SP28 Pipettor Manual

—SP28 Series

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目录

1 Product Overview

SP28 is a pipetting module developed by Keyto. Functions include automatic TIP pick up and ejection, liquid level detection,etc; Keyto SP28 offers a swift and reliable mechanical adapter module, as well as common communication interface, which are suitable for integration in transfer liquid platforms and transfer liquid units of laboratory equipment that are sensitive to cross-contamination, providing a reliable & high-performance pipetting module for all types of instruments.

1.1 Ordering Information

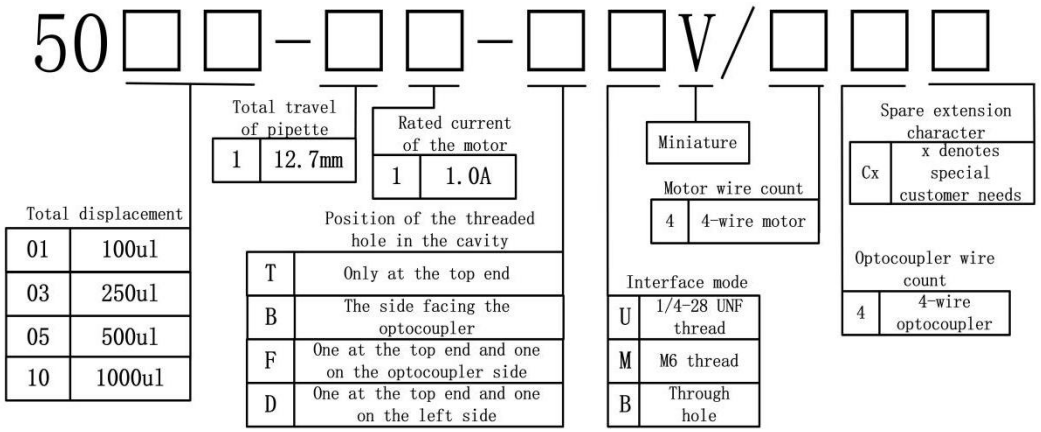


Figure 1-1 SP28 ordering information

Notes:

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

1.2 Main Features

◆ SP28 is equipped with a excellent-performance drive control unit, and provides CAN, RS232 and RS485 communication interface and the corresponding protocol, allowing SP28 achieve mulTIPle functional applications easily and quickly by the host controller.

◆ SP28 is driven by a step motor that enables precise aspiration and dispensing at high velocity.It supports automatically TIP pick up and ejection.

◆ SP28’s volume is optional, from 100 uL to 1mL.

◆ The end position of SP28 has optical detection, It can detect whether the SP28 is with TIP.

◆ SP28 Integrated Pressure Liquid Level Detection function and clot detection function.

◆ SP28 has advanced Pipetting barrel processing technology, strict inspection procedures, and unique sealing solutions 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 SP28
- **Response**：from SP28 to Host
- **Device**：SP28

2 Product Specifications

2.1 Specifications Table

Table 2-1 SP28 Specification table

Spec	SP28			
Max volume(uL)	100	250	500	1000
Volume per step(ul/step)	0.05	0.125	0.25	0.5
Pipetting life	1 million cycles			
Operating pressure (MPa)	≤0.06			
Liquid level detection	PLLD			
Stroke (mm)	12.7			
Lead (mm)	1.27			
Stroke/step(mm)	0.00635			
Communication	RS232、RS485、CAN			
Baud rate	Serial port: 9600, 19200, 38400 (default), 115200 CAN: 100K, 125K, 250K, 500K (default), 1000K			
TIP compatibility	10, 50, 200, 1000ul			
Installation	Three sides mounting			
working medium	Air			
Weight (g)	<500g			

2.2 SP28 Pipetting Performance

Table 2-2 SP28 Pipetting Performance

TIP volume/ul	Pipetting volume/ul	Pipetting type	CV
50 (with fliter)	5	Single Aspirate & Dispense	5.0%
50	10		3.0%
200 (with fliter)	10		4.0%
200	50		2.0%
1000	20		3.0%
1000 (with fliter)	20	Single Aspirate aliquot dispense	5.0%
1000	50		3.0%

1. The test environment is 21～25℃ (no wind),Medium is Pure water.
2. The test method is non-contact dispense method(Suspended dispensing liquid).
3. Replace the TIP with a new one after each test.
4. If the dispensed volume is inaccurate, increase the compensation value. For single aspiration, apply aspiration compensation as needed. in generally practice, single aspirate aliquot dispense does not need to do compensation.

	*Notice: disposable TIP are non reusable, please do not reuse TIP.*

A(Accuracy):refers to the deviation degree between the result of measurement and actual value

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

CV(Coefficient of Variation):allows for an objective and accurate reflection of the dispersion degree within a set of data.

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

Notes:

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.

