28 to 500 steps/s and the register 0x29 to 1000 steps/s.

Instruction frame		Response frame	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)

0xAA	Frame header (FH)	0x55	Frame header (FH)
0x07	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x28	Register address of the target speed	0x28	Register address of the target speed
0x00		0x00	
0xF4	Target speed (500 steps/s) (0x01F4)	0xD0	Target position (2000 steps) (0x07D0)
0x01		0x07	
0xD0	Target position (2000 steps) (0x07D0)	0x00	Actual position (0 step)
0x07		0x00	
0x2E	Checksum	0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x61	Checksum

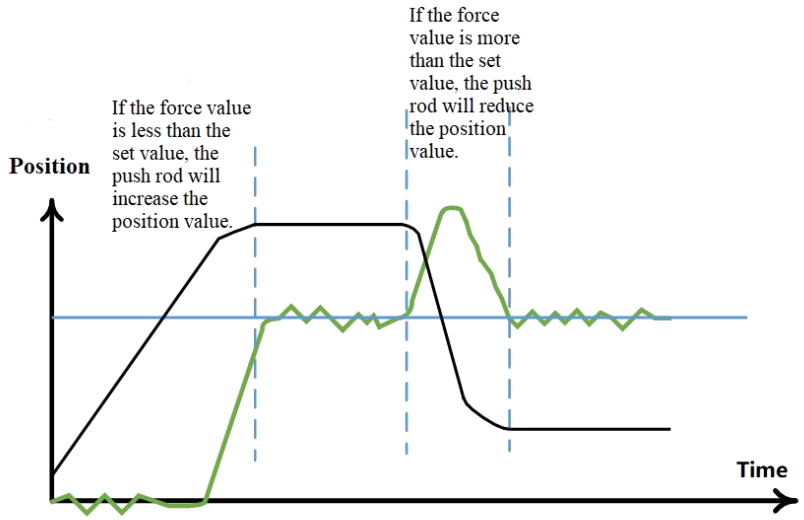
Method 2: Modify the register 0x25 (control mode), the register 0x28 (target speed) and the register 0x29 (target position) simultaneously.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x0D	Data length	0x0F	Data length
0x01	ID	0x01	ID

0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x02	2 Set the control mode as the speed mode.	0xD0	Target position (2000 steps) (0x07D0)
0x00		0x07	
0x00	Register of the motor output voltage Invalid in the speed mode; set it to 0x0000.	0x00	Actual position (0 step)
0x00		0x00	
0x00	Register of the target value for force control Invalid in the speed mode; set it to 0x0000.	0x00	Current (0 mA)
0x00		0x00	
0xF4	Target speed (500 steps/s) (0x01F4)	0x00	Force sensor value (0 g)
0x01		0x00	
0xD0	Target position (2000 steps) (0x07D0)	0x00	Original value of force sensor (0)
0x07		0x00	
0x33	Checksum	0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x5E	Checksum

3.5.6 Force control mode

In this mode, the actuator will dynamically adjust the position to ensure that the actual force value is close to the target value for force control.



Black: actual position; Green: force value; Blue: set value for force control

Method 1: First of all, set the control mode as the force control mode and modify the register 0x25 to 3.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x03	3 Set the control mode as the force control mode.	0x00	Target position (0 step)
0x00		0x00	
0x60	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)

		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x86	Checksum

Then set the target value for force control, and modify the register 0x27 to 1000 g.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x27	Register address of the target value for force control	0x27	Register address of the target value for force control
0x00		0x00	
0xE8	Target value (1000 g) for force control (0x03E8)	0x00	Target position (0 step)
0x03		0x00	
0x4A	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	

		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x89	Checksum

Method 2: Modify the register 0x25 (control mode) and the register 0x27 (target value for force control) simultaneously.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x09	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x03	3 Set the control mode as the force control mode.	0x00	Target position (0 step)
0x00		0x00	
0x00	Register of the motor output voltage; Invalid in the force control mode; set it to 0x0000.	0x00	Actual position (0 step)
0x00		0x00	
0xE8	Target value (1000 g) for force control (0x03E8)	0x00	Current (0 mA)
0x03		0x00	
0x4F	Checksum	0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of the sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0

		0x87	Checksum

3.5.7 Voltage mode

In this mode, the user can control the actuator motion by changing the voltages on both ends of the motor.

