SP16 Pipettor Manual

--16-02 Pipettor Series

Product Model:

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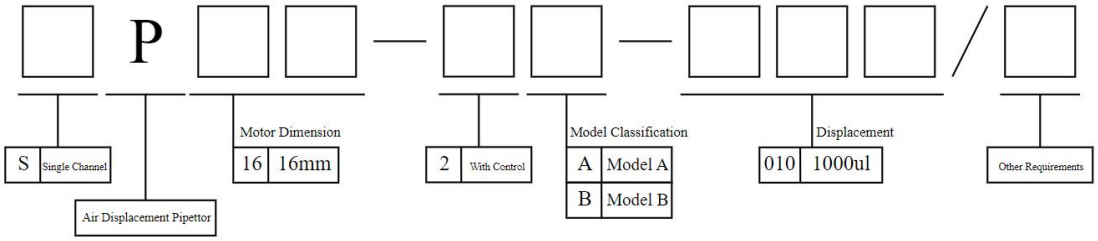
Contents

1 Product Overview

The SP16 Pipettor series is a module that Keyto uses air displacement to achieve aspiration and dispense, and works with disposable TIP for pipetting. The SP16 can achieve automatic aspiration and dispense in the range of 1 to 1000ul with TIP of different specifications. The pipettor provides a fast and reliable mechanical adapter module and a common communication interface. It is suitable for integration in pipetting platforms that are sensitive to cross contamination and pipetting units of inspection instruments, providing high-performance and reliable pipetting functions for various instruments.

1.1 Ordering information



Notes:

1. The naming rule includes the pipettor only, and the Axis-Z is not included.
2. For Axis-Z, please contact us.

1.2 Main Features

◆ This pipettor has a unique mechanical structure that allows multiple SP16 to be used in conjunction with each other as 9 mm TIP to TIP center spacing, which greatly increases the pipetting velocity.

◆ The pipettor is equipped with a excellent-performance drive control unit and provides CAN, RS232 and RS485 communication interface and the corresponding protocol, allowing SP16 achieve multiple functional applications easily and quickly by the host controller.

◆ Equipped with advanced pressure sensors and algorithms for rapid liquid level detection, aspiration of empty detection, and aspiration of foam detection in various reagents and high-humidity environments.

◆ This pipettor allows for automatic TIP pick-ups and ejection, as well as TIP drop detection.

◆ Advanced pipetting barrel processing technology, strict inspection procedures, and unique sealing solutions, which ensure that the pipetting barrel's service life can reach more than 1 million cycles without maintenance.

◆ The excellent chemical and wear resistance of the nozzle materials in contact with the disposable TIP ensure that the nozzle does not need to be replaced during its life cycle.

1.3 Glossary

- **PLLD**: pressure-based liquid level detection
- **ADP**: Air Displacement Pipettor
- **Host**: Customer Controller
- **Send**: from Host to SP16
- **Receive (Response)**: from SP16 to Host
- **Device**: SP16

2 Products Specifications

2.1 Specifications

Table 2-1 Specifications

Dispense range	1～1000ul
Liquid level detection	PLLD
Weight	<400g
Dimensions	265.3mm*100mm*16mm
Minimum Spacing	9mm
Driver Design	BLDC motor with ball screw
TIP compatibility	10,50,200,1000ul
Communication	RS232, RS485, CAN
Baud Rate	Serial Port port: 9600, 19200, 38400 (default), 115200 CAN: 100K, 125K, 250K, 500K (default), 800K, 1000K
Operating Temperature	+15～+35° C
Power Input	24V DC
Pipetting barrel life	One million cycles

Table 2-2 SP16 Pipetting Performance

TIP volume(uL)	Single/Aliquot dispense	Dispense Volume(uL)	Accuracy(A)	CV
10 (with filter)	single dispense	1	10%	10%
50 (with filter)	single dispense	2	5.0%	5.0%
50 (with filter)	single dispense	5	5.0%	2.0%
50	single dispense	10	3.0%	1.0%
200 (with filter)	single dispense	10	5.0%	2.0%
200	single dispense	50	2.0%	0.75%
1000	single dispense	10	7.5%	3.5%
1000	single dispense	1000	1%	0.75%
1000 (with filter)	aliquot-dispense	20	3.0%	3.0%
1000	aliquot-dispense	50	5.0%	2.0%
200	aliquot-dispense	10	5.0%	2.0%

1. The test environment is 21～25℃ (no wind).

2. The test method is non-contact dispense method(Suspended dispensing liquid).

3. You need replace the new TIP after each test.

4. When the dispense liquid volume is not good, you need to increase the compensation value, need do aspirating compensation when single aspirate single dispense. in generally practice, single aspirate aliquot dispense does not need to do compensation.

5. Single aspiration and single dispense: For example, use a TIP to aspirate 10ul of reagent once, and then dispense 10ul of reagent at one time. Replace the new TIP after each dispense of the reagent, and repeat the measurement ten times to calculate the accuracy and precision of the data.

6. Single aspiration aliquot dispense: For example, use one TIP to aspirate 1000ul of reagent at one time, and dispense 20ul each time for 50 times. Replace the TIP after all dispensing done. Calculate the accuracy and precision after discarding the head and tail data (48 times).

Note:

TIP is a disposable product, please do not reuse TIP.

Accuracy A (Accuracy): refers to the degree of deviation of the measurement result from the true value of the measured value.

$$\%\text{Accuracy} = \left[\frac{\left(\frac{\bar{X}}{sg}\right) * 100}{\text{Vol}_{\text{expected}}}\right] - 100$$

Precision CV (Coefficient of Variation): Expressed by precision, its value can objectively and accurately reflect the degree of discreteness of a set of data.

$$\%\text{CV} = \left(\frac{\sqrt{\frac{1}{n-1}\left\{\sum_{i=1}^{n} X_i^2 - n\bar{X}^2\right\}}}{\bar{X}}\right) * 100$$

Note:

Sg:Specific gravity of pure water at 25℃, Sg=0.99707.

$\text{Vol}_{\text{expected}}$: expected dispense volume.

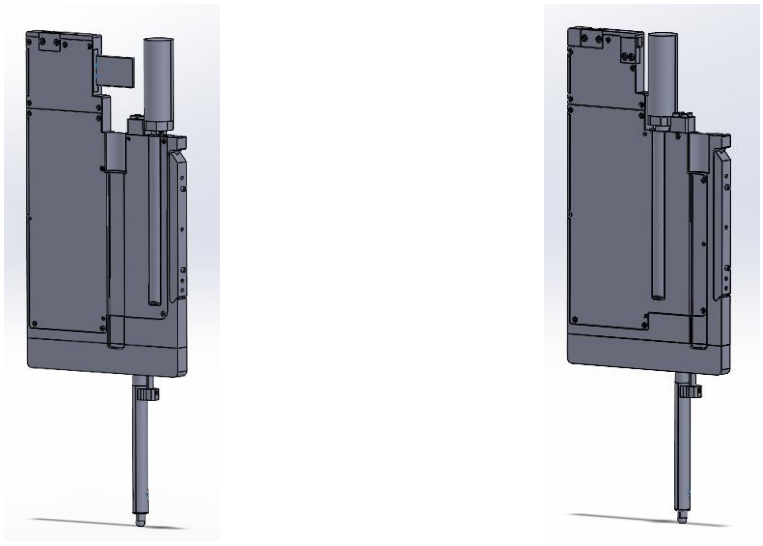
n:Dispense times.

X:Single test data.

$\bar{X}$: Average value of all test data.

2.2 SP16 Series Pipettor Dimension

2.2.1 Product Figure



Type A Type B

Figure 2-1 SP16 Product Figure

2.2.2 Dimensional and Mounting Drawings

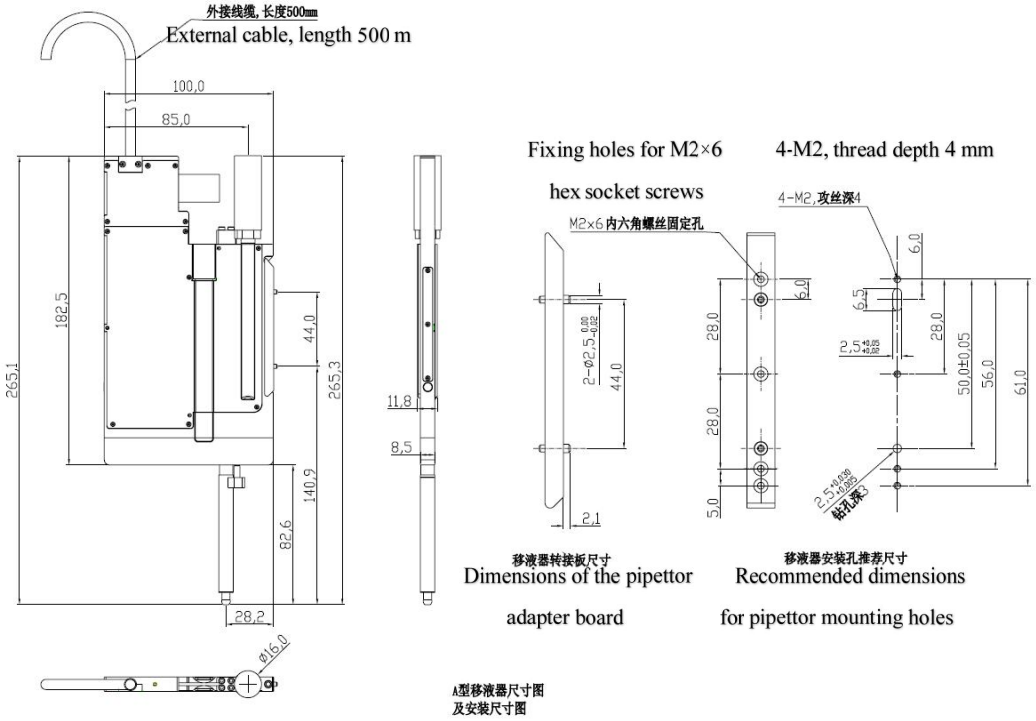


Figure 2-2 SP16 (Type A) Dimensional Drawing

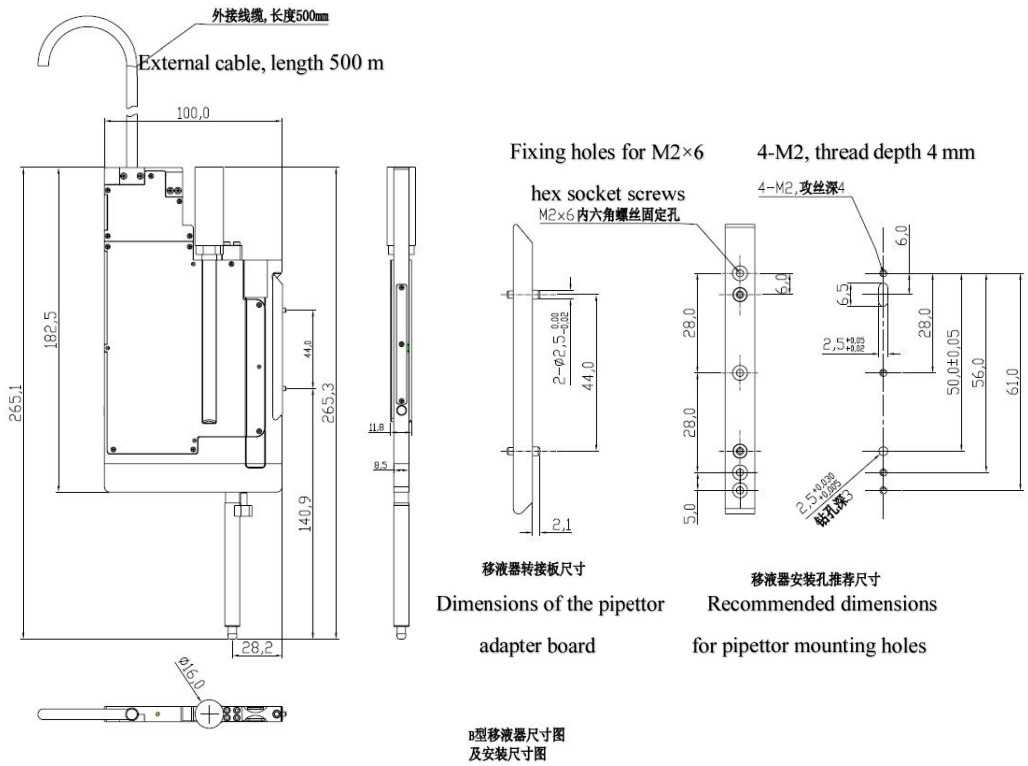


Figure 2-3 SP16 (Type B) Dimensional Drawing

Note: For the M2 screws used to fix the pipettor adapter plate, it is recommended to apply medium-strength thread locker during installation.

3 Electrical Interface

3.1 ※ Definition of DIP Switch

This DIP switch is located under the debugging port cover. To set the SP16 address or enable the terminal resistor operation, you need to first remove the debugging port cover using a Cross-head screwdriver. The SP16 has an 8-bit DIP switch, which is used to set the ID, enable the 120-ohm 485 terminal resistor, and enable the 120-ohm CAN terminal resistor. See Figure 3-1 for the DIP switch diagram.

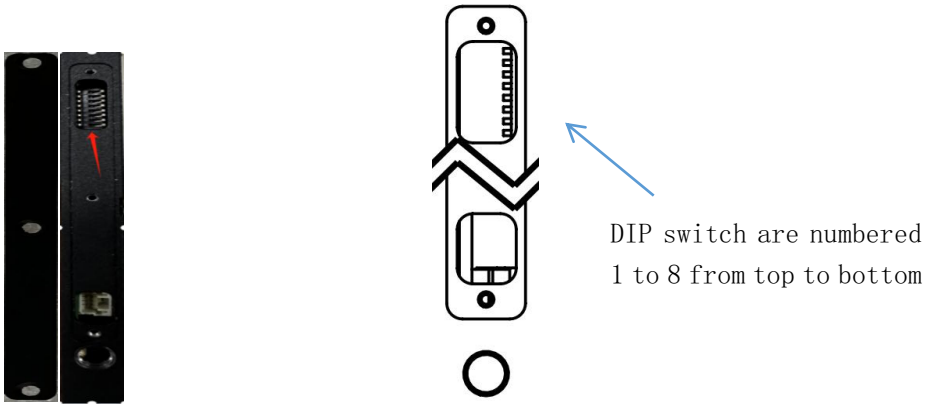


Figure 3-1 DIP Switch

Table 3-1 DIP Switch description

SW	Function	Description
1	120 ohm CAN termination resistor	ON: Enabled OFF: Disabled
2	120 ohm RS485 termination resistor	ON: Enabled OFF: Disabled
3	Reserve	
4	Address bit4	The DIP switch address is expressed in 5-bit binary, bit0 being the lowest bit. The binary value +1 is the ID (address value) and the ID range is: 1～32. DIP switches each set to ON for 1 and OFF for 0. For example,if the address value is configured as 6, the corresponding binary value is 5(0b00101), and the4～8 bit is as follows:OFF, OFF, ON, OFF, ON.
5	Address bit3	
6	Address bit2	
7	Address bit1	
8	Address bit0	

Reduce the RS485/CAN transmission distance when using the product. If communication is unstable, ensure the 120Ω termination resistors are properly enabled at both end and begin of the bus to maintain a total impedance of 60Ω.

3.2 Hardware Interface Definition

Warning:

Please insulate unused cores!

The cables must be connected or disconnected when the power is off!

The power supply of SP16 is 24V DC ±5%, the peak RMS value of the current does not exceed 300mA, and the RMS value of the current does not exceed 200mA.

The SP16 connects to external control systems via a highly flexible towline cable with AWG26 cores. Select a communication method and connect according to the Table below:

Table 3-2 Definition of Towline cable

Function	Core Color	Description
DC 24V+	Red	Power input 24V±5%. ≥1A
GND	Black	Grounding
RS232-RX	Green	Communication interface
RS232-TX	Blue	Communication interface
RS485A	Orange	Communication interface
RS485B	White	Communication interface
CANL	Yellow	Communication interface
CANH	Yellow-green	Communication interface
GPO1	Purple	pLLD digital output,5V level
GPO	Brown	Reserved

The GPO1 interface schematic circuit is shown below:

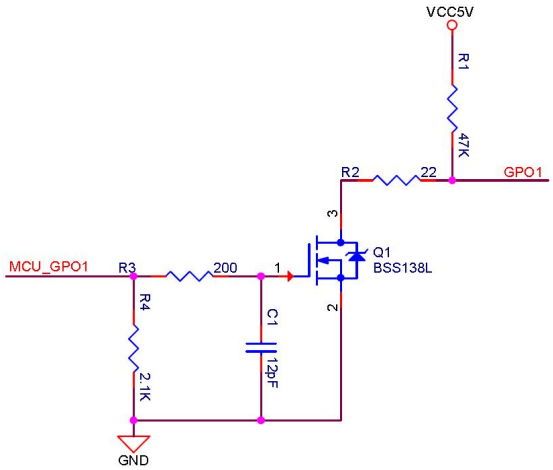


Figure 3-2 GPO Circuit Diagram

Additional TVS protection is required in customer PCBA when using the GPO1.

3.3 RS485/CAN Connection Topology Diagram

For RS485 communication, minimize the number of devices on the bus. A one-to-one

communication setup is recommended to improve efficiency and reliability.