2.3 SP28 Series Dimension

2.3.1 Design 1

Automatic TIP ejection design

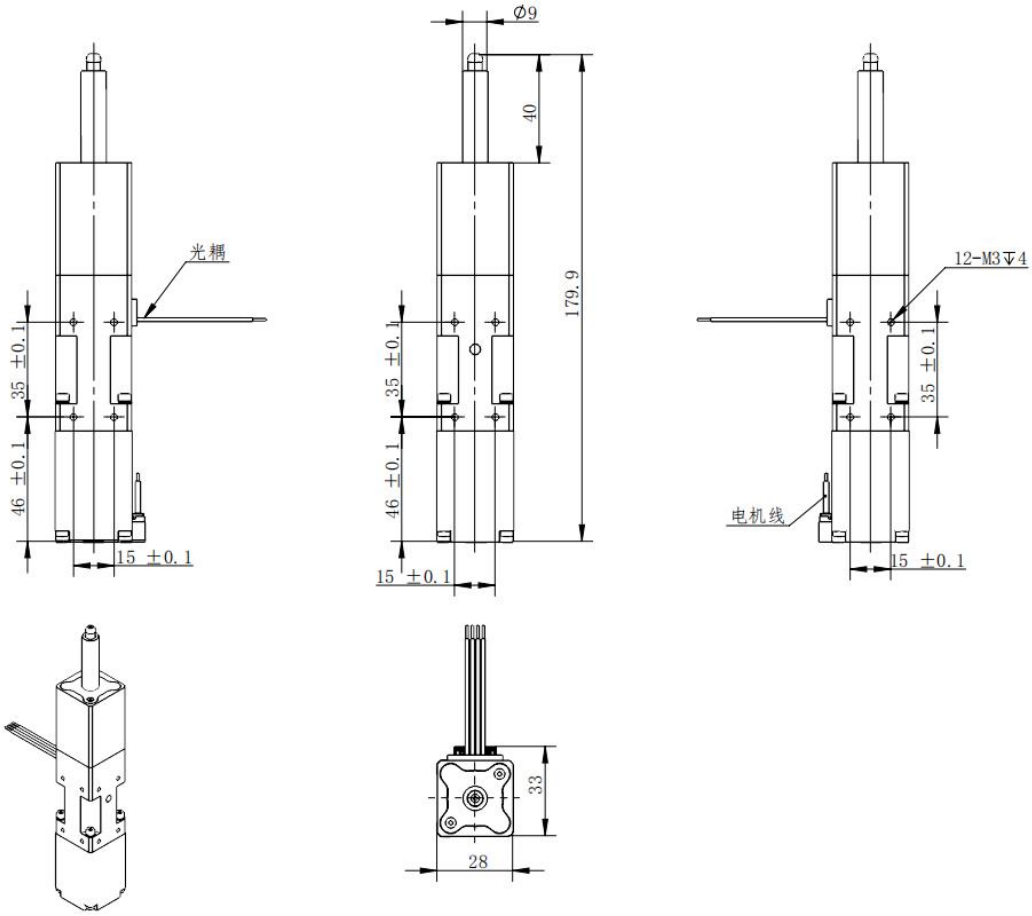


Figure 2-1 SP28 dimension and mounting Figure

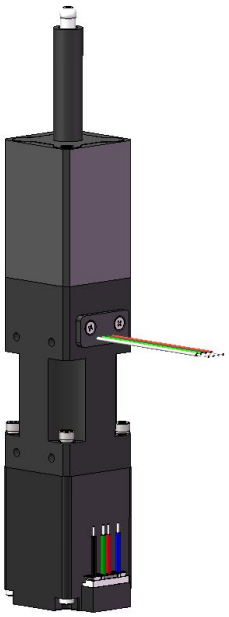


Figure 2-2 SP28 Product Figure

2.3.2 Design 2

Automatic TIP ejection design+TIP Presence Detection design

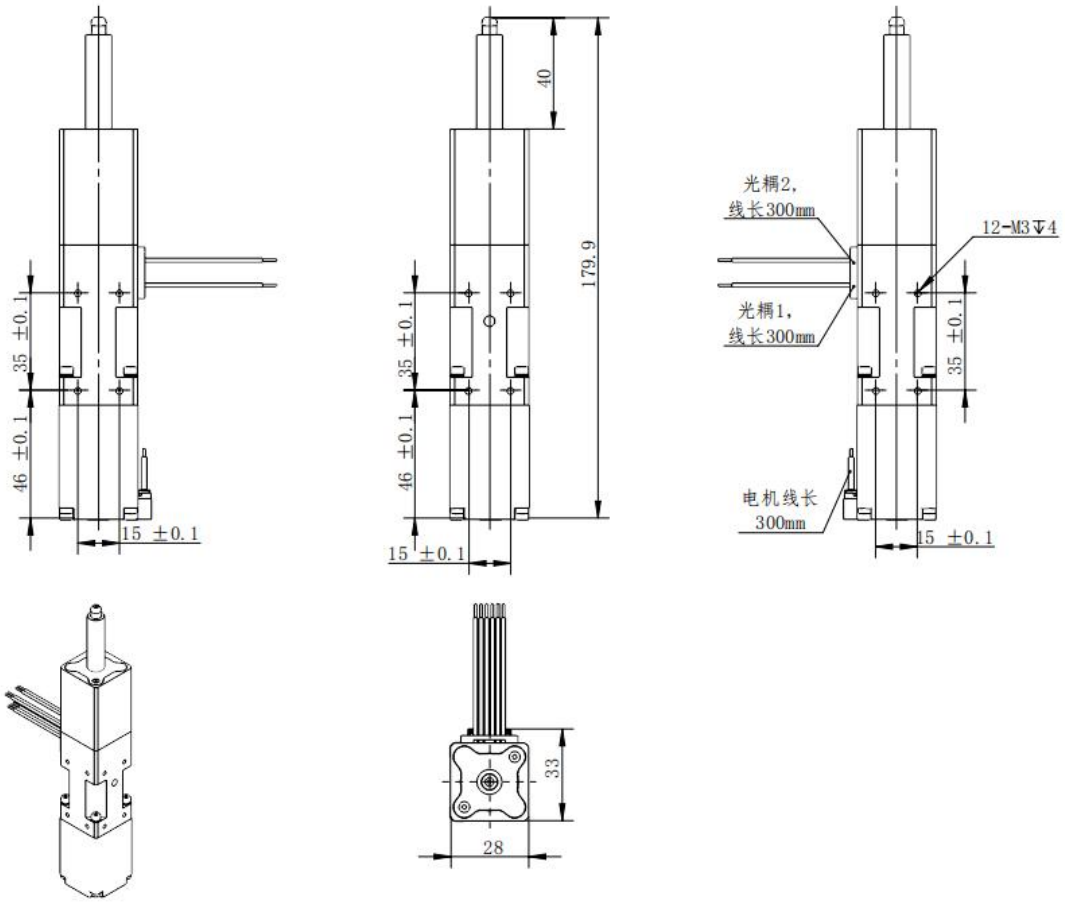


Figure 2-3 SP28 dimension and mounting Figure

Figure 2-4 SP28 Product Figure

2.3.3 Design 3

Automatic TIP ejection design+Liquid level detect design+TIP Presence

Detection design