Method 1: First of all, set the control mode as the voltage mode, and modify the register 0x25 to 4.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x04	4 Set the control mode as the voltage mode.	0x00	Target position (0 step)
0x00		0x00	
0x61	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)

		0x00	Error code 0
		0x87	Checksum

Then set the motor output voltage, and modify the register 0x26 to 500.

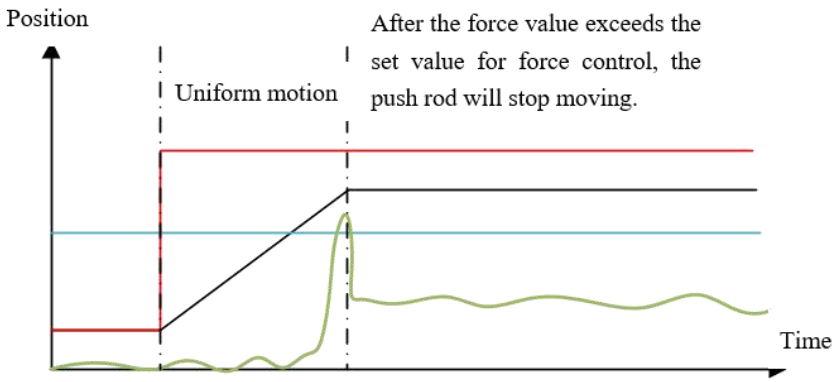
Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x26	Register address of the motor output voltage	0x26	Register address of the motor output voltage
0x00		0x00	
0xF4	Motor output voltage 500 (0x01F4)	0x00	Target position (0 step)
0x01		0x00	
0x53	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x88	Checksum

Method 2: Modify the register 0x25 (control mode) and the register 0x26 (motor output voltage) simultaneously.

Instruction frame		Response frame	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x07	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x04	4 Set the control mode as the voltage mode.	0x00	Target position (0 step)
0x00		0x00	
0xF4	Motor output voltage 500 (0x01F4)	0x00	Actual position (0 step)
0x01		0x00	
0x58	Checksum	0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x87	Checksum

3.5.8 Speed & force control mode

In this mode, the actuator will move to the target position at the pre-set speed. If the force value (extrusion force or tensile force) during its movement exceeds the target value for force control, it will stop operations immediately.



Red: target position;Black: actual position;
Green: force value; Blue: set value for force control

Modify the register 0x25 (control mode), the register 0x26 (target value for force control), the register 0x28 (target speed value) and the register 0x29 (target position) simultaneously.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x0D	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x25	Register address of the control mode	0x25	Register address of the control mode
0x00		0x00	
0x00	4 Set the control mode as the speed & force control mode.	0x00	Target position (0 step)
0x00		0x00	
0x00	Register of the motor output voltage Invalid in the positioning mode; set it to 0x0000.	0x00	Actual position (0 step)
0x00		0x00	
0xEB	Target value for force control (1000 g) (0x03EB)	0x00	Current (0 mA)
0x03		0x00	
0xEB	Target speed (1000 steps/s)	0x00	Force sensor value (0 g)

0x03	(0x03EB)	0x00	
0xEB	Target position (1000 step) (0x03EB)	0x00	Original value of force sensor (0)
0x03		0x00	
0x2F	Checksum	0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x87	Checksum

3.5.9 Fault clearance

If a fault (locked-rotor, over temperature, overcurrent, abnormal operations of the motor, Flash parameter error or not saved) occurs on an actuator, a fault clearance command can be sent to clear the error code and restore the actuator to the initial state after power-on.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x18	Clear the fault register address.	0x18	Clear the fault register address.
0x00		0x00	
0x01	1 Fault clearance command	0x00	Target position (0 step)
0x00		0x00	
0x5	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	

		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x80	Checksum

3.5.10 Parameter saving

When the parameters in a register are modified and expected to remain valid after power-off and restart, a parameter saving command can be sent to fix such parameters in the Flash.

After the parameter saving command is sent, two response frames will be received; 0x40 will be returned for the first byte in the data segment of the second frame, indicating successful data saving.