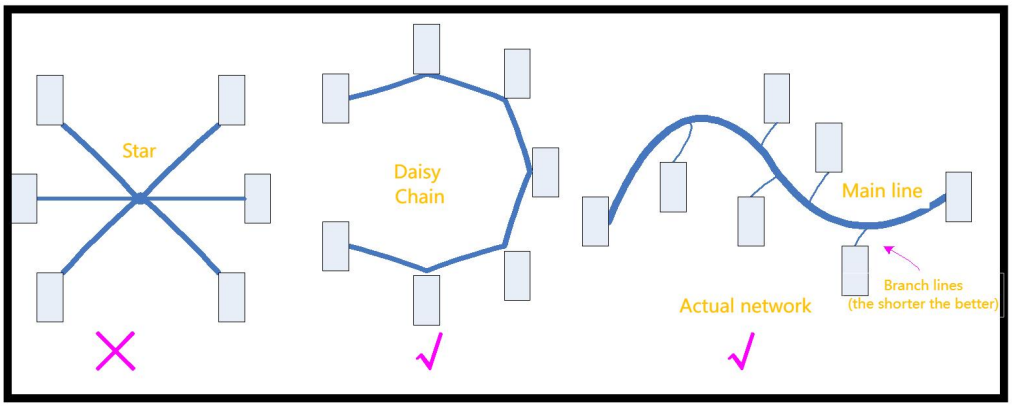


Figure 3-3 RS485/CAN Connection Topology Diagram

4 Installation and Debugging

4.1 Installing the pipettor

Ensure the system is powered off when connecting or disconnecting cables!

Install the pipettor on the Axis-Z or vertical plane as shown in Figure 4-1. For standalone SP16 use, connect using the 10-core highly flexible towline cable as Table 4-1 and Figure 4-2 . When used with the Keyto Axis-Z, insert the Axis-Z 10-core cable into the pipettor and connect the Axis-Z 8-core cable as Table 4-1. The relevant accessories are already configured at the factory.

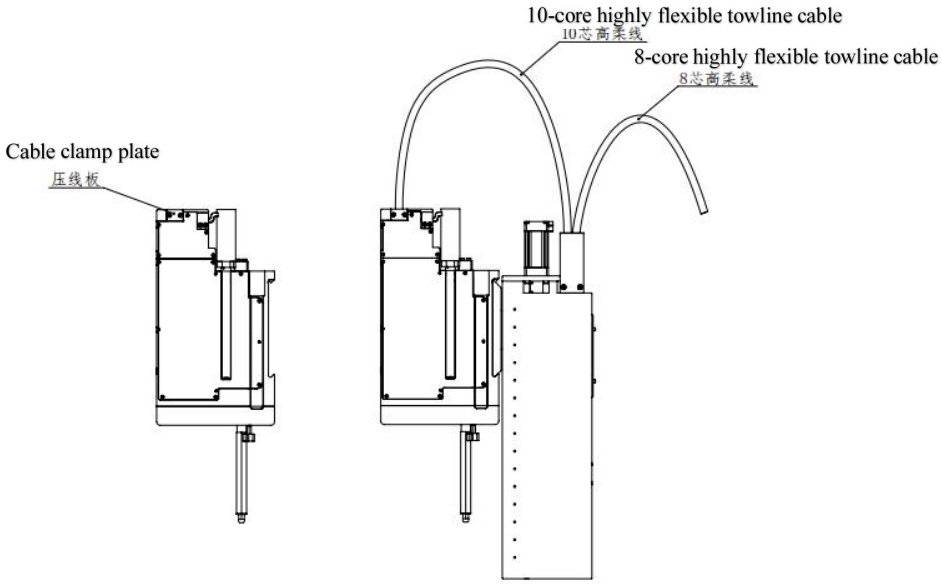


Figure 4-1 Pipettor Installation Diagram

4.2 Connecting Power and Communication Cables

This section uses RS485 communication as an example, using the single SP16 to connect the device power and communication cables according to Table 4-1 .

Note: The cables must be connected or disconnected when the power is off!

Table 4-1 Quick Debugging cable connecting

Function	Core Color	Description
DC 24V+	Red	Power input 24V±5%, ≥1A
GND	Black	Ground
RS485A	Orange	Communication interface

RS485B	White	Communication interface

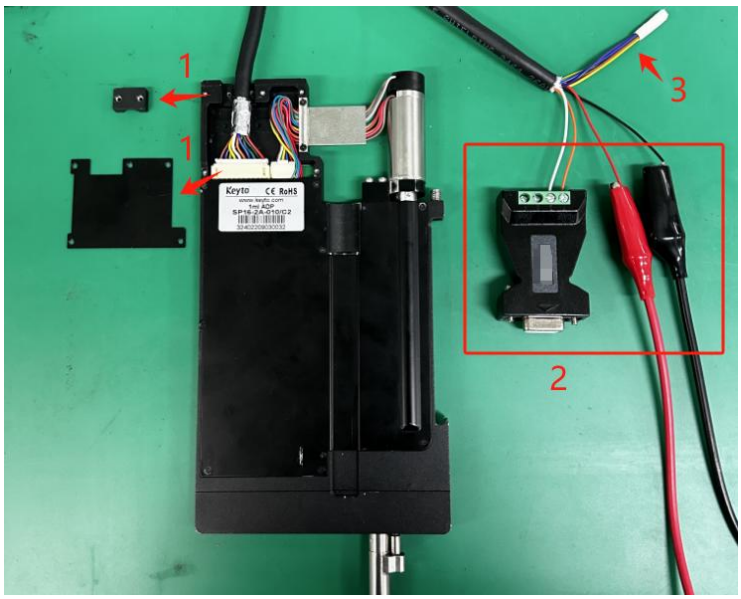


Figure 4-2 Single SP16 cable connecting Diagram

Connecting Steps:

1. Prepare the power supply with a DC voltage of 24V ±5% and current ≥1A.
2. According to **Figure 4-2 Single SP16 cable connecting Diagram**, remove the cable clamp and cover (marked 1) and connect the cables.
3. Referencing **Table 4-1 Quick Debugging cable connecting**, connect the power cores (red and black) and RS485 communication cores(marked 2).
4. Insulate unused cores as shown in **Figure 4-2 Single SP16 cable connecting Diagram** (marked 3).

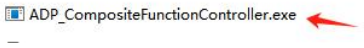
When assembling the cable clamp, ensure the cable is firmly in place and does not wobble!

5 PC Debug Software

The PC Debug Software supports combined control of the SP16 pipettor and the Keyto Axis-Z. The following commands describe the operation for this combination. The electrical connecting refer to Chapter 4. The standalone SP16 operation is the same as the combination use.

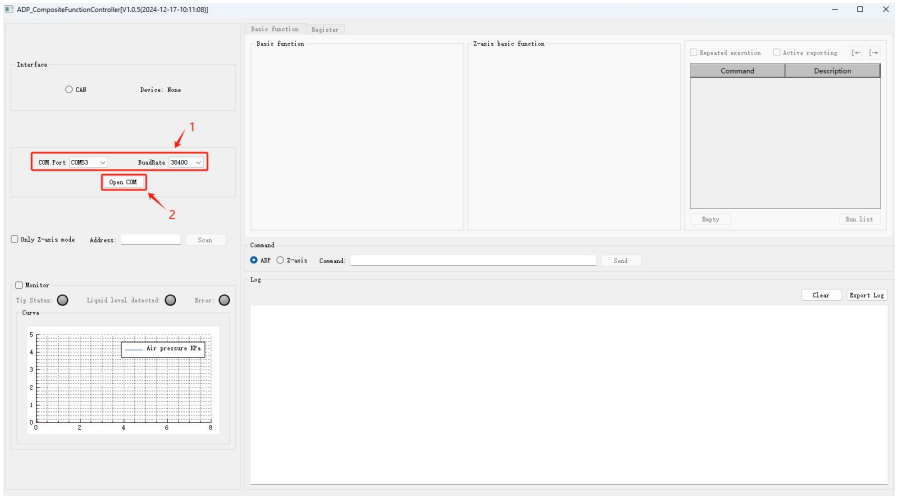
5.1 Open the PC Debug Software

Ensure all device connections are properly established and powered on, then open the PC Debug software.



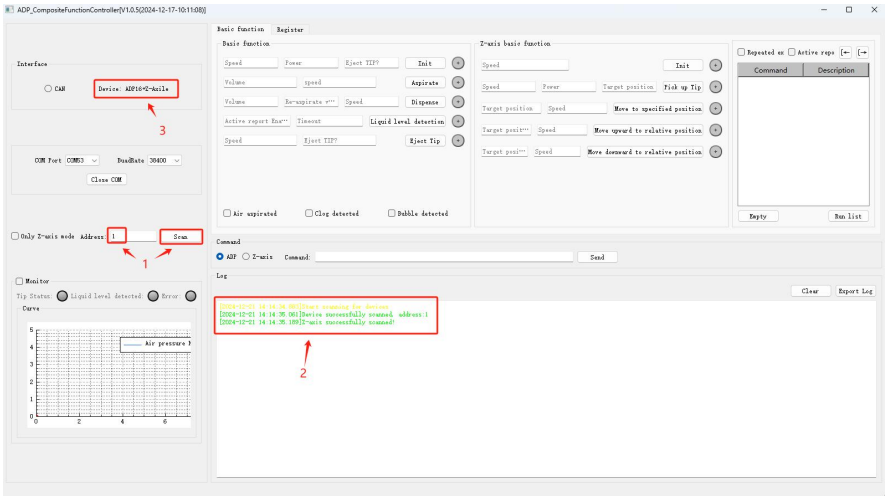
5.2 Serial Port and Baud Rate Selection

1. Select the appropriate serial port number and set the baud rate to 38400 (default factory setting).
2. Click the" Open COM" button to open the serial port.



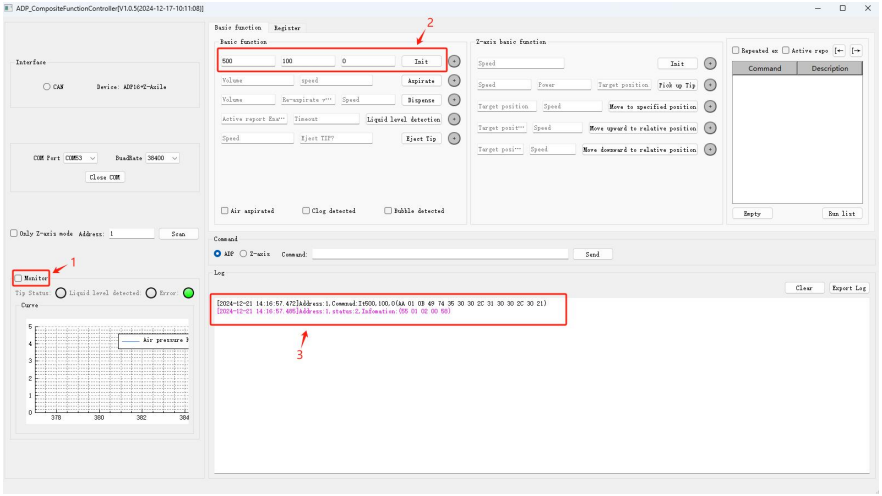
5.3 Scan Device

1. Click "Scan" button, the default address is 1. Once scanning is complete, the detected address will be automatically filled into the input field.
2. Note that other device operations will only be executed after the address is scanned.
3. The log window will display successful detection of both the ADP device and the Axis-Z device.
4. The "Device" field will show the current pipettor model.



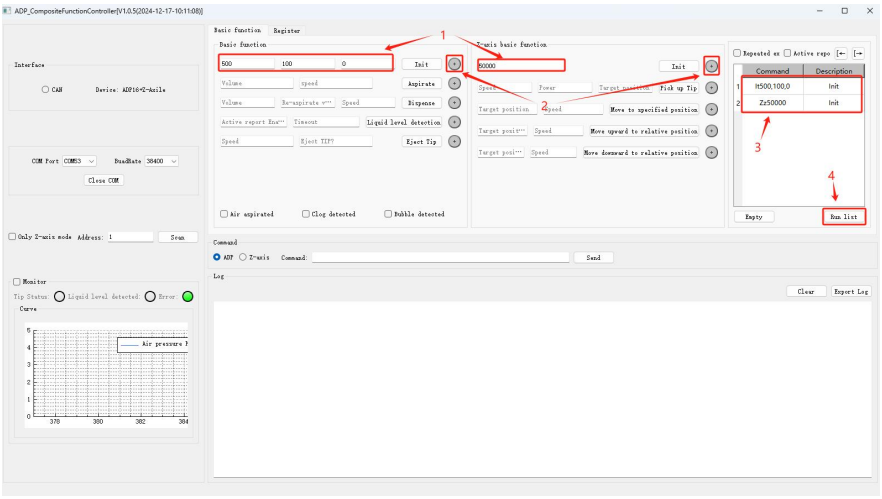
5.4 Single-Step Command Execution

1. Click "Monitor" to monitor real-time device statuses, including TIP pick-up status, liquid level detection status, error, pressure sensor ADC values
2. Fill in the initialization parameters and click "Zero" to initialization the ADP.
3. If the command executes successfully, the device will perform the initialization process normally.



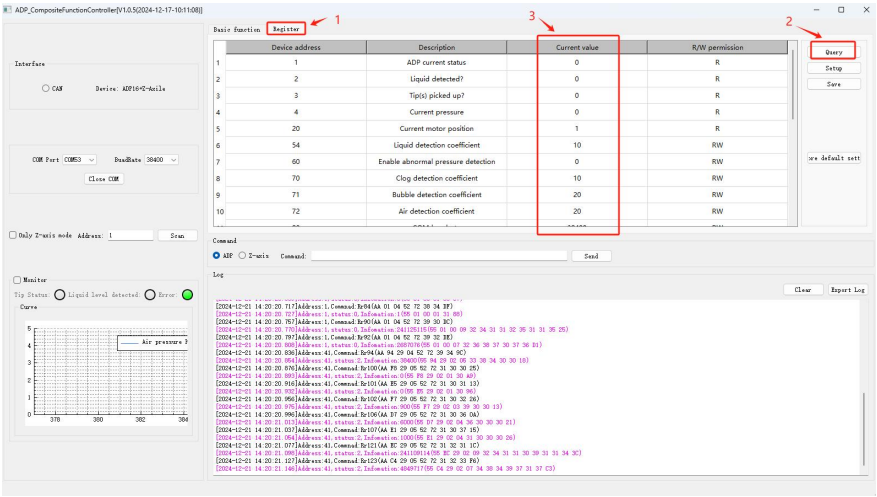
5.5 Command Set Execution

1. Configure the parameters for both the ADP and the Axis-Z.
2. Click "+" to add the commands to the combined command list.
3. The command list will display the added commands; double-click to modify them if necessary.
4. Click "Run List", and the host computer will sequentially send the commands. It will execute the next command after confirming the current one has completed.



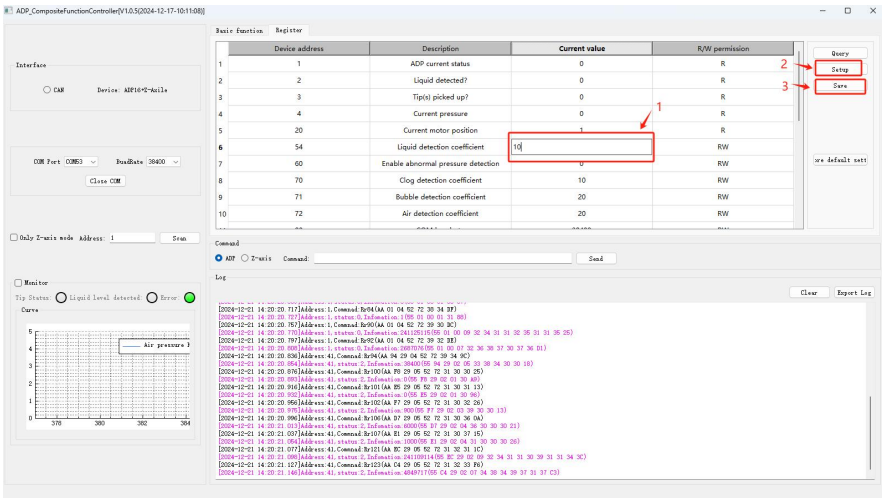
5.6 Register Query

1. Click "Register" button to switch to the register settings page.
2. Click "Query" to sequentially read the device registers.
3. The current register values will be displayed in the "Current Value" field.



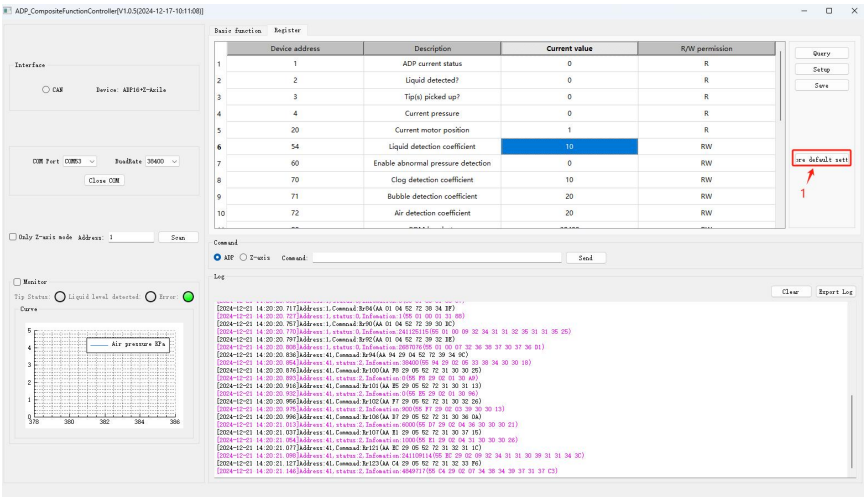
5.7 Register Parameter Setting

1. At the current value column of the register parameter page that needs to be modified (only writable ones can be modified), fill in the modified value, press the Enter key or click other blank areas.
2. Click "Setup" to save the modified register value.
3. Click "Save" button to set and save these parameters after power off.
4. Power down the device and restart. The PC debug software needs to reopen the serial port after power on.



5.8 Restore Factory Settings

1. Click "Restore default Settings" to reset all register values to their factory defaults.
2. Power down the device and restart. The PC debug software needs to reopen the serial port after power on.



6 Applications

6.1 Application Process

The basic liquid aspiration and dispense application typically includes single aspiration with single dispense or single aspiration with aliquot-dispense. **Figure 6-1 Aspiration and Dispense** illustrates a common single aspiration and single dispense workflow. Recommended communication framework and sample data are provided in section 8.4.