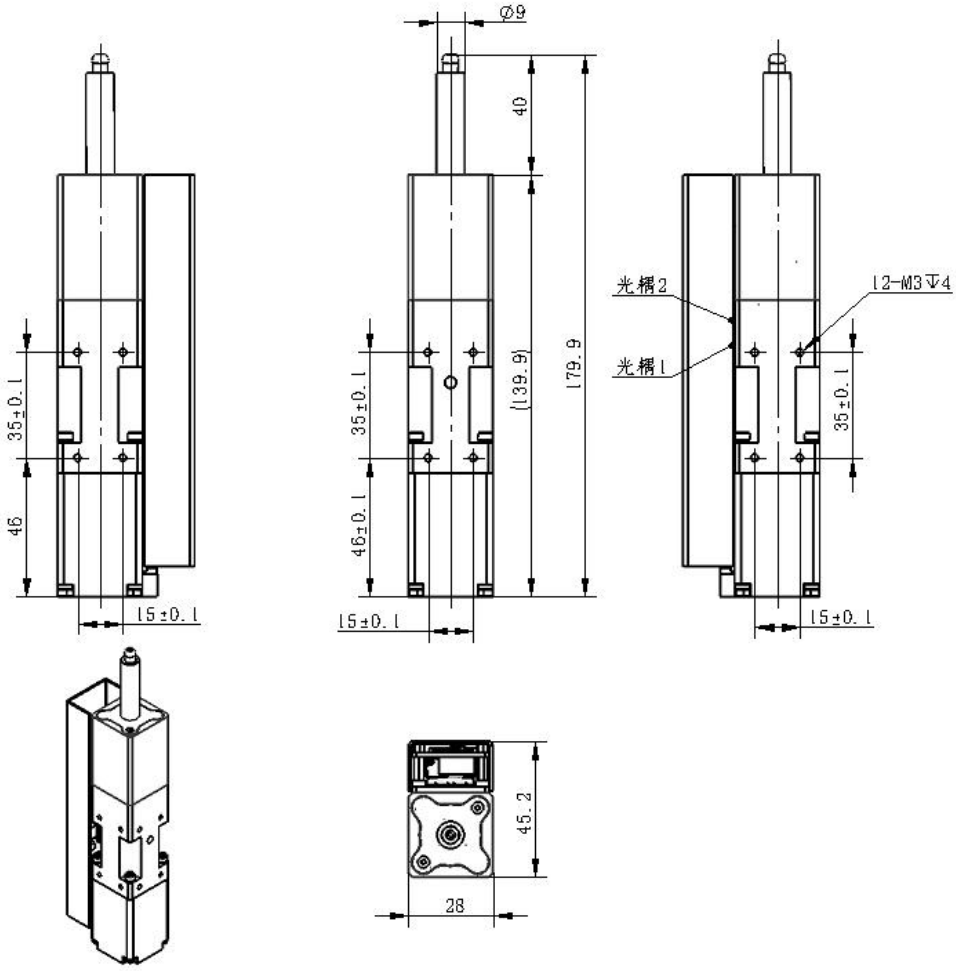


Figure 2-5 SP28 dimension and mounting Figure

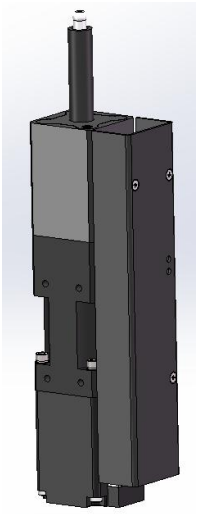


Figure 2-6 SP28 Product Figure

2.3.4 Design 4

Design 3 with 18mm center distance, 2-channel pipettor design

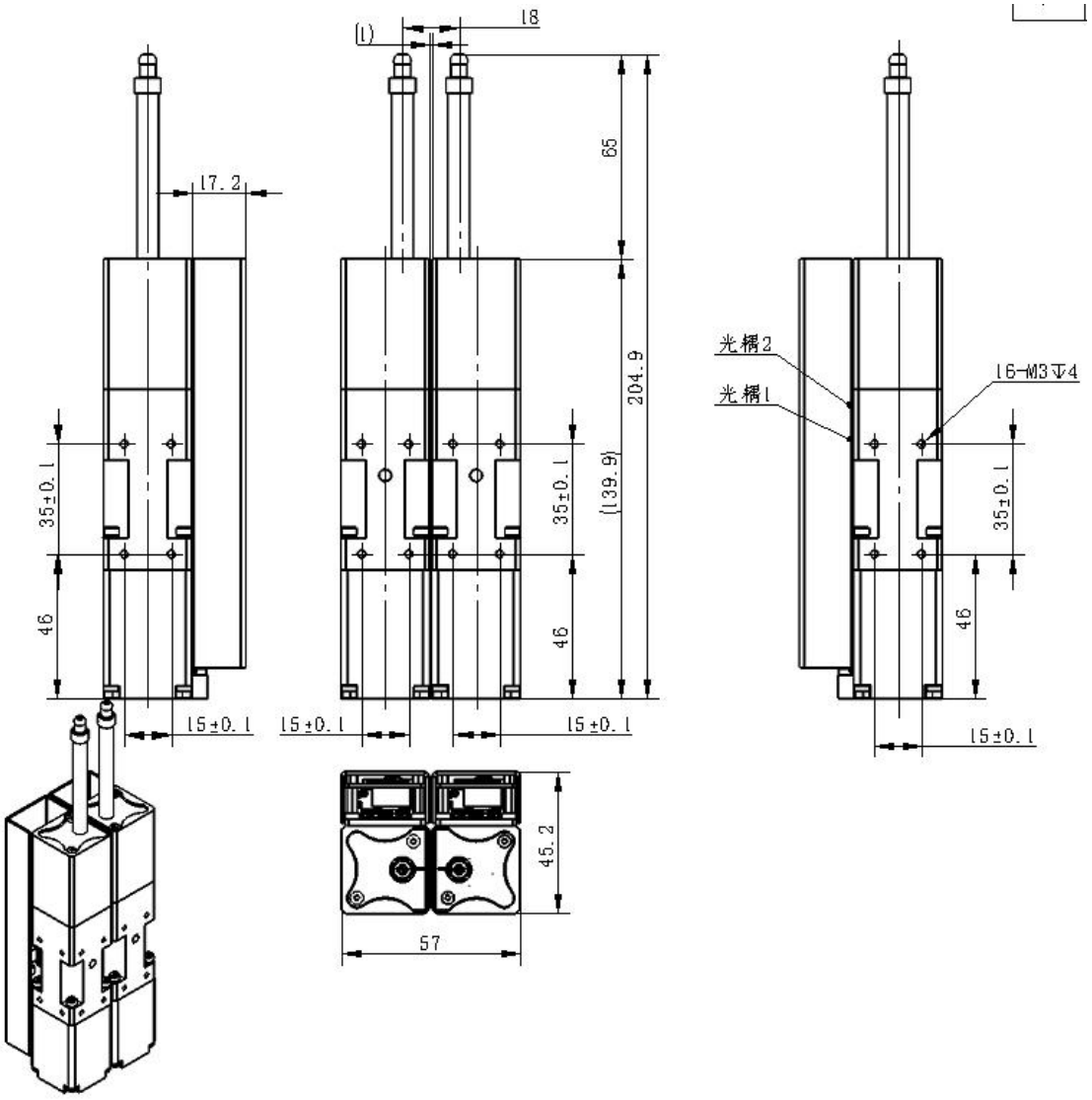


Figure 2-7 SP28 design 4 dimension and mounting Figure

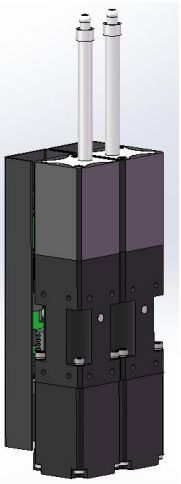


Figure 2-8 SP28 Product Figure

2.3.5 Design 5

Design 3, with 9mm center distance, 2-channel pipettor design

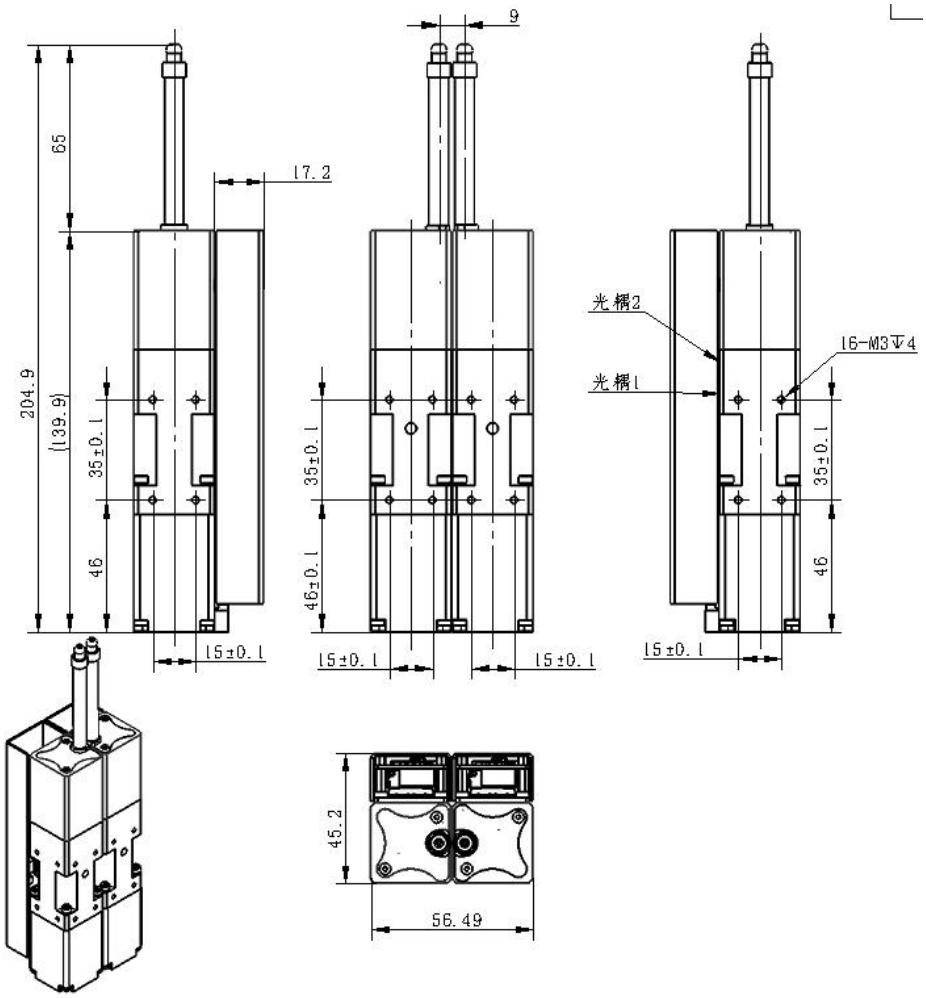


Figure 2-9 SP28 Design 5 dimension and mounting Figure