Instruction frame		**Response Frame 1**		**Response Frame 2**	
Values	**Description**	**Values**	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length	0x0F	Data length
0x01	ID	0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER	0x40	0x40 returned after successful saving
0x1C	Register address for parameter saving	0x1C	Register address for parameter saving	0x1C	Register address for parameter saving
0x00		0x00		0x00	
0x01	1 Parameter saving	0x00	Target position (0 step)	0x00	Target position (0 step)
0x00		0x00		0x00	
0x55	Checksum	0x00	Actual position (0 step)	0x00	Actual position (0 step)
		0x00		0x00	
		0x00	Current (0 mA)	0x00	Current (0 mA)

		0x00		0x00	
		0x00	Force sensor value (0 g)	0x00	Force sensor value (0 g)
		0x00		0x00	
		0x00	Original value of force sensor (0)	0x00	Original value of force sensor (0)
		0x00		0x00	
		0x20	Temperature (32 ℃)	0x20	Temperature (32 ℃)
		0x00	Error code 0	0x00	Error code 0
		0x7E	Checksum	0x8C	Checksum

3.5.11 Dwell motion

If the register 0x1A is set to 1, the current motion of an actuator can be suspended. Instructions are as follows.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x1A	Register address for dwell motion	0x1A	Register address for dwell motion
0x00		0x00	
0x01	1 Dwell motion	0x00	Target position (0 step)
0x00		0x00	
0x53	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	

		0x00	Force sensor value (0 g)
		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x7C	Checksum

3.5.12 Modify the ID of an actuator.

Modify the ID of an actuator to 2. After the register 0x16 is set to 0x02, the new ID will become effective immediately. Next, send the parameter saving command (see 3.5.10) to fix the ID in the Flash.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x16	ID register address	0x16	ID register address
0x00		0x00	
0x02	The new ID is 2.	0x00	Target position (0 step)
0x00		0x00	
0x50	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)

		0x00	
		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x78	Checksum

3.5.13 Modify the baud rate.

Modify the baud rate of the actuator to 115200. Set the register 0x17 to 0x02 ("2" corresponds to the baud rate of 115200). Then send the parameter saving command (see 3.5.10). After power-off and restart, the new baud rate will become effective.

Instruction frame		**Response frame**	
Values	**Description**	**Values**	**Description**
0x55	Frame header (FH)	0xAA	Frame header (FH)
0xAA	Frame header (FH)	0x55	Frame header (FH)
0x05	Data length	0x0F	Data length
0x01	ID	0x01	ID
0x32	CMD_WR_REGISTER	0x32	CMD_WR_REGISTER
0x17	Register address for baud rate	0x17	Register address for baud rate
0x00		0x00	
0x02	2 The baud rate is 115200.	0x00	Target position (0 step)
0x00		0x00	
0x51	Checksum	0x00	Actual position (0 step)
		0x00	
		0x00	Current (0 mA)
		0x00	
		0x00	Force sensor value (0 g)
		0x00	

		0x00	Original value of force sensor (0)
		0x00	
		0x20	Temperature (32 ℃)
		0x00	Error code 0
		0x80	Checksum

Notice:The function of force control is not supported after updating the force closed loop program for LA and LAS series actuator.

3.6 Exception handling mechanism

By reading the actuator status information instruction, the controller can get the error code of the actuator, including locked-rotor, over temperature, overcurrent, abnormal operation of the motor, Flash parameter error or not saved, etc.

When an actuator enters the protection mode due to locked-rotor, just wait for 5 seconds and then the error will be cleared automatically; or a fault clearance command can be sent, and the actuator will be restored to the initial state after power-on and will wait for a new instruction. If the first two errors are automatically cleared to resume work, the normal operations of the actuator can be restored by the fault clearance command after the third error occurs.

When the actuator experiences over temperature protection, it will stop operations and such error cannot be cleared; after its temperature decreases to the recovery temperature value, it can be automatically restored to the initial state after power-on and will wait for a new instruction.

When the actuator experiences an overcurrent fault, just wait for 5 seconds and then the error will be cleared automatically; or a fault clearance command can be sent and the actuator will be restored to the initial state after power-on and will wait for a new instruction. If the first two errors are automatically cleared to resume work, the normal operation of the actuator can be restored by the fault clearance command after the third error occurs.

When the actuator experiences abnormal operations of the motor, it means that the internal output of the actuator reaches the maximum value, but the actual current value acquired is 0. When the current value acquired is larger than 30 mA, the error code

regarding the abnormal operation of the motor will be cleared automatically. Such error code can also be cleared by the fault clearance command. Generally, this error code indicates that the service life of the actuator motor is to expire.