Note:

1. By default, both single aspirate single dispense and single aspirate aliquot dispense are no-contact dispense.
2. TIP detection: Enable this feature via Register 43. Aspiration commands cannot be executed without a TIP.
3. Clot detection: Reference Register 60 for pressure anomaly detection.
4. Liquid level detection delay: Delay liquid level detection by 500ms after the Axis-Z descends to avoid disturbances from Axis-Z moving.
5. Liquid level detection velocity: Maintain a speed of 20mm/s of Axis-Z to ensure the TIP does not submerge more than 3mm.
6. Aspiration delay: 100ms delay before leaving the reagent after aspirating, can improve liquid handling accuracy and CV in the application of micro-dispense.
7. Leading air gap: reduce the reagent residue in the TIP after dispense.
8. Trailing Air Gap: avoiding liquid spillage or dropping.
9. Leading Air Gap/Trailing Air Gap: For a nominal volume of 1000uL, allow an additional 40uL for aspiration of air. Total aspiration volume must not exceed 1040uL. Adjust volumes as needed within this limit.
10. aliquot-dispense data: Avoid using the first and last dispense results for accuracy; dispense these to the original reagent container or waste bin.
11. aliquot-dispense parameters: Adjust re-aspiration volume and cut-off velocity for better performance (see section 6.8).
12. Single dispense data: Default values for re-aspiration volume and cut-off velocity are recommended.
13. Dispense: When dispensing, make sure the end of the TIP is inside the container to prevent splashing.

When performing aspiration of liquid, the aspiration volume must not exceed the picked up TIP volume.

14. TIP limitations: Do not exceed the volume capacity of the picked up TIP during aspiration. For example, a 200uL TIP can not aspirate more than 200uL.
15. Error handling:
    - If TIP pickup fails, send a "eject TIP" command to prevent a stuck TIP

before retrying at another TIP position.

- During liquid level detection, set a lower limit to avoid bottoming out. For multi-channel applications,if the same liquid level for all channel, ensure consistent liquid levels for all channels to avoid premature detection triggers.

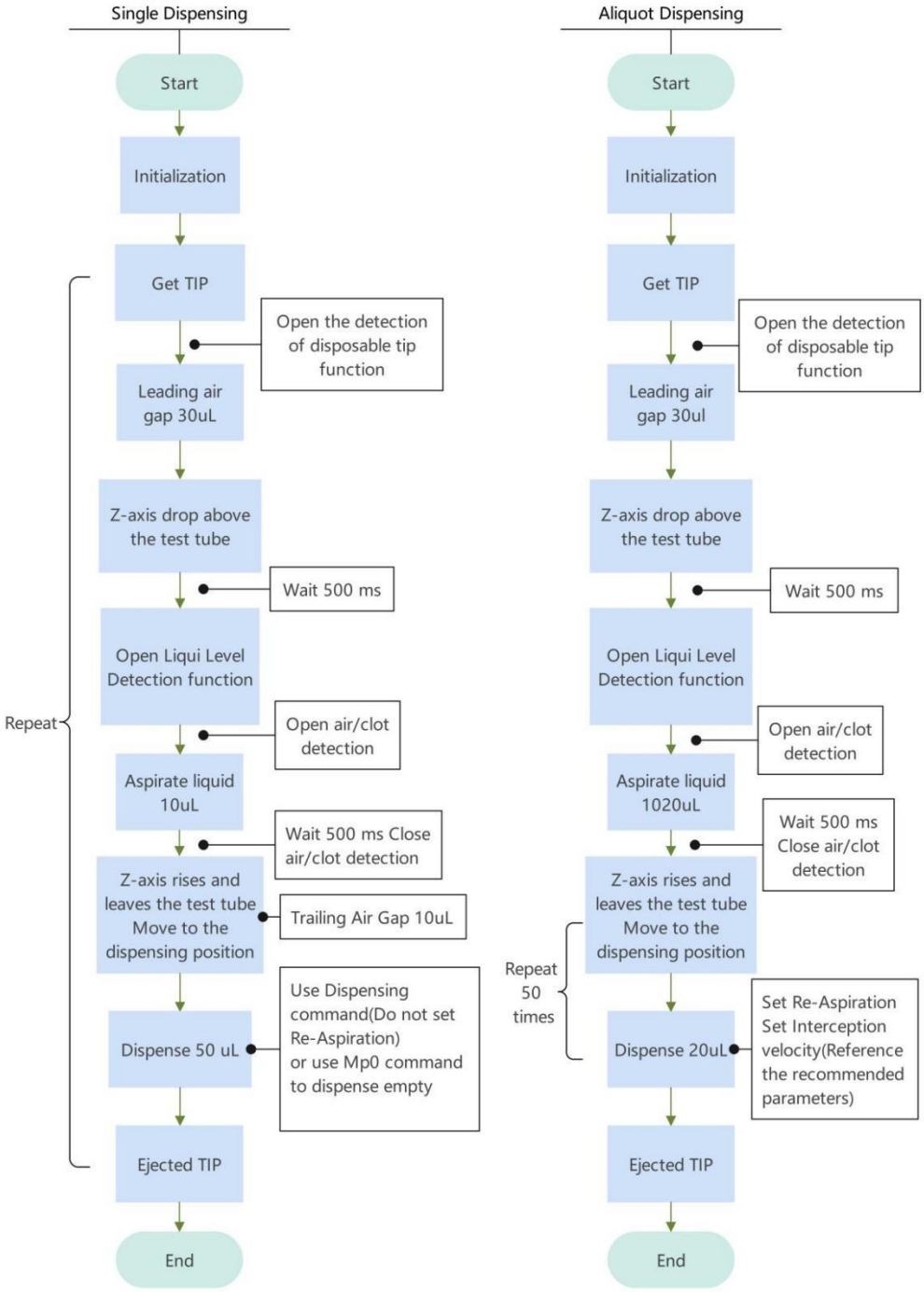


Figure 6-1 Aspiration and Dispense process

6.2 Pick up TIP

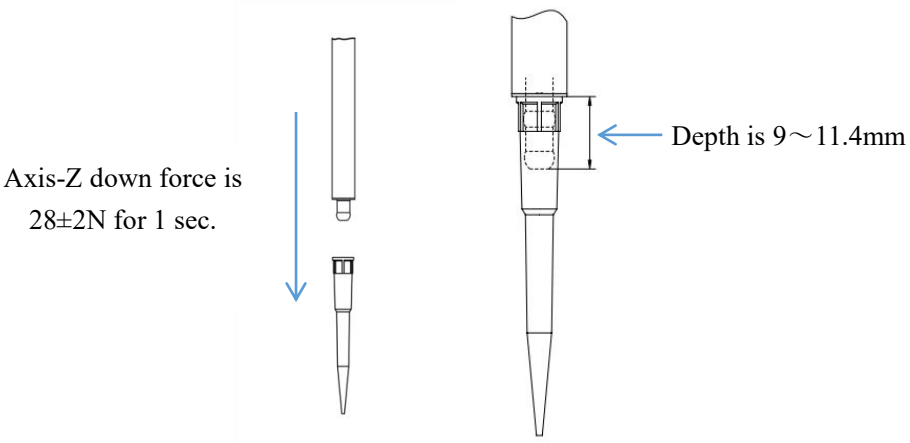


Figure 6-2 TIP Pickup Diagram

When the SP16 pipettor probe is positioned directly above the TIP, use Keyto Axis-Z TIP Pickup command to automatically apply the appropriate down force. When controlling the SP16 and customer Axis-Z for TIP pickup, we recommend starting with a inserting depth of 9 mm. Ensure the TIP is securely picked up after lifting and meets leakage requirements. The maximum inserting depth should not exceed 11.4 mm. The recommended down force is 28±2N for 1 second.

Convenient Leakage Testing Method: At room temperature, in the SP16 standby state, pick up a non-conductive, clean, 1000uL TIP with filter. Aspirate 1000uL of pure water, lift the TIP above the liquid level, and leave it static for one minute. If liquid leaks from the TIP, increase the inserting depth appropriately.

1. *Ensure correct TIP installation by applying a down force of 28 ±2 N for 1 second.*
2. *Insufficient down force may cause the TIP to fall off during moving, while excessive down force may result in TIP ejection failure or permanent damage to the SP16.*

6.3 Liquid Level Detection

Move down the SP16 rapidly until the end of TIP is located 15～20mm above the mouth of the test tube, then setting the speed becomes ≤20mm/s. The liquid level detection is started after 500 ms, and the liquid level detection status is obtained by query the GP01 signal or register 2. See **Table 10-12 Register**: Registers 2 and 10 for details.

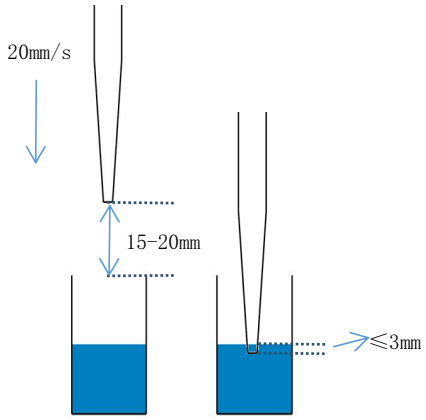


Figure 6-3 Liquid Level Detection Diagram

Start the liquid detection function by sending the Ld command through the serial port or using the KT_CAN_DIC protocol (Index 0x4007). Once activated, the SP16 will monitor pressure changes in real-time. Upon detecting a change, it will alert the customer controller through multiple signals.

Recommended process for liquid level detection: Position the SP16 with the loaded TIP 15～20 mm above the reagent container’s top surface. Delay 500ms and send the liquid detection command while continuing to lower. Stop the Axis-Z upon receiving a triggered liquid detection signal that lasts 1 ms (to filter interference) or a liquid detection command. Please refer to 8.4.3 or **错误！未定义书签。** for application examples.

Notes:

1. The liquid detection response time is approximately 20ms. Keep the Axis-Z descent speed below 20mm/s during detection.
2. Ensure the TIP is free of debris (including residual reagents), as debris may cause abnormal detection.
3. Factory parameters are preset for specific TIP models. If the liquid level detection is triggered before contacting the liquid level, the liquid level detection coefficient will be increased appropriately, and if the detection is deeper, the liquid level detection coefficient will be reduced appropriately, and the liquid level detection coefficients can be found in Table 10-12 register 54.

6.4 Mixing Process

Perform mixing using SP16 by executing aspiration and dispense cycles:

1. Cycle:Aspiration→Mp0 Dispense→Aspiration→Mp0 Dispense→...
2. Use the Mp0 absolute position move command for consistent dispense positions.
3. Do not reuse the TIP for mixing, otherwise the accumulated liquid film may be sucked into the pipetting barrel and maybe damage the SP16.

For practical examples, refer to Sections 8.4.3 or **错误！未定义书签。**.

6.5 Aspiration and Dispense Liquid Following

The SP16 used with Keyto Axis-Z, supports liquid following, refer to **Figure 6-4 Aspiration and Dispense Liquid Level Following Diagram** . For practical applications, see Sections 8.4.3 or **错误！未定义书签。**.

Aspiration and dispense TIP following: Automatically calculates Axis-Z descent speed and height based on aspiration volume and liquid level cross-sectional area.

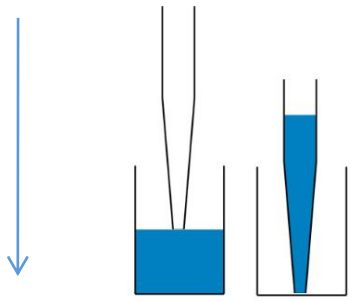


Figure 6-4 Aspiration and Dispense Liquid Level Following Diagram

6.6 Anti-droplet Control

The anti-droplet control prevents reagent leakage during the handling of organic solvents. Consider the following:

- Activate the anti-droplet control only after the end of TIP leaves the liquid surface. Any aspiration or dispense command stops the function. If reagent remains in the TIP after dispense, the anti-droplet control needs to be reactivated.
- **This function affects pipetting accuracy and is not recommended if the reagent is not prone to dripping (e.g., water-like).**
- During the execution of this command (means that enabling anti-droplet control without a subsequent disable command or without completing actions like aspiration or dispense that stop the anti-droplet execution), the pipettor will monitor pressure fluctuations. Therefore, the TIP must not be manually removed during this period. If a second reagent needs to be aspirated after aspirating the first reagent and enabling anti-droplet control, please disable the anti-droplet control before aspirating the second reagent.
- For reagents with excessively strong polarity, it is recommended to aspirate an additional 2～10uL of air after leaving the liquid surface, and then enable the anti-droplet control.

6.7 Pipetting Abnormality Detection

The SP16 uses a pressure sensor to monitor internal pipetting barrel pressure, enabling real-time detection of anomalies such as clots, foam, or aspiration of empty. By default, this feature is disabled. Enable it by configuring Register 60, each bit corresponds to a function, the corresponding bit to write 1 to enable, write 0 to disable. Ensure proper conversion from hexadecimal to decimal when configuring values. For example, to enable foam and clot detection, write 3 (0x03)

to Register 60.

Register	Description
60	Pressure Abnormality Detection Enable,HEX code, the corresponding bit is 1 to enable the function: Bit 0: Clot detection (minimum volume: 10uL) Bit 1: foam detection (minimum volume: 20uL) Bit 2: empty detection (minimum volume: 10uL)

Note: The pipettor will only detect pipetting anomalies if the pipettor volume is not less than the specified volume, because the pipettor volume is too small for the air pressure to change significantly. If there is a reagent in the TIP to aspirate the liquid, the aspiration of empty/foam detection are unreliable at this time. If users need to perform aspiration of air before normal aspiration and dispense of liquid, please set register 60 to turn off the pressure abnormal detection to prevent error reporting, and then turn on the pressure abnormal detection during normal aspiration and dispense of liquid, please refer to sections 8.4.3 and **错误！未定义书签。** for application examples.

6.8 Aspiration and Dispense Parameters

6.8.1 Aspiration and dispense velocity

Follow the basic principle of "slow aspiration, fast dispense" during liquid handling. The viscosity of the reagent and the TIP type may affect the velocity. The reference relationship between aspiration volume and aspiration velocity is shown in **Table 6-1 Recommended aspirate velocity**:

Table 6-1 Recommended aspirate velocity

When performing single aspiration and single dispense, set a reasonable dispense velocity to ensure complete dispense of the reagent and to avoid splashing. Recommended dispense volumes and speeds are shown in **Table 6-2 Recommended Dispense**. For single aspiration and single dispense, you can set the same cut-off velocity.

Table 6-2 Recommended Dispense velocity

TIP Type	50uL TIP		200uL TIP		1000uL TIP	
Dispensing Volume (uL)	5	10	50	100	500	1000
re-aspiration Volume(uL)	0	0	0	0	0	0
Dispense velocity(uL/s)	400	400	500	500	700	700
cut-off velocity(uL/s)	10					

6.8.2 re-aspiration volume

In single aspiration and aliquot-dispense, the re-aspiration volume can be adjusted according to Table 6-3 .

Table 6-3 Re-aspirate parameter reference for aliquot dispense

Dispense volume / TIP / Aspiration volume	5～10ul	10～20ul	20～100ul
50uL	≥5uL	/	/
200uL	≥2uL	≥4uL	/
1000uL	/	≥2uL	≥4uL
Dispense cut-off velocity	10～100uL/s (less than dispense velocity)		

6.8.3 Recommended aspiration and dispense parameters

The following data is based on pure water. When the dispensing accuracy and CV meet the SP16 series pipettor's performance requirements, the recommended parameters for each test are shown below:

Table 6-4 Recommended Parameters for Pure Water

TIP type	Single/aliquot dispense	dispense Volume (uL)	Leading Air Gap (0.01uL)	Aspiration Volume (0.01uL)	Aspiration velocity (uL/s)	Dispense Volume (0.01uL)	re-aspiration Volume (0.01uL)	Dispense velocity (uL/s)	Dispense Cutoff Velocity (uL/s)
10	Single dispense	1	3000	190	20	3190	0	700	100
50 Filter	Single dispense	2	3000	260	200	3200	0	400	0
50 Filter	Single dispense	5	3000	570	200	3500	0	400	0
50	Single dispense	10	2000	1000	200	3000	0	700	10
200 Filter	Single dispense	10	2000	1100	200	3000	0	700	10
200	Single dispense	50	2000	5000	200	7000	0	700	100
1000	Single dispense	10	2000	1000	200	3000	0	700	10
1000	Single dispense	1000	1000	101000	200	102000	0	700	10
200	aliquot-dispense	10	2000	21000	200	1000	200	400	50
1000	aliquot-dispense	5	1000	101000	200	500	2000	900	0
1000	aliquot-dispense	50	1000	101000	200	5000	500	700	0
1000 Filter	aliquot-dispense	20	2000	101000	200	2000	250	900	10

Other reagent parameter descriptions:

Table 6-5 Other Reagent Operation

Reagents	Viscosity	Aspiration Volume	Aspiration velocity	Dispense velocity	Number of Dispense	Remarks
Glycerol (100%)	viscous	Less than 1/2 TIP volume	Less than 50uL/s	Less than 300uL/s	No less than three times	Aspirate and wait for stabilization before leaving the liquid surface
Liquid paraffin	viscous	Less than 1/2 TIP volume	Less than 50uL/s	Less than 30uL/s	No less than three times	Aspirate and wait for stabilization before leaving the liquid surface
Anhydrous ethanol	low viscosity	/	/	/	/	Refer to pure water
Dimethyl sulfoxide	viscous	/	/	/	/	Refer to pure water
Bovine serum protein	viscous	/	/	/	two times	
Transparent liquid sodium silicate	viscous	/	/	/	two times	

Other reagent accuracy test results:

Table 6-6 CV of Other Reagents

Reagent	TIP Type	Dispense type	Target Aspirate (uL)	Target Dispense (uL)	Aspiration velocity (uL/s)	Dispense velocity (uL/s)	CV (%)
Glycerin for medical use	50 Filter	Single dispense	5	5	50	30	1.56
	50	Single dispense	10	10	50	30	1.63
	1000	Single dispense	10	10	50	30	1.04
Transparent liquid sodium silicate	50 Filter	Single dispense	5	5	50	50/200	1.83
	50	Single dispense	10	10	100	50/200	0.93
	1000	Single dispense	10	10	100	50/200	1.95
Liquid paraffin	50 Filter	Single dispense	5	5	200	700	2

Reagent	TIP Type	Dispense type	Target Aspirate (uL)	Target Dispense (uL)	Aspiration velocity (uL/s)	Dispense velocity (uL/s)	CV (%)
	50	Single dispense	10	10	200	30/260	1.16
	1000	Single dispense	10	10	200	30/30	2.94
Ethanol absolute	50 Filter	Single dispense	5	5	200	200	1.74
	50	Single dispense	10	10	200	200	1.65
	1000	Single dispense	10	10	100	200	0.86
DMSO	50 Filtered	Single dispense	5	5	200	100	1.58
	50	Single dispense	10	10	200	100	1.17
	1000	Single dispense	10	10	100	100	1.19
BSA	50 Filtered	Single dispense	5	5	200	300	1.81
	50	Single dispense	10	10	100	300	1.02
	1000	Single dispense	10	10	100	500	3.04
Ethyl acetate	1000	Aliquot dispense	1000	50	200	700	0.81
	1000	Aliquot dispense	1000	100	200	700	1.3

6.9 Accuracy and CV testing and compensation

6.9.1 Accuracy and CV testing

1. Preparation Before Testing

When performing the accuracy and CV tests, please note the following preparations:

Avoid placing the balance or performing accuracy and CV tests in the following environments: The environment with direct sunlight, severe temperature fluctuations, strong air convection, or vibration.