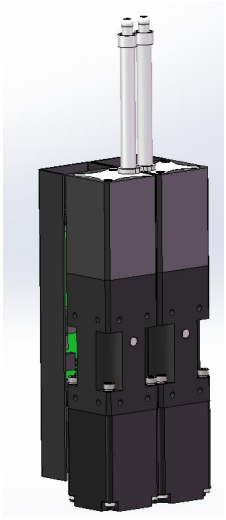


Figure 2-10 SP28 Design 5 Product Figure

3 Product Electrical Interface

3.1 Hardware Interface

The SP28 is connected to the external control system using a highly flexible towline cable, The cable core is AWG26, and the power supply is 24V±5% DC, the peak RMS current does not exceed 540mA, and the RMS current does not exceed 430mA. The cable must be connected or disconnected when the power is off. Grounding is required when using CAN and RS232 communication systems:

⚠	*Warning:* *Unused cores should be insulated!* *Cable connections or disconnections should only be performed with the power turned off!*

Table 3-1 Core definition of the communication cable

Function	Cable Color	Remarks
DC 24V+	Red	Power input 24±5%, current≥1A
GND	Black	Grounding
RS232-RX	Green	Communication Interface
RS232-TX	Blue	Communication Interface
RS485A	Orange	Communication Interface
RS485B	White	Communication Interface
CAN L	Yellow	Communication Interface
CAN H	Yellow-green	Communication Interface
GPO 1	Purple	PLLD GPO, 5V level
GPO	Brown	Reserved

❗	*Note:Reduce the RS485/CAN transmission distance as much as possible. When the communication is unstable, please add 120Ω termination resistance to the first and last device on the bus, and keep the two-phase resistance at 60Ω.*

GPO1 interface schematic circuit is shown as below:

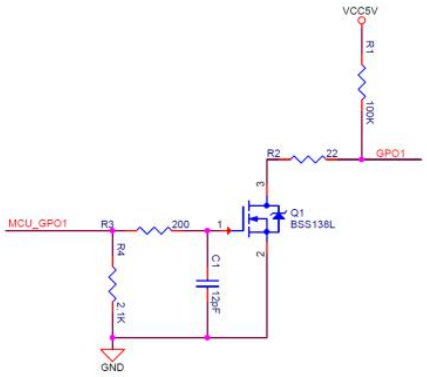
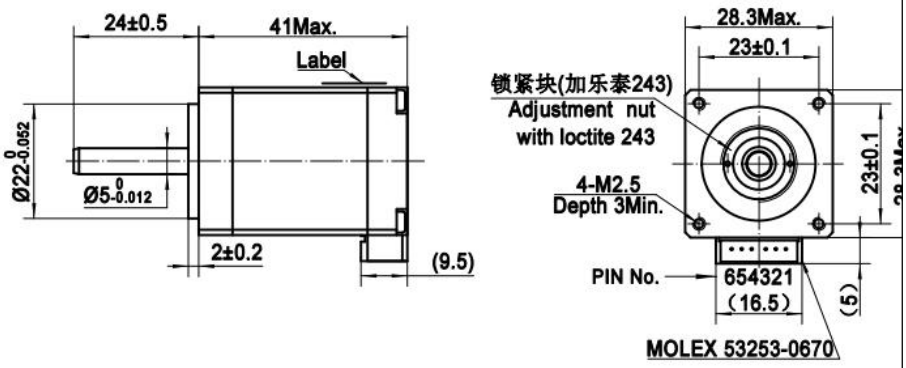
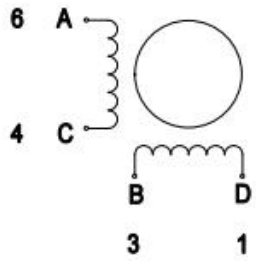


Figure 3-1 The GPO1 circuit

	*Note: TVS should be added on customer PCBA for GP01*

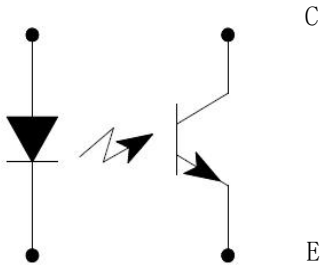
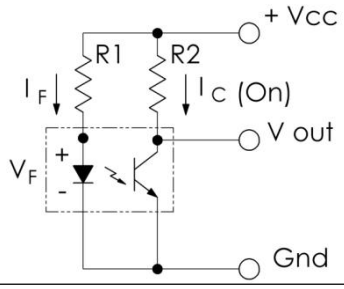
3.2 Stepper Motor

Table 3-2 Stepper Motor parameters

	1A MOTOR	
Dimension		
Wiring Instruction	接线图 Wiring Diagram 	联接器针位vs.引线颜色 Pin No. vs. Lead Wire Colour 51065-0600 PIN No. / 颜色 Color 1 BLUE/蓝 2 N/A 3 RED/红 4 GREEN/绿 5 N/A 6 BLACK/黑
Electrical Specification	Lead wire length	300±10mm
	Step angle	1.8°
	Rated voltage	3.7 V
	Rated current	1A
	Resistor	3.7ohm±10%（20℃）
	Inductance	2.8 mH±20%（1Khz 1Vrms）
	Holding torque	≥0.12N.M
	Rotational inertia	12 g-cm2
	Maximum speed	6r/s
Current Setting	The output current is set equal to or slightly less than the rated motor current	