Preparation materials: 0.1mg or 0.01mg scale interval balance, TIP, 1mL plastic centrifuge tubes, rubber gloves, pure water.

2. Single Dispensing Process

During testing, operators are required to wear a lab coat and rubber gloves to maintain a stable environment.

3. Balance Leveling and Zeroing

Follow the balance manual to level and zero the balance.

4. Weighing Empty Centrifuge Tubes

Prepare 10 centrifuge tubes and record the weight and serial port number of each empty tube.

5. Initialization the Pipettor, TIP Installation, and Aspiration of Air

Before each test, initialize the pipettor and replace with a new TIP. Discard data if the TIP is deformed or contaminated. Perform aspiration of 30uL air before aspirating liquid to ensure complete dispensing of the reagent inside the TIP.

6. Single Dispensing Operation

Lower the pipettor until the TIP is ≤ 3mm below the liquid level.

Send an aspiration command; after aspiration, wait (refer to viscosity-related delays) before raising the pipettor.

Dispense the liquid with the volume: 30uL (air) + liquid volume. Keep the TIP edge near the centrifuge tube to prevent splashing.

7. Weighing the Reagent in Centrifuge Tubes

Repeat steps 5～6 ten times. Record the weight of each filled tube and calculate the reagent weight by subtracting the empty tube weight.

8. Factors Affecting Accuracy and CV

Accuracy and CV testing are affected by a number of factors, the main ones being:

- For aspiration and dispense parameters, refer to the 6.8.3 section.
- Reagent temperature, which affects the aspiration volume.
- Reagent density, which affects the dispense volume.
- TIP submerge depth, causing liquid to hang on the outer wall of the TIP affects the accuracy and CV of the dispense.
- Aspiration volume, which affects dispense accuracy and CV.
- Whether or not to use the liquid level detection function, which affects the TIP submerge depth.
- The delay time after aspiration and the speed when leaving the liquid level.

6.9.2 Accuracy compensation

For higher precision, perform aspiration calibration for single aspiration and single dispensing operations. Aliquot-dispensing operations typically do not require calibration. Segmental calibration is recommended for different aspiration volumes and TIP types.

1. Determine calibration points. For small volumes, use more points; for large volumes, fewer points are sufficient, we recommend no less than 5 calibration points, you can use different volumes of TIP to calibrate 5 or more points, or you can calibrate 5 or more points per each of the different volumes of TIP separately. Here we use 50uL and 1000uL TIP to calibrate the full stroke.

Table 6-7 Calibration Points

Calibration point/uL	50uL TIP	1000uL TIP
	5	50

	8	200
	10	500
	20	700
	50	1000

2. Measure dispensing accuracy at each point ten times and calculate the average. Compensate based on the deviation. For example, if the average at the 1000uL point is 990uL, adjust the aspiration volume to 1010uL.

3. Adjust linearly for precise compensation, as theoretical and measured values follow a linear trend.

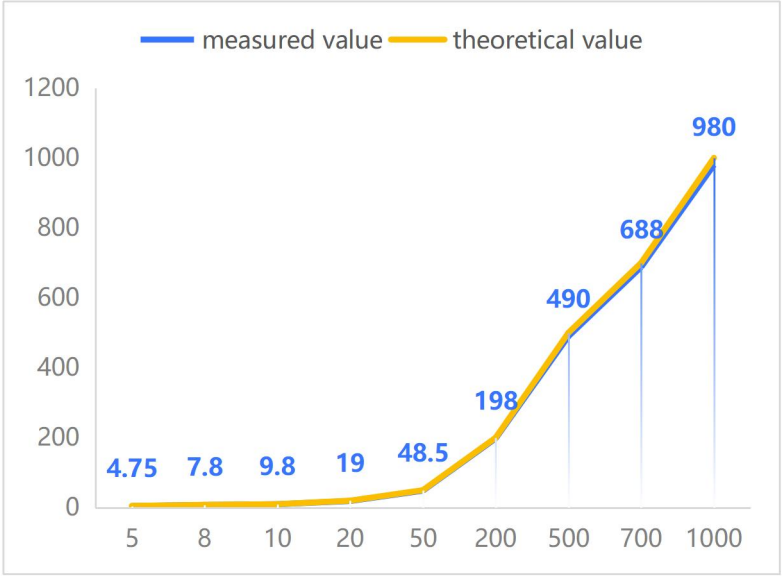


Figure 6-5 Comparison of Theoretical and Measured Aspiration Values

7 Communication Protocol

7.1 Communication Method

7.1.1 Communication interface

The following methods are supported for communicating with the SP16:

- RS232
- RS485
- CAN

Baud rate:

Serial Port port:9600,19200,38400(default),115200.**8 data bits,no parity,1 stop bit.**

CAN:100K,125K,250K,500K(default),1000K.

7.1.2 Protocols

SP16 supports serial port and CAN communication. The serial port communication includes RS232 and RS485, which share the same protocol.

- KT_CAN_DIC Protocol (Recommended)
- KT_OEM Protocol (Recommended)
- KT_DT Protocol

KT_CAN_DIC Protocol (Recommended)

This communication protocol is used for LAN-based CAN communication. It operates by reading and writing the CAN dictionary to control and configure SP16. The SP16 automatically uploads its status upon changes, eliminating the need for polling. See Section 7.2 for details.

KT_OEM Protocol (Recommended)

This protocol is based on RS232 and RS485 communication. It includes a communication sequence number and a checksum byte, effectively preventing data loss. Users can poll SP16’s status during operation and parse responses to determine if a command was successfully executed or if errors occurred. See Section 7.3 for details.

KT_DT Protocol

This protocol is also based on RS232 and RS485 communication but does not include a checksum. ASCII strings are used for data transfer, making it easier to debug via serial port debugging tools. However, the lack of checksum increases the risk of data loss. See Section 7.4 for details.

7.2 KT_CAN_DIC Protocol Format

KT_CAN_DIC message type is an Extended frame, comprising a frame ID and a Data Area.

Frame Type: Data frame.

Message Identifier Type: Extended frame.

Frame ID: Uses extended ID (see **Table 7-1 KT_CAN_DIC Message ID Area Format**).

DLC: Fixed data length of 8.

Data Area: Fixed 8 bytes, including communication sequence number and register address (see **Table 7-2 KT_CAN_DIC Message Data Area Format**).

Frame ID Data Format:

Table 7-1 KT_CAN_DIC Message ID Area Format

	Bit28～16	bit15～8	bit7～0
Send	Command	Source address	Destination address
Response	0x0000	Destination address	Source address

Source address: The address of the Host.

Destination address: The address of the SP16.

Frame ID Command:

see **Table 7-3 KT_CAN_DIC ID Command:**

Table 7-2 KT_CAN_DIC ID Command

Command	Function	Description
0x0000	Response	Response for reading and writing
0x0001	Write	Write object dictionary Return value: status, refer to Table 10-1 Status
0x0002	Read	Read object dictionary; if there is no corresponding object dictionary, no data is returned.
0x0003	Process Data	Used for uploading real time data which does not require an answer, e.g. status change active uploading send should via this commands
0x0004	Heartbeat	Timely uploaded heartbeat data; can be used to check device online status. The data uploaded in the heartbeat is node status; status information can be found in the Status Table
0x0080	Warning	The device will automatically report the commands if error occurs, the error information is shown in the Table 10-1 Status

Data Area Format:

Table 7-3 KT_CAN_DIC Message Data Area Format

	byte0	byte1～2	byte3	byte4～7
Send/response	Sequence number	Object Index	Object sub-index	4 bytes of data

Data Field Components:

1. Sequence Number: Distinguishes each frame of sent and received data. The sequence number of sent and received frames must match. Increment the sequence number by 1 for each frame.
2. Object Index: A 16-bit index defining the KT_CAN_DIC dictionary Table. See **Table 9-1 KT_CAN_DIC Control Command**.
3. Object Sub Index: An 8-bit sub-index used with the index to define the KT_CAN_DIC dictionary.

Each control command has a unique index and multiple sub-index. Non-zero sub-index frames are sent first, and the zero sub-index frame is sent last. The SP16 starts operating upon receiving the zero sub-index frame.

4. Data: A data length of 32 bits represents the communication data, which is a signed integer, see section 9.1 for more details.

7.3 KT_OEM Protocol Format

KT_OEM protocol is based on RS232 or RS485 communication, and the Fields are consistent with KT_DT protocol. the protocol contains a checksum field, which is able to effectively identify abnormal commands, and the protocol fields contain sequence number, which can simplify the handling of communication exceptions, so when using serial port communication, it is recommended to use the KT_OEM protocol to communicate with the SP16. the SP16 parses the string in real time, verifies whether the address matches the checksum and the protocol format is correct, and immediately returns the status of executing the command. During working, the SP16 status can be obtained by sending the query status command to confirm whether the execution of the command is completed or there is an error.

Table 7-4 KT_OEM Protocol Sending Format

Field	Type	Number of bytes	Description
Frame Header	Uint8	1	Fixed value 0xAA, indicating start of command.
Sequence number	Uint8	1	Command sequence number (0x80～0xFF),if the sequence number of the current command is the same as the sequence number of the previous command, the current command will not executed, but will respond with the same response as the previous command.
Address	Uint8	1	Target communication address, each pipettor on the bus should be set to a unique address number in the range 1～32. Communication will only occur when the address matches, otherwise, the received command will be ignored.
Data Length	Uint8	1	Length of the Data area Field.
Data area	Byte	n	ASCII command strings, see section 10.3 for details.
Checksum	Uint8	1	An 8-bit checksum is calculated from the frame header to the end byte of the data area. The value obtained takes the last 8 bits of data.

Table 7-5 KT_OEM Protocol Response Format

Field	Type	Number of Bytes	Description

Frame Header	Uint8	1	Fixed value 0x55, indicates the start of response.
Sequence number	Uint8	1	Consistent with the received command sequence number. If the send command sequence number is omitted, this sequence number is also omitted.
Address	Uint8	1	Communication address, each pipettor on each bus should be set to a unique address number, which is the original address of the device when returning data.
Status	Uint8	1	Current pipettor status, see Table 10-1 .
Data Length	Uint8	1	Data area length, when the data length is 0 , the data field data is empty.
Data Area	Byte	n	ASCII code return data, if data length is 0, there is no this field.
Checksum	Uint8	1	An 8-bit checksum is calculated from the frame header to the end byte of the data area. The value obtained takes the last 8 bits of data.

7.4 KT_DT Protocol Format

The KT_DT protocol processes ASCII strings for commands and verifies address and syntax. Status of the first command in the string is returned.

Table 7-6 KT_DT Protocol Sending Format

Field	Type	Number of bytes	Description
Address	Byte	1～2	The target communication address, each SP16 on each bus should be set to a unique address number, taking values from 1 to 32. It will communicate properly when the addresses match, otherwise it will ignore the received commands
Direction	Byte	1	Fixed to the character ' > ' (0x3E), means from Host to Device
Data area	Byte	n	ASCII command strings, see section 10.3 for details.
End character	Byte	1	Fixed to Carriage Return(0x0D), indicates the end.

Table 7-7 KT_DT Protocol Response Format

Field	Type	Number of bytes	Description
Address	Byte	1～2	The device address that response to the command, with a value range of 1～32 in ASCII character format, must match the command address
Direction	Byte	1	‘<’ (0x3C), means from the Device to Host
Status	Byte	2	See status Table 10-1
‘:’	Byte	1	':' if no return data this symbol is not displayed

Data area	Byte	n	Response string, see the corresponding return data in section 10.3
End character	Byte	1	Fixed to Carriage Return(0x0D), indicates the end.

8 Communication Process

Note that when using serial port communication, KT_DT protocol has no data verification, so it is recommended to be used only for debugging. For the machine integrating SP16, please use KT_OEM protocol. The data format of KT_OEM protocol and KT_DT protocol data area is the same, but the data format of frame header and frame tail is different. When using KT_OEM protocol, the status should be queried for each step of operation to ensure that the command is executed before executing the next step. In the following example, the SP16 address is 1.

8.1 Examples of KT_CAN_DIC Protocol

Refer to Section 9.1, where each control command has a unique index and multiple sub-index. Non-zero sub-index frames are sent first, followed by the zero sub-index frame. The SP16 begins operating once receiving the zero sub-index frame.

Table 8-1 Examples of KT_CAN_DIC Protocol

Function	Direction	ID(HEX)	Data(HEX)	Description
Initialization	Send	0001 00 01	01 4000 01 00000064	ID: 0001: write command; 00: source address; 01: destination device address; Data: 01: communication sequence number; 4000: index (Initialization control); 01: sub-index (initialization power setting); 00000064: data (initialization power setting to 100%).
	Response	0000 01 00	01 4000 01 00000002	ID: 0000 Response; 01: Response device address; 00: Host address; Data: 01: communication sequence number (same as send command sequence number); 4000: index; 01: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Resend	0001 00 01	02 4000 02 00000000	ID: 0001: write command; 00: source address; 01: destination device address; Data: 02: communication sequence number; 4000: index (initialization control); 02: sub-index (initialization TIP mode setting); 00000000: data (initialization power will eject TIP whether TIP is detected or not).
	Response	0000 01 00	02 4000 02 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 02: communication sequence number (same as send command sequence number); 4000: index; 02: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Final send	0001 00 01	03 4000 00 000001F4	ID: 0001: write command; 00: source address; 01: destination device address; Data: 03: communication sequence number; 4000: index (initialization control); 00: sub-index (initialization velocity setting); 000001F4: data (initialization velocity setting to 500uL/s).
	Response	0000 01 00	03 4000 00 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 03: communication sequence number (same as send command sequence number); 4000: index; 02: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
Liquid Level Detection	Send	0001 00 01	04 4007 01 00001388	ID: 0001: write command; 00: source address; 01: destination device address; Data: 04: communication sequence number; 4007: index (liquid level detection); 01: sub-index (liquid level detection timeout time setting); 00001388: data (liquid level detection timeout setting to 5000ms).
	Respons	0000	04 4007 01	ID: 0000: response; 01: response device address; 00: Host address;

Function	Direction	ID(HEX)	Data(HEX)	Description
	e	01 00	00000002	Data: 04: communication sequence number (consistent with send command sequence number); 4007: index; 01: sub-index; 00000002: status (command execution successful, other see Table 10-1).
	Resend	0001 00 01	05 4007 00 00000001	ID: 0001: write command; 00: source address; 01: destination device address; Data: 05: communication sequence number; 4007: index (liquid level detection); 00: sub-index (liquid level detection data reporting type setting); 00000001: data (liquid level detected and automatically reported).
	Response	0000 01 00	05 4007 00 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 05: communication sequence number (same as send command sequence number); 4007: index; 00: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Responses when liquid level is detected	0003 01 00	E2 7000 00 00000003	ID: 0003: process data; 01: Response device address; 00: Host address; Data: E2: process sequence number; 7000: index (liquid level detected); 00: sub-index; 00000003: status (liquid level detected).
	Response if timeout	0080 01 00	E9 0000 00 00000016	ID: 0080: warning data; 01: response device address; 00: Host address; Data: E9: process sequence number; 0000: index; 00: sub-index; 00000016: status (timeout error).
Aspiration	Send	0001 00 01	06 4001 01 000000C8	ID: 0001: write command; 00: source address; 01: destination device address; Data: 06: communication sequence number; 4001: index (aspiration); 01: sub-index (aspiration velocity setting); 000000C8: data (aspiration velocity 200uL/s).
	Response	0000 01 00	06 4001 01 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 06: communication sequence number (same as send command sequence number); 4001: index; 01: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Resend	0001 00 01	07 4001 02 0000000A	ID: 0001: write command; 00: source address; 01: destination device address; Data: 07: communication sequence number; 4001: index (aspiration); 02: sub-index (aspiration cut-off velocity setting); 0000000A: data (aspiration cut-off velocity set to 10uL/s).
	Response	0000 01 00	07 4001 02 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 07: communication sequence number (same as send command sequence number); 4001: index; 02: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Final send	0001 00 01	08 4001 00 00002710	ID: 0001: write command; 00: source address; 01: destination device address; Data: 08: communication sequence number; 4001: index (aspirated liquid); 00: sub-index (aspirated liquid volume setting); 00002710: data (aspirated liquid 100uL).
	Response	0000 01 00	08 4001 00 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 08: communication sequence number (same as send command sequence number); 4001: index; 00: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
Dispense	Send	0001 00 01	09 4002 01 000001F4	ID: 0001: write command; 00: source address; 01: destination device address; Data: 09: communication sequence number; 4002: index (dispense); 01: sub-index (re-aspirate volume setting); 000001F4: data (re-aspirate volume set to 5uL).
	Response	0000 01 00	09 4002 01 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 09: communication sequence number (same as send command