3.3 Optocoupler

Table 3-3 Optocoupler parameters

<table>
<tr><th></th><th colspan="3">Four-wire optocoupler</th></tr>
<tr><td>Schematic diagram</td><td colspan="3"> 
</td></tr>
<tr><td rowspan="5">Wire definition</td><td>Lead Wire Colour</td><td colspan="2">Electrical signal</td></tr>
<tr><td>Red</td><td colspan="2">Anode</td></tr>
<tr><td>Black</td><td colspan="2">Cathode</td></tr>
<tr><td>White</td><td colspan="2">Collector</td></tr>
<tr><td>Green</td><td colspan="2">Emitter</td></tr>
<tr><td>Application example</td><td colspan="3"> 
</td></tr>
<tr><td rowspan="9">Electrical specification</td><td colspan="3">Input Diode (E)</td></tr>
<tr><td>Input Diode Power Dissipation</td><td>70mW(max)</td></tr>
<tr><td>Input Diode Forward D.C. Voltage</td><td>2V</td></tr>
<tr><td>Forward Voltage(VF)</td><td>1.8V(max)</td></tr>
<tr><td colspan="3">Output Emitter (S)</td></tr>
<tr><td>Collector-Emitter Voltage</td><td>30V(max)</td></tr>
<tr><td>Output Philological Power Dissipation</td><td>80mW(max)</td></tr>
<tr><td>Emitter -Collector Voltage</td><td>5V(max)</td></tr>
<tr><td>Collector DC Current</td><td>30mA(max)</td></tr>
<tr><td rowspan="4"></td><td colspan="3">Collector-Emitter Saturation</td></tr>
<tr><td>VCE(SAT)</td><td>0.4V(max)</td></tr>
<tr><td>IC</td><td>400uA</td></tr>
<tr><td>IF</td><td>20mA</td></tr>
<tr><td>Reference formula</td><td colspan="3">$$R_1 = \frac{(V_{CC} - V_F)}{I_F}$$
$$R_2 = \frac{(V_{CC} - V_{CESAT})}{I_{C(ON)}}$$</td></tr>
</table>

Wiring instruction	▼ Red wire: Select a power supply voltage within the range of DC5~24V and connect a current-limiting resistor in series before use. Note: 1. The values of R1 and R2 can be calculated according to the formula and adjusted as necessary. 2. When VOUT (white wire) is used as a PLC input, consider whether to connect an amplification circuit based on the PLC input current. When connected to +3.3V, the recommended resistance value of the series resistor R1 is 84.5 ohms. When connected to +5V, the recommended resistance value of the series resistor R1 is 160 ohms. When connected to +12V, the recommended resistance value of the series resistor R1 is 510 ohms. When connected to +24V, the recommended resistance value of the series resistor R1 is 1K ohms. ▼ Black wire: Connect to the negative terminal of the power supply. ▼ White wire: Signal output wire. Connect to the positive terminal of the logic power supply with a voltage of 5V~24V (if necessary, connect a pull-up resistor R2). Note: The output driving capability of the photoelectric switch is weak, and it is recommended to be less than 1mA. When connected to +3.3V, the recommended resistance value of the series resistor R2 is 10K ohms. When connected to +5V, the recommended resistance value of the series resistor R2 is 20K ohms. When connected to +12V, the recommended resistance value of the series resistor R2 is 50K ohms. When connected to +24V, the recommended resistance value of the series resistor R2 is 100K ohms. ▼ Green wire: Connect to the negative terminal of the logic power supply

3.4 RS485/CAN Connection Topology Diagram

For RS485, it is recommended to reduce the number of bus devices,favoring one-to-one communication, which helps enhance communication efficiency and reliability.

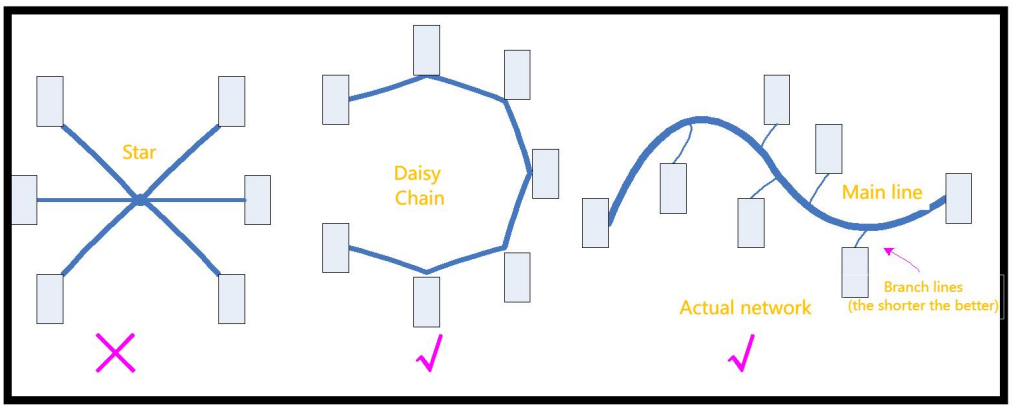


Figure 3-2 Topology Diagram

4 Installing and Debugging

4.1 Mounting the SP28

As shown in Figure 4-1, mount the SP28 within the ADPZ-axis or vertical plane. When using the SP28 alone, you can use the provided 10-core highly flexible towline and connect it according to Table 4-1. When using the SP28 with Keyto ADPZ-axis, insert the ADPZ-axis 10-core cable into the SP28, and connect the ADPZ-axis 8-core highly flexible cable according to Table 4-1. Users should refer to the matching colors for both the 10-core and 8-core cables. Relevant accessories are go with the goods.