Function	Direction	ID(HEX)	Data(HEX)	Description
				sequence number); 4002: index; 01: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Resend	0001 00 01	0A 4002 02 000003E8	ID: 0001: write command; 00: source address; 01: destination device address; Data: 0A: communication sequence number; 4002: index (dispense); 02: sub-index (dispense velocity setting); 000003E8: data (dispense velocity set to 1000uL/s).
	Response	0000 01 00	0a 4002 02 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 0A: communication sequence number (same as send command sequence number); 4002: index; 02: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Resend	0001 00 01	0B 4002 03 0000000A	ID: 0001: write command; 00: source address; 01: destination device address; Data: 0B: communication sequence number; 4002: index (dispense); 03: sub-index (dispense cut-off velocity setting); 0000000A: data (dispense cut-off velocity set to 10uL/s).
	Response	0000 01 00	0B 4002 03 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 0B: communication sequence number (same as send command sequence number); 4002: index; 03:sub-index; 00000002: status (command executed successfully, other see Table 10-1).
	Final send	0001 00 01	0C 4002 00 000003E8	ID: 0001: write command; 00: source address; 01: destination device address; Data: 0C: communication sequence number; 4002: index (dispense); 00: sub-index (dispense volume setting); 000003E8: data (dispense 10uL).
	Response	0000 01 00	0C 4002 00 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 0C: communication sequence number (same as send command sequence number); 4002: index; 00: sub-index; 00000002: status (command executed successfully, other see Table 10-1).
Read register	Send	0002 00 01	0D 2000 01 00000000	ID: 0002: read command; 00: source address; 01: destination device address; Data: 0D: communication sequence number; 2000: index (register operation); 01: sub-index (current status register, see Table 10-12); 00000000: data.
	Response	0000 01 00	0D 2000 01 00000000	ID: 0000: response; 01: response device address; 00: Host address; Data: 0D: communication sequence number (same as send command sequence number); 2000: index; 01: sub-index; 00000000: data (idle state, other see Table 10-1).
	Send	0002 00 01	0E 2000 02 00000000	ID: 0002: read command; 00: source address; 01: destination device address; Data: 0E: communication sequence number; 2000: index (register operation); 02: sub-index (Liquid Level Detection status register, see Table 10-12); 00000000: data.
	Response	0000 01 00	0E 2000 02 00000001	ID: 0000: response; 01: response device address; 00: Host address; Data: 0E: communication sequence number (same as send command sequence number); 2000: index; 02: sub-index; 00000001: data (liquid level is detected, if 00000000 then liquid level is not detected).
Write register	Send	0001 00 01	0F 2000 36 0000000A	ID: 0001: write command; 00: source address; 01: destination device address; Data: 0F: communication sequence number; 2000: index (register operation); 36: sub-index (liquid level detection coefficient, see Table 10-12); 0000000A: data (set liquid level detection coefficient to 10).
	Response	0000 01 00	0F 2000 36 00000002	ID: 0000: response; 01: response device address; 00: Host address; Data: 0F: communication sequence number (same as send command sequence number); 2000: index; 36: sub-index; 00000002: data (setup

Function	Direction	ID(HEX)	Data(HEX)	Description
				successful, other see Table 10-1).

8.2 Example of KT_OEM Protocol(HEX Mode)

Note: KT_OEM protocol is a encapsulation of KT_DT protocol. For the description of command string and return string, see section 10.3.

Table 8-2 Example of a single command of OEM protocol

Function	Direction	Data(HEX)	Description
Initialization	Send	AA 01 0B 49 74 35 30 30 2C 31 30 30 30 2C 30 21	AA: frame header; 01: destination device address; 0B: command string length; 49 74 35 30 30 2C 31 30 30 30 2C 30: string command "It500,100,0"; 21: frame end checksum.
	Response	55 01 02 00 58	55: frame header; 01: destination device address; 02: command execution success status (other see Table 10-1); 00: return string length; 58: frame end checksum.
Liquid Level Detection	Send	AA 01 08 4C 64 31 2C 35 30 30 30 85	AA: frame header; 01: destination device address; 08: command string length; 4C 64 31 2C 35 30 30 30 30: string command "Ld1,5000"; 85: frame end checksum.
	Response	55 01 02 00 58	55: frame header; 01: destination device address; 02: command execution success status (other see Table 10-1); 00: return string length; 58: frame end checksum.
	Response	55 01 03 00 59	55: frame header; 01: destination device address; 03: detected level state status (other see Table 10-1); 00: return string length; 59: frame end checksum.
Aspiration	Send	AA 01 0E 49 61 31 30 30 30 30 30 2C 32 30 30 30 2C 31 30 9F	AA: frame header; 01: destination device address; 0E: command string length; 49 61 31 30 30 30 30 30 30 2C 32 30 30 30 2C 31 30: string command "Ia10000,200,10"; 9F: frame and parity.
	Response	55 01 02 00 58	55: frame header; 01: destination device address; 02: command execution success status (other see Table 10-1); 00: return string length; 58: frame end checksum.
Dispense	Send	AA 01 12 44 61 31 30 30 30 30 2C 35 30 30 30 2C 31 30 30 30 30 2C 31 30 5E	AA: frame header; 01: destination device address; 12: command string length; 44 61 31 30 30 30 30 2C 35 30 30 30 2C 31 30 30 30 30 2C 31 30: string command "Da1000,500,1000,10"; 5E: frame end checksum.
	Response	55 01 02 00 58	55: frame header; 01: destination device address; 02: command execution success status (other see Table 10-1); 00: return string length; 58: frame end checksum.
Read Status	Send	AA 01 01 3F EB	AA: frame header; 01: destination device address; 01: command string length; 3F: string command "? "; EB: frame end checksum.
	Response	55 01 00 00 56	55: frame header; 01: destination device address; 00: idle state (see Table 10-1 for others); 00: return string length; 56: frame end checksum.
Read register	Send	AA 01 03 52 72 33 A5	AA: frame header; 01: destination device address; 03: command string length; 52 72 33: string command "Rr3"; A5: frame end checksum.
	Response	55 01 02 01 30 89	55: frame header; 01: destination device address; 02: successful execution of the command (see Table 10-1 for others); 01: return string length; 30: return string "0"; 89: frame end checksum.
Write register	Send	AA 01 07 57 72 35 34 2C 31 30 71	AA: frame header; 01: destination device address; 07: command string length; 57 72 35 34 2C 31 30: string command "Wr54,10"; 71: frame end checksum.
	Response	55 01 02 00 58	55: frame header; 01: destination device address; 02: command execution success status (other see Table 10-1); 00: return string length; 58: frame end checksum.

8.3 Example of KT_DT Protocol(String Mode)

Explanation: Transmit direction means from master to SP16, receive direction means from SP16 to master device.

Table 8-3 KT_DT Protocol Single Command

Function	Direction	Data(String)	Description
Initialization	Send	1>It500,100,0	1: destination device address; 500: initialization velocity is 500uL/s; 100: initialization power is 100%; 0: TIP will be ejected during initialization regardless of whether the TIP is detected or not.
	Response	1<2	1: destination device address; 2: command execution success (other see Table 10-1).
Liquid Level Detection	Send	1>Ld1,5000	1: destination device address; 1: automatic reporting status after detecting the liquid level; 5000: detection timeout time of 5000 milliseconds.
	Response	1<2	1: destination device address; 2: command execution success (other see Table 10-1).
	Response	1<3	1: Target device address; 3: Liquid level status detected; at the same time the yellow LED is always on.
Aspiration	Send	1>Ia10000,200,10	1: destination device address; 10000: aspiration 100uL; 200: running velocity of 200uL/s during aspiration; 10: aspiration cut-off velocity of 10uL/s.
	Response	1<2	1: destination device address; 2: command execution success (other see Table 10-1).
Dispense	Send	1>Da1000,500,1000,10	1: Target device address; 1000: 10uL of dispense; 500: 5uL of re-aspiration volume; 1000 running velocity during dispense is 1000uL/s; 10: dispense cut-off velocity is 10uL/s.
	Response	1<2	1: destination device address; 2: command execution success (other see Table 10-1).
Read Status	Send	1>?	1: destination device address; ? : used to query the current status of SP16, equivalent to reading the register 1.
	Response	1<0	1: destination device address; 0: idle state (see Table 10-1).
Read register	Send	1>Rr3	1: destination device address; 3: check for TIP status (see Table 10-12 for details of other register addresses).
	Response	1<2:0	1: destination device address; 2: successful execution of the command (see Table 10-1); 0: no TIP.
Write register	Send	1>Wr54,10	1: destination device address; 54: set liquid level detection coefficient (see Table 10-12 for details of other register addresses); 10: liquid level detection coefficient is set to 10.
	Response	1<2	1: destination device address; 2: successful execution of the command (for others see Table 10-1).

8.4 Development Process Practice

8.4.1 CAN communication flow

It is recommended to use CAN Event-Triggered Communication mode. The pipettor will automatically report its completion status after finishing the operation.

Configure automatically reporting via Index 0x9F00 sub-index 0x05 to enable the event-triggered communication mode.

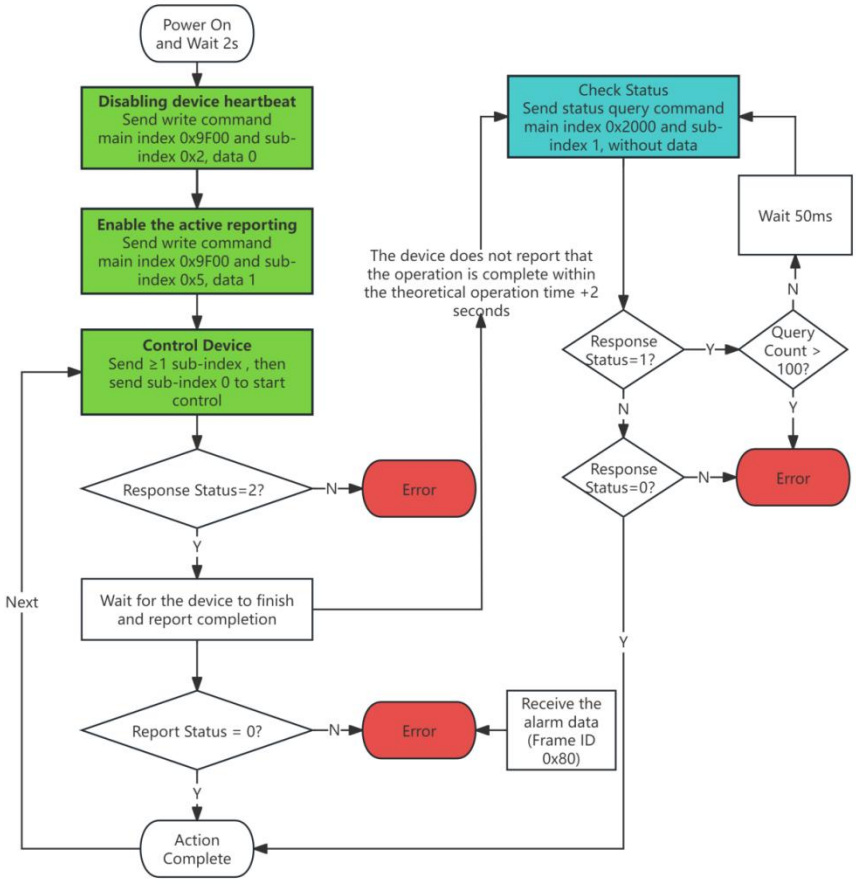


Figure 8-1 KT_CAN_DIC Protocol Communication Framework

Green Box: Write registers and control SP16 action operations (right side of the flowchart).

Blue Box: Query SP16 status and read registers (left side of the flowchart).

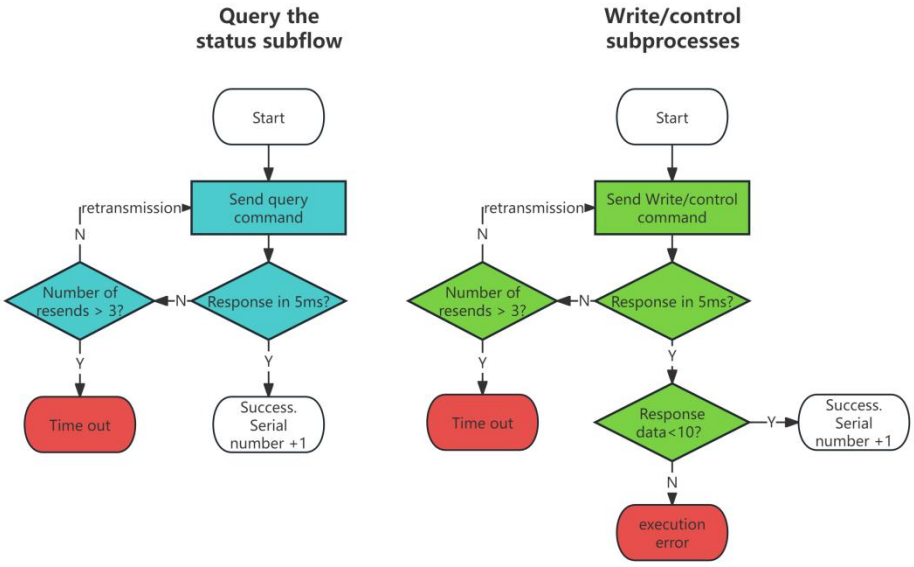


Figure 8-2 KT_CAN_DIC Protocol Communication Sub-flow Framework

8.4.2 Serial Port communication flow

1. *When using serial port communication, wait ⩾10ms after receiving a response before sending the next command to avoid bus interference.*
2. *Use a one command-one response mode: each command must wait for acknowledgment before sending the next command.*

The one command-one response mode is available at Figure 8-3 .

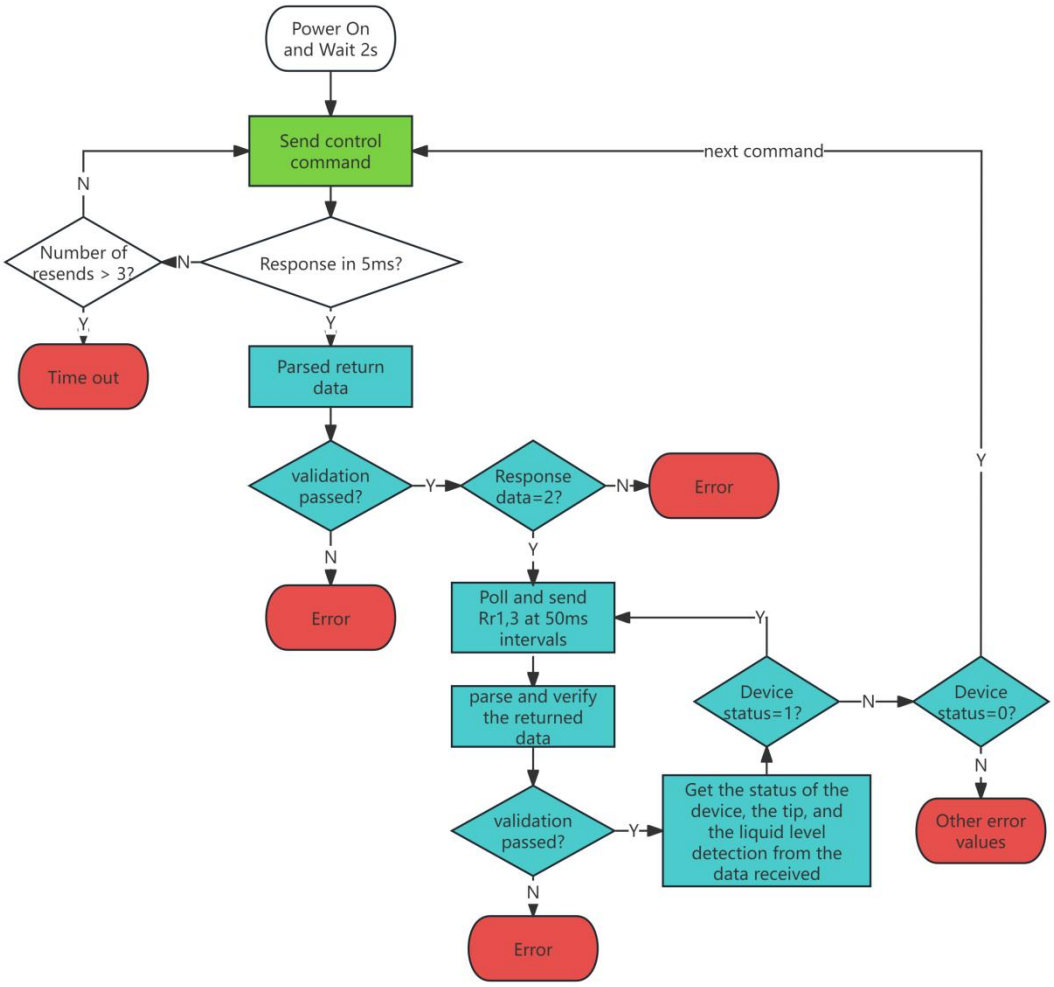


Figure 8-3 KT_OEM Protocol Communication Framework

8.4.3 CAN development process practice

Table 8-4 CAN Development Process

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
0	Response	Power-on default heartbeat upload	0x0004 0100	Data frame	Extended frame	0x08	00 00 00 00 00 00 00 00
1	Response	Power-on default heartbeat	0x0004	Data	Extended	0x08	00 00 00 00 00 00 00 00

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
		upload	0100	frame	frame		
2	Response	Power-on default heartbeat upload	0x00042900	Data frame	Extended frame	0x08	01 00 00 00 00 00 00 00
3	Response	Power-on default heartbeat upload	0x00040100	Data frame	Extended frame	0x08	01 00 00 00 00 00 00 00
4	Response	Power-on default heartbeat upload	0x00042900	Data frame	Extended frame	0x08	02 00 00 00 00 00 00 00
5	Send	Disable Axis-Z heartbeat	0x00010029	Data frame	Extended frame	0x08	01 20 00 6B 00 00 00 00
6	Response		0x00002900	Data frame	Extended frame	0x08	01 20 00 6B 00 00 00 02
7	Send	Disable pipettor heartbeat	0x00010001	Data frame	Extended frame	0x08	01 20 00 53 00 00 00 00
8	Response		0x00000100	Data frame	Extended frame	0x08	01 20 00 53 00 00 00 02
9	Send	Enable Pipettor Movement Completion automatically Reporting	0x00010001	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 01
10	Response		0x00000100	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 02
11	Send	Open Axis-Z Movement Completion automatically Reporting	0x00010029	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 01
12	Response		0x00002900	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 02
13	Send	Set pipettor initialization power to 100%	0x00010001	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 64
14	Response		0x00000100	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 02
15	Send	Configure pipettor initialization with TIP ejection	0x00010001	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 00
16	Response		0x00000100	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 02
17	Send	Execute pipettor initialization	0x00010001	Data frame	Extended frame	0x08	05 40 00 00 00 00 01 F4
18	Response		0x00000100	Data frame	Extended frame	0x08	05 40 00 00 00 00 00 02
19	Response	Pipettor motion completion frame	0x00030100	Data frame	Extended frame	0x08	02 70 02 00 00 00 00 00

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
20	Send	Axis-Z initialization	0x00010029	Data frame	Extended frame	0x08	03 41 00 00 00 00 C3 50
21	Response		0x00002900	Data frame	Extended frame	0x08	03 41 00 00 00 00 00 02
22	Response	Axis-Z action completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
23	Send	Configure the pipettor aspiration velocity to 100uL/s	0x00010001	Data frame	Extended frame	0x08	06 40 01 01 00 00 00 64
24	Response		0x00000100	Data frame	Extended frame	0x08	06 40 01 01 00 00 00 02
25	Send	Configure pipettor aspiration cut-off velocity to 0uL/s	0x00010001	Data frame	Extended frame	0x08	07 40 01 02 00 00 00 00
26	Response		0x00000100	Data frame	Extended frame	0x08	07 40 01 02 00 00 00 02
27	Send	Execute pipettor aspiration of 30uL air	0x00010001	Data frame	Extended frame	0x08	08 40 01 00 00 00 0B B8
28	Response		0x00000100	Data frame	Extended frame	0x08	08 40 01 00 00 00 00 02
29	Response		0x00030100	Data frame	Extended frame	0x08	03 70 02 00 00 00 00 00
30	Send	Set the power of Axis-Z pickup TIP to 80%	0x00010029	Data frame	Extended frame	0x08	01 41 04 01 00 00 00 50
31	Response		0x00002900	Data frame	Extended frame	0x08	01 41 04 01 00 00 00 02
32	Send	Execute Axis-Z to pickup TIP	0x00010029	Data frame	Extended frame	0x08	01 41 04 00 00 00 4e 20
33	Response		0x00002900	Data frame	Extended frame	0x08	01 41 04 00 00 00 00 02
34	Response	Pipettor has pickup TIP	0x00030100	Data frame	Extended frame	0x08	00 70 01 00 00 00 00 01
35	Response	Axis-Z motion completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
36	Send	Configure Axis-Z velocity 30000um/s	0x00010029	Data frame	Extended frame	0x08	04 41 01 01 00 00 75 30
37	Response		0x00002900	Data frame	Extended frame	0x08	04 41 01 01 00 00 00 02
38	Send	Execute Axis-Z moving to position 180000um	0x00010029	Data frame	Extended frame	0x08	05 41 01 00 00 02 bf 20

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
39	Response		0x00002900	Data frame	Extended frame	0x08	05 41 01 00 00 00 00 02
40	Send	Configure liquid level detection without detecting timeout	0x00010001	Data frame	Extended frame	0x08	09 40 07 01 00 00 00 00
41	Response		0x00000100	Data frame	Extended frame	0x08	09 40 07 01 00 00 00 02
42	Send	Execute liquid level detection	0x00010001	Data frame	Extended frame	0x08	0A 40 07 00 00 00 00 00
43	Response		0x00000100	Data frame	Extended frame	0x08	0A 40 07 00 00 00 00 02
44	Response	Axis-Z motion completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
45	Response	Pipettor motion completion frame	0x00030100	Data frame	Extended frame	0x08	04 70 02 00 00 00 00 00
46	Response	Axis-Z motion completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
47	Send	Execute mixing of aspirates 100uL	0x00010001	Data frame	Extended frame	0x08	01 40 01 00 00 00 27 10
48	Response		0x00000100	Data frame	Extended frame	0x08	01 40 01 01 00 00 00 02
49	Response	Pipettor motion completion frame	0x00030100	Data frame	Extended frame	0x08	04 70 02 00 00 00 00 00
50	Send	Perform pipettor dispensing and emptying	0x00010001	Data frame	Extended frame	0x08	05 40 09 00 00 00 01 F4
51	Response		0x00000100	Data frame	Extended frame	0x08	05 40 00 00 00 00 00 02
52		... Cycle 47-51 for mixing					
53	Send	Configuration of pipettor aspiration anomaly detection	0x00010001	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 05
54	Response		0x00000100	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 02
55	Send	Configure the pipettor liquid following surface area of 90mm^2	0x00010001	Data frame	Extended frame	0x08	0b 40 11 02 00 00 00 5a
56	Response		0x00000100	Data frame	Extended frame	0x08	0b 40 11 02 00 00 00 02
57	Send	Configuration of the aspiration following	0x00010001	Data frame	Extended frame	0x08	0C 40 11 01 00 00 00 64

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
		velocity 100uL/s					
58	Response		0x00000100	Data frame	Extended frame	0x08	0C 40 11 01 00 00 00 02
59	Send	Execute pipetting of 100uL of liquid	0x00010001	Data frame	Extended frame	0x08	0E 40 11 00 00 00 27 10
60	Response		0x00000100	Data frame	Extended frame	0x08	0E 40 11 00 00 00 00 02
61	Response	Axis-Z motion completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
62	Response	Pipettor motion completion frame	0x00030100	Data frame	Extended frame	0x08	05 70 02 00 00 00 00 00
63	Send	Configure pipettor re-aspiration volume 0uL	0x00010001	Data frame	Extended frame	0x08	10 40 02 01 00 00 00 00
64	Response		0x00000100	Data frame	Extended frame	0x08	10 40 02 01 00 00 00 02
65	Send	Configure the pipettor to dispense at a velocity of 500uL/s	0x00010001	Data frame	Extended frame	0x08	11 40 02 02 00 00 01 F4
66	Response		0x00000100	Data frame	Extended frame	0x08	11 40 02 02 00 00 00 02
67	Send	Configure pipettor dispense up to velocity 0	0x00010001	Data frame	Extended frame	0x08	12 40 02 03 00 00 00 00
68	Response		0x00000100	Data frame	Extended frame	0x08	12 40 02 03 00 00 00 02
69	Send	Execute pipettor dispense 130uL	0x00010001	Data frame	Extended frame	0x08	13 40 02 00 00 00 32 C8
70	Response		0x00000100	Data frame	Extended frame	0x08	13 40 02 00 00 00 00 02
71	Response	Pipettor motion completion frame	0x00030100	Data frame	Extended frame	0x08	06 70 02 00 00 00 00 00
72	Send	Close pipettor aspiration abnormality detection	0x00010001	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 00
73	Response		0x00000100	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 02
74	Send	Configure the pipettor to always eject TIP	0x00010001	Data frame	Extended frame	0x08	14 40 06 01 00 00 00 00
75	Response		0x00000100	Data frame	Extended frame	0x08	14 40 06 01 00 00 00 02
76	Send	Execute Pipettor eject TIP	0x00010001	Data frame	Extended frame	0x08	15 40 06 00 00 00 7D 00

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
77	Response		0x0000 0100	Data frame	Extended frame	0x08	15 40 06 00 00 00 00 02
78	Response	Pipettor motion completion frame	0x0003 0100	Data frame	Extended frame	0x08	07 70 02 00 00 00 00 00

8.4.4 Serial Port Development Process practice

Table 8-5 Serial Port Development Process

Direction	Command(HEX)	Function	Command String ASCII
Send	AA29075A7A31303030309F	Axis-Z initialization	Zz10000
Response	5529020080		
Loop sending	AA01055272312C3304	Polling SP16 and Axis-Z status	
Response	552901007F	Axis-Z status 01 busy	
	.....	Omit (continue polling status until idle)	
Send	AA29013F13	Query Axis-Z status	
Response	552900007e	Axis-Z state 0 idle	
Send	AA010B49743530302C3130302C3021	Pipettor initialization	It500,100,0
Response	5501020058		
Loop sending	AA01013FEB	Polling Pipettor Status	
Response	5501010057	Pipettor Status 01 Busy	
	.....	Omit (continue polling status until idle)	
Send	AA01013FEB	Check Pipettor Status	
Response	5501000056	Pipettor status 0 idle	
Send	AA290A5A6732303030302C383024	Axis-Z downward action pickup TIP	Zg20000,80
Response	5529020080		
Send	AA29013F13	Query Axis-Z status	
Response	552900007e	Axis-Z state 0 idle	
Send	AA0103527233A5	Query TIP status	Rr3
Response	55010201318A		
Send	AA010C4961333030302C313030302C303D	Pipettor aspirate 30.00uL air	Ia3000,100,0
Response	5501020058		
	.....	Omit	
Response	5501000056	Idle	
Send	AA01054C64302C30EC	Activate liquid level detection	Ld0,0
Response	5501020058		

Direction	Command(HEX)	Function	Command String ASCII
	.....	Omit	
Response	5501000056	Idle	
Send	AA01157B496131303030302C313030302C30446 53530307D35DF	Aspirate 100.00uL and emptying, cycle 5 times for mixing	{Ia10000,100,0De500} 5
Response	5501020058		
Send	AA0106577236302C3541	Setting up aspiration abnormality detection	Wr60,5
Response	5501020058		
Send	AA010D496131303030302C313030302C306C	Pipettor aspiration 100.00uL	Ia10000,100,0
Response	5501020058		
	.....	Omit	
Response	5501000056	Idle	
Send	AA29095A70302C383030303030FA	Axis-Z rises to position 0	Zp0,80000
Response	5529290200a9		
	.....	Omit	
Response	552900007e	Idle	
Send	AA010F4461313330303030302C302C313030302C30C 8	Pipettor dispense 130.00uL	Da13000,0,100,0
Response	5501020058		
	.....	Omit	
Response	5501000056	Idle	
Send	AA0106577236302C303C	Turn off aspiration anomaly detection	Wr60,0
Response	5501020058		
Send	AA010744743530302C305B	Pipettes perform a TIP ejection	Dt500,0
Response	5501020058		
	.....	Omit	
Response	5501000056	Idle	

9 KT_CAN_DIC Object Dictionary

The object dictionary includes a 16 -bit index and an 8-bit sub-index. Different operations are indicated by ordered index numbers. All data include read and write permissions. Control command include initialization, aspirate liquid, and dispense liquid. Different indexes represent different command. Sub-indexes are different parameters. The number of parameters is the same as that of serial port command. For example, the serial port command <It>n1,[n2],[n3], It corresponds to the index 0x4000, and n1[n2][n3] corresponds to the sub-index 0～2.

Note: Each control command has a unique index and multiple sub-indexes. The frame data with non-zero sub-index is sent first, and the frame data with zero sub-index is sent last. The pipettor starts moving when it receives a command with zero sub-index.

To control SP16 to aspirate 100uL with an aspiration velocity of 500uL/s and cut-off velocity of 100uL/s, send the KT_CAN_DIC data in the following order:

	Index	Sub-Indexes	Data
1.	0x4001	1	500
2.	0x4001	2	100
3.	0x4001	0	10000

9.1 Control Command

Table 9-1 KT_CAN_DIC Control Command

Function	Index	Sub-index	R/W	Data range	Default	Description
Initialization	0x4000	0	W	10～1000	/	**Mandatory parameter** Initialization velocity in uL/s
		1	R/W	0～100	100	Power percentage during initialization
		2	R/W	0～2	0	TIP ejection mode: 0: Eject TIP regardless of whether there is a TIP 1: Eject TIP if detected 2: Do not eject TIP
Aspiration	0x4001	0	W	1～104000	/	**Mandatory parameter** Aspiration volume (0.01uL)
		1	R/W	1～2000	500	Aspiration velocity (uL/s)
		2	R/W	0～2000	10	cut-off velocity (uL/s)
		3	R/W	0～2	0	TIP compensation mode: 0: No compensation 1: 1000uL TIP compensation 2: 50uL TIP compensation

Function	Index	Sub-index	R/W	Data range	Default	Description
Absolute Volume Movement	0x4003	0	W	0～250880	/	**Mandatory parameter** Position value(PPS, 4096PPS=17.35uL)
		1	R/W	0～500000	128000	Running velocity(PPS/s)
		2	R/ W	0～256000	32000	Stop velocity(PPS/s)
Dispense	0x4002	0	W	1～104000	/	**Mandatory parameter** Dispense volume (0.01uL)
		1	R/W	0～1000	0	re-aspiration volume (0.01uL)
		2	R/W	1～2000	500	Dispense velocity (uL/s)
		3	R/W	0～2000	10	cut-off velocity (uL/s)
TIP Ejection	0x4006	0	W	10～1000	/	**Mandatory parameter** TIP ejection velocity (uL/s)
		1	R/W	0～1	0	0: Eject TIP regardless of whether there is a TIP 1: Eject TIP if detected
Liquid Level Detection	0x4007	0	W	0～1	/	**Mandatory parameter** 0: No automatic report after liquid level is detected; 1: Automatically report after liquid level detection (see **Table 9-3 KT_CAN_DIC Process Data** for details).
		1	R/W	0～100000	0	Detection timeout duration: 0: No timeout detection; Other values: Timeout duration in milliseconds. A timeout error will be reported if liquid level is not detected within this period.
		2	R/W	0～1	1	0: for TIP > 50uL; 1: for TIP ≤50uL.
Stop	0x4008	0	W	0	0	Stop motion and liquid level detection.
Anti-Droplet Control	0x4010	0	W	0～1	/	**Mandatory parameter** 0: Disable anti-droplet; 1: Enable anti-droplet. Note: This feature is optional.
		1	R/W	0～1000	200	Anti-droplet velocity in uL/s.
		2	R/W	0～1000	50	Maximum value per 5ms, in

Function	Index	Sub-index	R/W	Data range	Default	Description
						PPS(4096PPS=17.35uL).
Aspiration with Liquid Following	0x4011	0	W	0～100000	/	**Mandatory parameter** Aspiration volume in 0.01uL. **Remarks**: It needs to be used in combination with Keyto Axis-Z.
		1	R/W	0～1000	100	Aspiration velocity in uL/s.
		2	R/W	0～10000	78	Surface area of the liquid level, in mm².
		3	R/W	0～180000	0	0: No limit; Other values: Lowest position. Once reached, the Axis-Z will no longer fall.
Dispense with Liquid Following	0x4012	0	W	0～100000	/	**Mandatory parameter** Dispense volume in 0.01uL. **Remarks**: It needs to be used in combination with Keyto Axis-Z.
		1	R/W	0～1000	100	Dispense velocity in uL/s.
		2	R/W	0～10000	78	Surface area of the liquid level, in mm².
The filter Density of TIP	0x4020	0	W	0	0	Detects the filter Density of TIP. The value can be obtained by querying register 180.

9.2 General Commands

Table 9-2 KT_CAN_DIC General Command

Function	Index	Sub-index	R/W	Data Range	Default Value	Description
Read status	0x2000	1	R/W	0～255	/	SP16 status: 0: Idle; 1: Busy; Other values: Error status(refer to Table 10-1). Write 0 to clear error
Device Type	0x9F00	0	R	/	/	Device type code: 0x00200001.
Emergency Stop	0x9F00	1	W	0	0	Stop motion.
Heartbeat Interval	0x9F00	2	R/W	0～10000	1000	Heartbeat interval for CAN upload in ms: 0: Stop heartbeat;

Function	Index	Sub-index	R/W	Data Range	Default Value	Description
						Other values: Interval time.
Restart	0x9F00	3	W	0	0	Restart the device.
Firmware Version	0x9F00	4	R	/	/	Firmware version.
automatically Reporting	0x9F00	5	R/W	0～1	/	0: Disable automatically reporting; 1:Enable automatically reporting;Movement completion is actively reported using KT_CAN_DIC command 0x0003, index 0x7002 sub-index 0.0 indicates motion completion. Other values are error codes with the same error code as the device error code.
Power-off Save	0x9F10	0	W	/	/	Save parameters after power off.
Factory Reset	0x9F10	1	W	/	123456	Restore factory settings.

9.3 Register Read and Write

Read/write the SP16 registers through the index 0x2000, and the sub-index corresponds to the Register Address, which is shown in Table 10-12 . The read/write function commands can be found at Table 7-2 .

9.4 Process Data

The SP16 device automatically reports process data through Command 0x0003. The process data dictionary is shown in the table below:

Table 9-3 KT_CAN_DIC Process Data

Function	Index	Sub-index	R/W	Data Range	Default Value	Description
Liquid level detected	0x7000	0	R	0～1	0	0:The liquid level is not detected 1: The liquid level is detected.
TIP Detection status	0x7001	0	R	0～1	0	TIP detection status Automatically reporting of the disposable TIP status when it is picked up or ejected 0: No disposable TIP 1: With disposable TIP
Motion Completed	0x7002	0	R	0～255	0	After moving done then automatically report the status 0: normal

	Other data:Error status, see Table 10-1 for details).

9.5 Heartbeat Data

The pipettor sends heartbeat data via command 0x0004, which the Host can use it to detect whether the device is online..

9.6 Warning Data

The SP16 device sends warning information using Command 0x0080 of the KT_CAN_DIC protocol. The warning data format is identical to the error information format used for status query command. For detailed warning information, refer to Table 10-1.

10 Serial Port Commands

This chapter describes the data format for operation commands in the KT_OEM and KT_DT protocols, specifically the data block of the command string. The data is formatted as ASCII strings, and multiple command sets can be sent simultaneously. The SP16 will parse and execute the commands sequentially. The command types are categorized as follows:

- Initialization command
- Control commands
- Parameter read/write commands
- System control commands

10.1 Command Syntax

Send multiple commands to pipettor, and the format is as follows:

<CMD><n1,n2,n3><CMD><n1,n2,n3><CMD><n1,n2,n3>

The pipettor responds data in the following ASCII format:

<n1,n2,n3>

Among them:

<CMD>: command, consists of the letters a～z and A～Z, up to two letters, please refer to section 10.3.

<n1,n2,n3>: command parameters, commands parameters are separated by ' , ' sign, and the command without parameters can be empty. If some of the parameters need to be by default, you can fill in the parameters as empty. For example, the second parameter will be empty command: ID1000,,2. If the next part of the parameters are empty, it can be omitted. For example, the last two parameters are empty command: ID1000 means that the last two parameters are empty.

	*Note:* *1) <> is used to differentiate data blocks and does not need to be sent.* *2) The commands are case-sensitive.* *3) It is agreed that the instruction letters are at most two letters long, with two-letter instructions consisting of an uppercase letter followed by a lowercase letter. Single-letter instructions are represented by uppercase letters. The special character '?' denotes a query instruction, and '{}' denotes a loop control instruction. A single uppercase letter instruction is for system control, while an uppercase letter followed by a lowercase letter is for operation control.*

10.2 Status

Each command has a return status to indicate whether it was successfully

executed, if an error occurred, or if the device is idle or busy. Status codes are represented as a single byte in hexadecimal format.

Rules:

0～9: Working status.

10～19: Command execution error code.

20～49: Warning code, aspiration and dispense is still allowed.

>=50: Error code, need to troubleshoot and re-initialization.

Table 10-1 Status

Code	Function	Description
0	Idle	Device is in idle status
1	Busy	Pipettor is in busy status and does not accept the commands
2	Execution Success	Commands executed successfully
3	Liquid level detected	When the serial port communication mode is connected and the liquid level detection command [n1]=1 turns on the automatically reporting function of liquid level detection, the status is automatically reported after the liquid level is detected, while the other modes obtain whether the liquid level is detected by querying register 2.
10	Parameter exceeded limit	Commands parameters out of range
11	Parameter error	Commands parameter error
12	Syntax error	Commands syntax error
13	Invalid commands	Commands does not support
14	Address error	Read and write register address error
15	Prohibit writing	This address is inhibited from being written to
16	Prohibit reading	This address is inhibited from being readout
17	Pipettor uninitialized	Uninitialized
18	Axis-Z uninitialized	Axis-Z is uninitialized, detail see Axis-Z manual
19	Axis-Z unconnected	Axis-Z is unconnected, detail see Axis-Z manual
20	No TIP warning	Allow aspirate and dispense of liquid after this warning
21	Eject disposable TIP failure warning	Allow aspirate and dispense of liquid after this warning
22	Timeout warning	Allow aspirate and dispense of liquid after this warning
23	Aspiration clot detection warning	Allow aspirate and dispense of liquid after this warning
24	Aspiration foam detection warning	Allow aspirate and dispense of liquid after this warning
25	Aspiration air detection warning	Allow aspirate and dispense of liquid after this warning

Code	Function	Description
28	Anti-droplet range exceeds the limit	Aspiration and dispense of liquid is prohibited and needs to be re-initialized and troubleshot.
50	Motor stall error	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
51	Drive failure	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
52	Optocoupler 1 error	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
53	Optocoupler 2 error	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
54	Pressure Sensor error	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
55	EEPROM error	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
56	Power supply under-voltage	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
57	Power supply over-voltage	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
58	Motor short circuit	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot
59	Motor open circuit	Prohibit aspirate and dispense of liquid, require re-initialization and troubleshoot

10.3 Command Details

This section provides detailed explanations for each command.

Notice:

[] indicates optional parameters. If the optional parameters are empty, the default parameters in the protocol will be used. No [] indicates a mandatory parameter.

<> contains command. The symbol <> does not need to be sent. It is only used to distinguish letters from command.

10.3.1 Initialization Command

10.3.1.1 <It>[n1], [n2], [n3] Initialization Device to zero Position

Used to initialize the SP16 by automatically moving the plunger to position 0. The command parameters determine whether the TIP is ejected.

Table 10-2 It Command

Command	Parameter	Data Range	Unit	Default	Description
It	[n1]	10～1000	uL/s	500	Initialization velocity.
	[n2]	0～100	%	100	Power during Initialization.

					Percentage of maximum power.
	[n3]	0～2	None	0	0: TIP will be ejected Regardless of whether there is a TIP 1: If a TIP is detected, the TIP will be ejected 2: Don't eject the TIP

Response: Refer to Table 10-1.

10.3.2 Control Command

10.3.2.1 <Ia>n1, [n2], [n3] [n4] Aspiration

Used for aspirating liquid, it automatically converts the parameters corresponding to the volume into the piston movement distance, and controls the piston to move upward to aspirate liquid.

Table 10-3 Ia Command

Command	Parameter	Data Range	Unit	Default	Description
Ia	n1	1～104000	0.01uL	0	Aspiration volume.
	[n2]	1～2000	uL/s	500	Aspiration velocity.
	[n3]	0～2000	uL/s	10	Cut-off velocity.
	[n4]	0～2		0	TIP compensation: 0: No compensation. Keep to 0 if customer does the accuracy compensation as section 6.9.2; 1: 1000uL TIP compensation; 2: 50uL TIP compensation.

[n1] Aspiration Volume: This parameter is mandatory. The aspiration volume refers to the theoretical volume aspirated into the TIP. However, due to various physical factors, the aspirated volume and target volume may differ. For high-precision aspirations, it is necessary to calibrate based on the aspiration velocity, liquid viscosity, aspiration volume, and TIP type to create an appropriate calibration curve.

[n2] Aspiration velocity: The flow rate should be set according to the physical properties of the liquid, such as viscosity and surface tension. For certain liquids, an excessively fast flow rate may result in low pipetting barrel pressure in the SP16, causing the liquid to continue flowing into the TIP after the plunger stops, leading to over-aspiration. The recommended approach is to match the liquid flow rate with the aspiration velocity.

[n3] Cut-off Velocity: This parameter controls the final stopping velocity of the fluid, which should be adjusted based on the specific physical properties of the liquid.

[n4] TIP Compensation: This compensation mode is based on single aspiration and single dispense cycles using Keyto's TIP and pure water, ensuring precision

within the range of pipettor performance.

Response: see Table 10-1.

Do not aspirate volumes exceeding the TIP capacity, such as using a 200uL TIP to aspirate 1000uL of liquid.

10.3.2.2 <Da>n1, [n2], [n3], [n4] Dispense

Used for dispense liquid, it automatically converts the parameters corresponding to the volume into the piston movement distance, controls the piston movement to dispense the liquid, and chooses whether to re-aspirate according to the parameters to prevent liquid hanging.

Table 10-4 Da Command

Command	Parameter	Data Range	Unit	Default	Description
Da	n1	1～104000	0.01uL	0	Dispense volume.
	[n2]	0～10000	0.01uL	0	re-aspiration volume.
	[n3]	1～2000	uL/s	500	Dispense velocity.
	[n4]	0～2000	uL/s	10	Cut-off velocity.

[n1] Dispense Volume: This parameter refers to the theoretical volume dispensed from the TIP. Due to various physical factors, the dispensed volume and target volume may differ. For high-precision dispensing, calibration should consider dispensing velocity, liquid viscosity, dispensing volume, and TIP type.

[n2] re-aspiration Volume: To prevent liquid droplet formation at the TIP end, which can impact accuracy and cause cross-contamination, a re-aspiration function is designed to retract a specified volume of liquid after dispensing. The re-aspiration volume depends on the dispense volume, TIP type, and reagent viscosity. It may also affect dispensing precision. Users should optimize settings to avoid droplet formation and achieve desired precision.

[n3] Dispense velocity: This parameter should be set according to the liquid's physical properties. For certain liquids, excessively fast flow rates can cause high pipetting barrel pressure in the SP16. A reasonable approach is to match the liquid flow rate with the dispense velocity.

[n4] Cut-off Velocity: This parameter determines the velocity at the end of dispensing. The piston decelerates to the stop velocity before coming to a complete stop. The cut-off velocity must be lower than the dispensing velocity. A higher cut-off velocity can improve droplet detachment at the needle TIP.

Response: see Table 10-1 .

1. *Parameter n1 is the target volume of liquid dispensed, [n2] does not affect the target volume of liquid dispensed, but only affects the effect of aliquot-dispense of hanging droplet; single aspiration single dispense should be kept [n2] is 0;*
2. *The cut-off velocity must be less than the dispense velocity.*

10.3.2.3 <Mp>n1,[n2] [n3] Absolute Positioning

The control plunger moves to an absolute position within the entire stroke from 0～245855 PPS corresponding to 0～1040uL.

Table 10-5 Mp Command

Command	Parameter	Data Range	Unit	Default	Description
Mp	n1	0～250880	PPS	0	Position value.
	[n2]	0～500000	PPS	128000	Running velocity.
	[n3]	0～256000	PPS	32000	Stop velocity.

Response: see Table 10-1 .

10.3.2.4 <Dt>[n1],[n2] Eject TIP

Controls the motor moving to eject the TIP. TIP status can be verified through Register 3.

Table 10-6 Dt Command

Command	Parameter	Data Range	Unit	Default	Description
Dt	[n1]	10～1000	uL/s	500	Ejecting velocity.
	[n2]	0～1	/	0	0: TIP will be ejected Regardless of whether there is a TIP; 1: Eject TIP if detected.

Response: see Table 10-1.

10.3.2.5 <Ld>[n1],[n2],[n3] Liquid Level Detection

This command is used to detect the surface of the reagent. When the liquid level is detected, SP16 sends a liquid level detection signal. Users can monitor this signal in three ways: by checking the SP16 automatically reporting message, monitoring the GP01 output, or querying the status.

Table 10-7 Ld Command

Command	Parameter	Data Range	Unit	Default	Description
Ld	[n1]	0～1	None	1	0: No automatic reporting after liquid level detection; users should query Register 2 to confirm. 1: Automatically reporting of status after liquid level is detected.
	[n2]	0～100000	ms	10000	0: No timeout. Other values: Timeout duration. If no pressure change is detected within the timeout period, an error is reported.
	[n3]	0～1	None	1	0: for TIP > 50uL; 1: for TIP ≤50uL.

Response: see Table 10-1 .

10.3.2.6 <Pc>n1,[n2],[n3] Anti-Droplet Control (Optional)

This command enables anti-droplet functionality after completing aspiration. Set parameter n1 to 1 to enable the feature. Note: For products supporting this function, users must resend this command to reactivate anti-droplet control after executing other commands.

Table 10-8 Pc Command

Command	Parameter	Data Range	Unit	Default	Description
Pc	n1	0～1	/	0	0: Disable anti-droplet control. 1: Enable anti-droplet control.
	[n2]	0～1000	uL/s	200	Anti-droplet velocity.
	[n3]	0～1000	PPS	50	Maximum value per 5ms, in PPS(4096PPS=17.35uL).

Response: see Table 10-1 .

Configure parameters [n2] and [n3] appropriately based on the reagent's polarity. Higher polarity requires larger parameter values.

10.3.2.7 <Iz>n1,n2,n3 Liquid Following for Aspiration

This function works with Keyto's Axis-Z to achieve liquid following during aspiration. It automatically controls the Axis-Z to fall down along with the descending liquid level during aspiration.

This function works with Keyto's Axis-Z.

Table 10-9 Iz Command

Command	Parameter	Data Range	Unit	Default	Description
Iz	n1	1～104000	0.01uL	0	Aspiration volume.
	n2	1～2000	uL/s	100	Aspiration velocity.
	n3	1～10000	mm^2	78	Liquid surface area.
	[n4]	0～180000	um	0	Axis-Z lowest position. 0: No limit. Other values: Lowest position. The Axis-Z will stop falling down if reaching this position.

Response: see Table 10-1 .

10.3.2.8 <Dz>n1,n2,n3 Liquid Following for Dispensing

This function works with Keyto's Axis-Z to achieve liquid following during dispensing. It automatically controls the Axis-Z to rise along with the ascending liquid level during dispensing.

This function works with Keyto's Axis-Z.

Table 10-10 Liquid Level Following for Dispensing Command

Command	Parameter	Data Range	Unit	Default	Description
Dz	n1	1～104000	0.01uL	0	Dispense volume.
	n2	0～2000	uL/s	100	Dispense velocity.
	n3	1～10000	mm^2	78	Liquid surface area.

Response: see Table 10-1 .

10.3.2.9 <Dc> The Filter Density of TIP Detection

This function detects whether the density of the current filter in TIP is suitable for liquid level detection.

Table 10-11 Dc Command

Command	Parameter	Data Range	Unit	Default	Description
Dc	None	/	/	/	/

Detection Methods:

1. Perform initialization on SP16, then install the filter TIP to be tested. Send the Dc command.
2. Query Register 180 to obtain the current air permeability value, which serves as a basis for determining filter density.
3. Judging criteria:
   1) For filter TIPs ≤ 50uL, a Register 180 value between 0 and 1800 indicates suitability; otherwise, the liquid level detection coefficient must be adjusted.
   2) For 200uL and 1000uL filter TIPs, the filter density does not significantly affect liquid level detection, so density detection is unnecessary.

1. Initialization is required before sending the command, and the TIP must not touch any objects or reagents.

2. This function applies is only used for ≤ 50uL filter TIPs.

10.3.3 Parameter Read/Write commands

10.3.3.1 Registers

Registers are used by users to configure and view the parameters of the SP16, which is convenient for users to use flexibly.

Table 10-12 Register

Register Address	R/W	Data Range	Unit	Default Value	Description
1	R/W	/	/	0	Current status, write 0 to clear error, return value is same as “?” command.
2	R	0～1	/	0	Whether the liquid level is detected: 0: Liquid level not detected. 1: Liquid level detected.
3	R	0～1	/	0	The TIP is picked up? 0:No, no TIP

Register Address	R/W	Data Range	Unit	Default Value	Description
					1:Yes, with TIP （after executing the eject TIP command, this register cannot replace register 1 to determine if the device enters the idle state. ）
4	R	/	/	0	Current pressure sensor ADC value.
10	R/W	/	/	0	GPO1 output configuration: 0: Outputs a 10ms high-level pulse. 1: Outputs high level after detecting the liquid level. 2: Outputs low level after detecting the liquid level.
20	R	0～max	P	0	Current motor position.
21	R	0～max	P/s		Current motor velocity.
22	R	0～max	uL/s		Current fluid velocity.
29	R	/	uL	1058	Maximum volume.
35	R	/	uL	/	Current reagent volume, roughly calculated based on current pressure. For reference only.
43	R/W	0～1	/	0	0: Does not check TIP picked-up status; no error when performing aspiration or dispensing even no TIP. 1: Checks TIP picked-up status; reports an error if performing aspiration or dispensing if no TIP.
54	R/W	0～100	/	10	Liquid level detection coefficient. The default value is suitable for most applications.
60	R/W	0～0x3F	/	0	Abnormal pressure detection enable (HEX, enables corresponding functions when the bit is set to 1): Bit 0: Enables clot detection during aspiration. Bit 1: Enables foam detection during aspiration. Bit 2: Enables aspiration of empty detection.
70	R/W	0～100	/	10	Aspiration of clot detection coefficient.
71	R/W	0～1000	/	20	Aspiration of foam detection coefficient.
72	R/W	0～100	/	20	Aspiration of empty detection coefficient.

Register Address	R/W	Data Range	Unit	Default Value	Description
80	R/W	9600/19200/38400	bps	38400	Serial Port port baud rate.
81	R/W	100/125/250/500/1000	Khz	500	CAN baud rate.
82	R/W	0～1	/	0	If the movement is completed,whether reported automatically the status or not: 0: Disable automatically reporting 1: Enable automatically reporting
83	R/W	0～10000	ms	1000	CAN heartbeat interval: 0: No heartbeat data. Other values: Heartbeat interval, in ms.
90	R	/	/	/	Firmware version.
91	R	/	/	0x00200001	Device type.
92	R	/	/	/	Device sequence number.
180	R	/	/	/	Pressure sensor ADC value after the Dc command, used to determine filter density in TIP.

10.3.3.2 <Wr>n1,n2 Write Register

Write registers.

Table 10-13 Wr Command

Command	Parameter	Data Range	Unit	Default	Description
Wr	n1	1～100	/	/	Register address.
	n2	/	/	/	Data to be written.

Response: see Table 10-1 .

10.3.3.3 <Rr>n1,[n2] Read Register

This command reads the values of registers, starting from the specified address and reading a specified number of registers.

Table 10-14 Rr Command

Command	Parameter	Data Range	Unit	Default	Description
Rr	n1	1～100	/	/	Starting address.
	[n2]	1～255	/	1	Number of registers to read.

Response:

The status part is shown in Table 10-1, the data area is the read data, and the return data of multiple addresses are separated by ','.

10.3.4 System Operation Command

10.3.4.1 <?>Query Status

This ? command queries the current status of the device.

Response: see Table 10-1 .

10.3.4.2 {} Loop Control Command

The loop control command is used to control the loop execution of the command string. The loop can be nested. A maximum of 20 loops including nested loops are supported in one command string.

Table 10-15 {} command

Command	Parameter	Data Range	Unit	Default	Description
{	/	/	/	/	Start of the loop.
}	[n1]	/	/	0	0: infinite loop. other values: number of loops

10.3.4.3 <L>n1 Delay

The delay is used for internal system delays and is mainly used as a delay between the execution of two commands.

Table 10-16 L Command

Command	Parameter	Data Range	Unit	Default	Description
L	n1	0～2147483647	ms	/	**Mandatory parameter** Delay time

Response: see Table 10-1 .

10.3.4.4 <T> Stop command

Stop the command currently being executed by the device.

Table 10-17 T Command

Command	Parameter	Data Range	Unit	Default	Description
T	/	/	/	/	Stop

Response: see Table 10-1 .

10.3.4.5 <U> Reset Command

This command is used to restart and reset the device.

Table 10-18 U command

Command	Parameter	Data Range	Unit	Default	Description
U	/	/	/	/	/

Response: see Table 10-1 .

10.3.4.6 <M>n1 Restore Factory Settings Command

After executing this command, you need to restart the device.

Table 10-19 Restore Factory Settings Command

Command	Parameter	Data Range	Unit	Default	Description
M	n1	123456	/	/	**Mandatory parameter** The parameter should be 123456.

Response: see Table 10-1 .

10.3.4.7 <S> Save after power off

After executing this command, the modified register parameters will be saved after power off.

Table 10-20 Power-down Data Retention Command

Command	Parameter	Data Range	Unit	Default	Description
S	/	/	/	/	The modified register parameters will be saved after power off

Response: see Table 10-1 .

11 LED Indication

The different colors of the tri-color LED represent various states of the device. The LED states are shown in the Table below.

Table 11-1 LED Status

LED Status	Description
Off	Idle, no TIP.
pale blue	During liquid level detecting.
green	Idle, TIP picked up.
blue	Busy.
yellow	Liquid level detected.
red	Warning, number of flashes = error code - 19.
bright red	Error, number of flashes = error code - 49.

Example: If the red LED flashes once each time, the state is 1 + 19 = 20, which indicates "No TIP warning." Refer to Table 10-1 for specific error code.

12 Troubleshooting and Q&A

12.1 Common problems and solutions

Note: The following descriptions are troubleshooting methods for issue arisen when performed in a compliant operating environment and under rated operating conditions.

Here are four types of common issue:

- Communication issues (Table 12-1)
- TIP related issues (Table 12-2)
- Liquid level detection issues (Table 12-3)
- Accuracy and CV issues(Table 12-4)

Table 12-1 Communication Issues

Issue	Possible causes	Recommended Solutions
The pipettor indicator light does not light up after power on	The plug cable is not fixed, and the pipettor moves up and down, causing the cable to bend and break at the terminal connection.	If the cable is not in good contact when shaking, consider replacing the cable and make sure it is properly installed. See Section 4.1"Installing the Pipettor".
	Short circuit between power lines	Use a multimeter to check if the pipettor power supply is short-circuited. If so, please send it back for repair.
	The cable connector is not plugged in tightly/is loose	Disconnect the power supply and reconnect it as described in section 4.1"Installing the Pipettor”.
	Incorrect cable connection	according to section 3.2"Hardware interface Define”.
Unable to Pipettor communication	The baud rate is set incorrectly	The default baud rate of the pipettor is 38400
	The wiring sequence is incorrect	Confirm the RS485/CAN line sequence, see section 3.2.
	Serial port tool is not compatible	Replace the USB to serial cable or RS485 adapter of different brands.
	command format is incorrect	Check the command format.
Unstable communication	Communication line is disturbed	1. Make sure the communication cable is as short as possible. 2. If necessary, turn the termination resistor switch to ON. 3. Separate the communication cable from the high current cable.

		4. Keep the resistance between the two phases of CAN\RS485 at 60Ω.
	Data is sent too frequently	1. Use a slower baud rate for communication. 2. Use a one command-one response communication method with an interval of more than 10ms between serial port commands. 3. Use re-transmission mechanism to ensure communication reliability.

Table 12-2 TIP related issues

Issue	Possible Cause	Recommended Solution
After aspiration, the device lifts up the TIP and reagent drips out	TIP is not tied tight	You can rotate the TIP by hand to confirm whether it is properly installed. If it is not properly installed, please refer to Section 6.2"Pick up TIP".
	Normal gravity causes	1. Our leakage tester can test air pressure leakage with an accuracy of up to pa level. Each pipettor will be tested before leaving the factory. 2. Recommended test method: Put the pipettor in standby mode at room temperature, install a (non-conductive) clean 1000ul TIP without filter, aspirate 1000ul of pure water and let it stand for 30s to check if there is no leakage at the TIP, which is normal. 3. Please note: During the test process, the TIP must be tied tightly. During the aspirate liquid process, avoid inserting the TIP too deeply into the liquid surface, which may cause liquid to hang on the outer wall of the TIP and cause the test to fail.
	Reagent type reason	Organic reagents or some solvents with certain substances added will leak faster than ordinary reagents. You can use the tail end to suck out the air to prevent liquid from hanging.
	Reagent temperature	If the reagent temperature is high, it will leak faster due to heat. This can be solved by sucking out the liquid and then sucking out some air.
LED indicator light does not turn on after picking up the TIP.	TIP dimensions are inconsistent or incompatible.	If it is a batch issue, it is recommended to change the TIP brand or install the TIP using a greater down force, but not more than 30N. If it is occasional, the TIP consistency may be poor and it is recommended to change the TIP brand.
When the TIP is reused, the accuracy and precision are poor, and there is residue on the inner wall.	TIP can only be used once	Reusing the TIP will affect the accuracy and precision of liquid aspirate and dispense and the success rate of liquid level detection. Reusing the TIP is not recommended.
Failed to withdraw TIP	After executing TIP eject, the TIP is still	1. If it is a batch problem, the TIP size is not suitable. It is recommended to change the TIP brand.

	hanging at the end of the nozzle	2. If it happens occasionally, it may be due to poor TIP consistency. It is recommended to change the TIP brand.
	TIP cannot be ejected.	Follow Section 6.2, apply a down force of 28±2 N to install the TIP. Excessive down force may cause TIP ejecting failure.

Table 12-3 Liquid level detection issues

Issue	Possible Cause	Recommended Solution
Liquid level detection is too deep	Water in the pipettor pipetting barrel	After dispensing the water, wait for 48 hours for natural air drying and then test whether the liquid level detection function can be used normally. If there is still a problem, return it to the factory for repair.
	The pipettor is falling down too fast	Please refer to section 6.3"Liquid Level Detection" and control the Z-axis moving down velocity for the pipettor to detect the liquid level at about 20mm/s.
Liquid level detection is triggered in advance\the liquid level detection is detected as soon as it is started	Water in the pipettor pipetting barrel	After dispensing the water, wait for 48 hours for natural air drying and then test. If there are still problems, return it to the factory for repair.
	TIP Reuse	Reusing the TIP will affect the accuracy and precision of liquid aspirate and dispense and the success rate of liquid level detection. Reusing the TIP is not recommended.
	TIP filter element quality is unqualified, low air permeability	Replace the TIP of another brand or use a TIP without a filter element for testing. If it is related to the filter element, modify the liquid level detection coefficient to adapt or replace the TIP of another brand.
	Start the liquid level detection function below liquid level	The liquid level detection must be started on above the liquid surface.
GPO1 signal cannot drive external devices	GPO1 provides a signal only, without high driving capability.	GPO1 output signal current is only a few microamps. It cannot be used to drive high load external devices.

Table 12-4 Accuracy and CV issues

Issue	Possible Cause	Recommended Solution
Good CV but poor accuracy	Requires accuracy compensation.	Configure aspiration compensation parameters as described in Section 6.9.2.
	Incorrect parameter settings.	Set appropriate aspiration and dispensing parameters according to Section 6.8.
	Incorrect testing method.	Please refer to the section 6.9.1 to follow the recommended test procedure for accuracy and CV.
Residue left in the TIP after	No leading air gap or insufficient air gap.	A leading air gap of 30uL is sufficient for most scenarios. Adjust based on the reagent type and remaining volume in the pipette.

dispensing.	Reagent properties.	1. Viscous reagents may not be fully dispensed in one attempt. Use slow, multiple dispensing method. 2. Organic reagents may adhere to the TIP inner wall. Residual liquid may drop slowly after dispensing.
	Poor-quality TIP.	Compare with other TIP brands. If residue is caused by the TIP, replace the TIP brand.
Poor CV and accuracy.	Liquid level detection was not used during aspiration.	1. Use liquid level detection to ensure the TIP reaches the liquid level, or keep the end of the TIP≤3mm below the liquid surface. Avoid immersing too deeply. 2. For higher aspiration accuracy, consider using aspiration liquid following instead of using aspiration trailing air gap.
	No leading air gap or insufficient leading air gap.	A leading air gap of 30uL is sufficient for most scenarios. Adjust based on the reagent type and remaining volume in the pipette.
	Incorrect testing method.	Please refer to the section 6.9.1 to follow the recommended test procedure for accuracy and CV.

12.2 Q & A

Q1: **Why did the pipettor work yesterday but suddenly stop working today? / Why can’t I communicate with the device after connecting?**

1. Check the wiring, power, voltage.
2. Power off and measure the resistance between the 24V (red) and GND (black) terminals. If there’s a short circuit, the board is likely damaged. Contact us for repair.
3. Verify wiring sequence, serial port, or CAN configuration.
4. Use the default address (1) for sending commands, as described in Section 5.
5. Ensure a resistance of 60 Ω between CAN/RS485 phases and minimize transmission distances.
6. Confirm the RS232 three-wire connections: Rx → Tx, Tx → Rx, GND → GND.

Q2: **What should I do if water/reagent is drawn into the pipettor?**

1. Immediately stop using the pipettor. Dry the device and let it air-dry for 48 hours before testing the liquid level detection function.
2. If the liquid level detection function fails or returns errors, send the device back to the manufacturer for repair.

Q3: **How can I use the Axis-Z with the SP16? / How is liquid level detection achieved?**

1. Use the ADP_CompositeFunctionController.exe software to control both the pipettor and Axis-Z together, as detailed in Section 5.

2. Special symbols like "*" can enable simultaneous Axis-Z descent and ADP liquid level detection.

Q4: How do I use TIP presence detection, aspiration of air and clot TIP detection features?

1. Refer to Table 10-12 for details on Register 43 and Register 60.
2. When TIP presence detection is enabled, executing aspiration/dispense or liquid level detection commands without a TIP will trigger an error (state 20).

Q5: Liquid Level Detection is not sensitive? / Unable to detect liquid level? / Liquid level detection failure?

1. It is recommended to execute the liquid level detection command after a 500ms Axis-Z descent in the workflow.
2. Water ingress during debugging can cause function failure.
3. Do NOT reuse TIPS.
4. For filtered TIPS, poor filter quality may affect liquid level detection performance.

Q6: What ' s the difference between single dispense and aliquot-dispense? How should aspiration parameters be set?

1. Single Aspiration-Single Dispense: Aspirate 100uL and dispense the entire 100uL into one tube. Use the recommended flow: leading air gap → aspiration → dispensing. Leave aspiration cut-off velocity, dispensing re-aspiration volume, and dispensing cut-off velocity at default values to maintain accuracy and CV.
2. Single Aspiration-Multi Dispense: Aspirate 1000uL and dispense 20uL into different tubes up to 50 times. Configure re-aspiration volume and cut-off velocity specifically for this case, referring to Table 6-4 for guidance.

Q7: How can I fully dispense or empty the reagent?

1. Recommended flow: Leading air gap of 30uL → aspirate 20uL → dispense 50uL. The leading air gap volume is flexible within the maximum volume of 1040uL.
2. Use the Mp command to achieve full dispensing or reset position.

Q8: Why won' t the TIP eject or certain commands execute?

1. Verify that the command was sent successfully and that the device acknowledged it.
2. Check the device's return information and status for errors or LED indications.
3. For reliable communication, use a query-response model and send subsequent commands only after receiving responses.

Q9: Is there a DEMO library?

1. We provide STM32 microcontroller demo code and C/C# host software reference code.

Q10: Which communication method is recommended?

1. Recommended: KT_CAN_DIC protocol with automatically reporting for action

completion or error codes.

2. For serial port communication, use the KT_OEM protocol with response-based transmissions. Ensure a minimum 10 ms delay between frames.

Q11: How can I ensure every command is received successfully?

1. Use KT_CAN_DIC commands with sequence number for one-to-one mapping of responses and transmissions.
2. Wait for a response before sending the next command. If a response times out, resend the command.

Q12: How do I confirm action completion? / Can action completion trigger a flag?

1. During action execution, query the device's state: "busy." The device returns to "idle" upon completion.
2. KT_CAN_DIC heartbeat status changes from 1 ("busy") to 0 ("idle").
3. Refer to Register 82 for action completion reporting.

Q13: Why aren’t modified parameters retained after restarting?

1. Follow Section 5.6 for proper parameter setup (do not modify system parameters unnecessarily).
2. Ensure a complete power cycle if using a switch power supply.
3. Note that some parameters are not saved during power-down.

Q14: How can I verify successful reagent aspiration?

1. Enable Axis-Z following during aspiration to ensure the TIP reaches the reagent.
2. Set Register 60 to enable air-gap detection. If the air-gap volume reaches the detection standard, the device returns an error (state 25).

Q15: What if the device reports an error?

Record the status of the device feedback and the current execution process when the error is reported. If the following solution measures do not provide effective help, please contact us. Some of the status trigger scenarios and solution measures:

1. Error status 10～ 16 (DEC below): check parameter case, parameter writable range.
2. Error Condition 17～ 18: Initialization the unit before controlling aspiration and dispense or action.
3. Error state 20: Register 43 enables this warning function, which sends a aspiration/dispense/level detection command to feed back this error when no TIP is detected, and suggests stopping the operation to prevent the reagent from being sucked into the device cavity.
4. Error status 21: Detecting TIP in place at the end of the execution of the push TIP command feeds back this error, checking whether the TIP is installed too tightly, avoiding repeated use of the TIP, etc.
5. Error Condition 22: Liquid level not detected within the specified time of performing liquid level detection Feedback on this error ensures that the TIP has access to the reagent during pipettor descent.

6. Error Status 23-25: Register 60 enables this warning function, which feeds back such error when abnormal air pressure is detected during liquid aspiration, adjusts according to the user's process, and allows the device to continue to be controlled when the error is reported.
7. Error status 50～ 55: We recommend contacting our company for assistance.

Q16: How can I test the gas tightness of a pipettor?

1. Our leakage testing equipment can measure pressure leakage with a precision of up to the Pa level.
2. Convenient Method:

In standby mode, at room temperature, install a clean, non-conductive, non-filter 1000uL TIP.

Aspirate 1000uL of pure water, then let the system stand for 30 seconds.

Verify no leakage from the TIP TIP.

3. Important Notes:

Ensure the TIP is securely attached. During aspiration, avoid inserting the TIP too deeply into the liquid to prevent droplet.

Leakage from organic reagents like ethanol is normal.

Q17: How should Register 60 be configured for detecting aspiration abnormalities?

1. Refer to Table 12-5. For example, writing Wr60,5 enables detection for air-gap and clot detection only.

Table 12-5 Register 60 Function Configuration

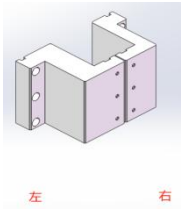
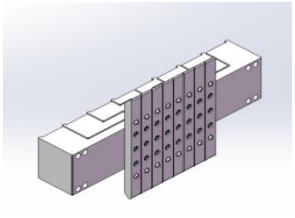
DEC	Bit2	Aspiration of Empty Detection	Bit1	Aspiration of Foam Detection	Bit0	Aspiration of Clot Detection
0 (default)	0	Off	0	Off	0	Off
1	0	Off	0	Off	1	On
2	0	Off	1	On	0	Off
3	0	Off	1	On	1	On
4	1	On	0	Off	0	Off
5	1	On	0	Off	1	On
6	1	On	1	On	0	Off
7	1	On	1	On	1	On

Q18: What is the role of RS485/CAN termination resistors?

Without termination resistors, self-oscillation may occur on the communication bus. Adding termination resistors improves communication reliability and stability.

13 Accessory Ordering information

Table 13-1 Accessories List

Name	Remarks	Illustration
Single Adapter Plate	Single pipettor with our Axis-Z	
Foldable Right Adapter Foldable Left Adapter	With Keyto Axis-Z	
Multi unit SP16 Adapter Plate-4 Multi unit SP16 Adapter Plate-3 Multi unit SP16 Adapter Plate-2 Multi unit SP16 Adapter Plate-1	2-unit:(adapter plate-2)*2 4-unit:(adapter plate-1,2)*2 8-unit:(adapter plate-1,2,3,4)*2 With Keyto Axis-Z	
Cover Plate Screws	M1.6*3*2.5 small countersunk head Phillips screws	/
50/200/1000uL TIP	Overall length 57.85/58.45/95.75mm	/

14 Environmental Conditions

Table 14-1 Environmental Conditions

Item	Unit	Value
Operating environmental temperature	℃	+15℃～+35℃
Operating environmental humidity	RH%	40%～80% non-condensing
Storage temperature	℃	-20℃～+70℃
Storage humidity	RH%	40%～80% non-condensing

15 Safety Precautions

For your and other users' safety, please read the safety precautions carefully.

This manual uses the following marks. Please fully understand what they mean before reading on.

WARNING 	Any content with this mark, related to the safe use of the product and the user's safety, must strictly follow the requirements of the operation, otherwise, it may cause damage to the product or endanger the user's safety.		
CAUTION 	Any content with this mark is a part of the user must pay attention to, otherwise, it will cause damage to the product or other losses due to improper operation.		
	Must operate as warned, with specific warnings or caution messages described within the triangle.		Actions that must be prohibited, with specific prohibitions described in circles.
	Important commands or actions must be performed.		
 CAUTION			
	Please turn off the power when it is idle for a long time or when the whole machine is repaired, otherwise, it will cause fire or electric shock.		Do not put it in wet, dusty, greasy environment or close to heat generating equipment, otherwise, it will cause product failure, even malfunction, fire or electric shock.
	Prohibit hot-swapping any serial port interface cable, motor cable, optocoupler cable or valve power cable, otherwise, it will cause communication or other parts to fail.		If there is a long-term non-use of the hole please use the matching plug, otherwise, may cause impurities and airflow into the pipettor body and affect normal use.
	It is forbidden to disassemble the valve or adjust any parameters by yourself, otherwise, the valve may not work properly.		
 WARNING			

	Do not disassemble Do not disassemble, repair or modify the product by yourself, otherwise, it may cause fire or electric shock.		Avoid use in wet environments Moisture may cause electric shock.
	Cut off the power when abnormal If there is an abnormal situation, immediately cut off the power. Otherwise, it may cause fire or electric shock.		Protection when using corrosive fluids Strictly follow the applicability medium of the specification book to use, when using corrosive fluids must pay attention to protection.

Contact Information

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16 Appendix of Figures and Tables

Figures

Tables