	Notice: *Cable connections or disconnections should only be performed with the power turned off!* *The cable plate must be firmly pressed against the 10-core cable sheath during installation!*

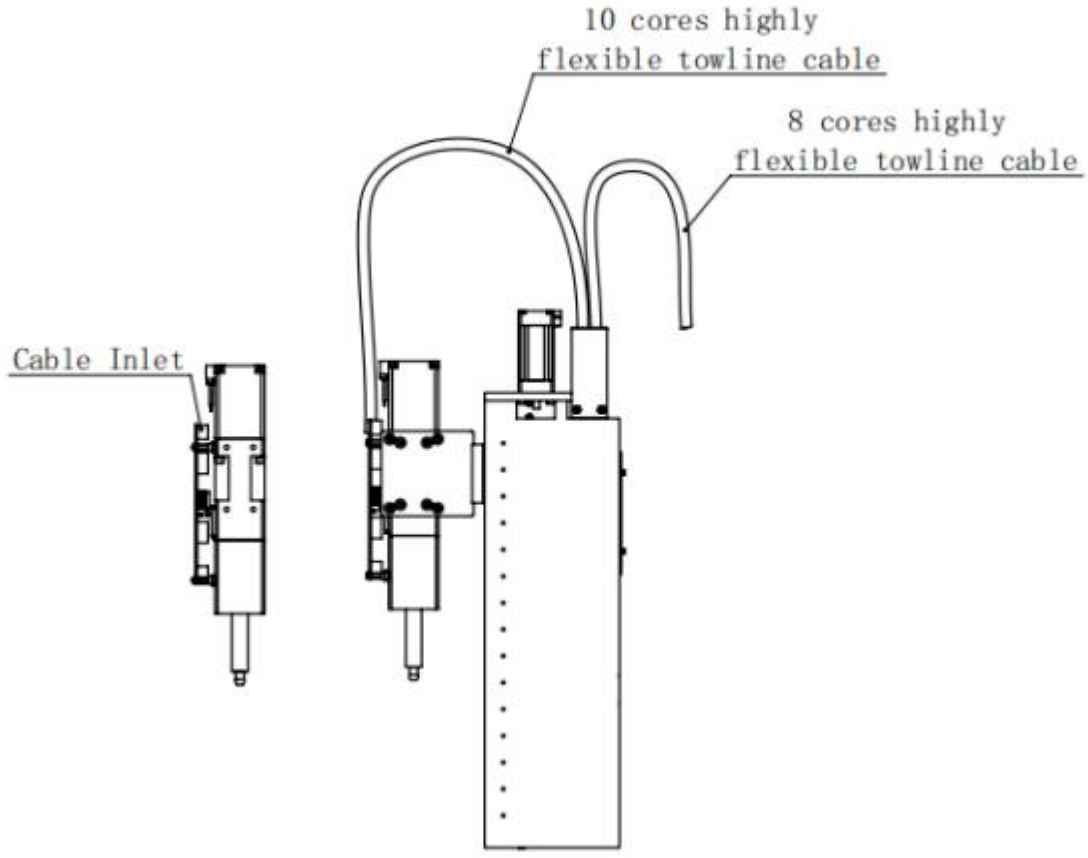


Figure 4-1 SP28 Installation Diagram

4.2 Connection of Power Supply and Communication

Cables

When using the SP28 with Keyto ADPZ-axis, insert the ADPZ-axis 8-core highly flexible cable according to Table 4-1.

Table 4-1 Quick Debugging Wiring

Function	Cable color	Description
DC 24V+	Red	Power input 24V±5%, Current≥1A
GND	Black	Grounding
RS485A	Orange	Communication interface
RS485B	White	Communication interface

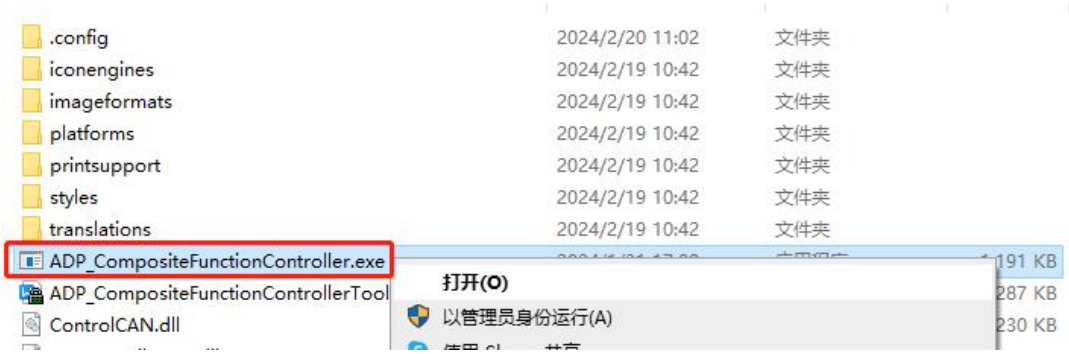
Notice: Cable connections or disconnections should only be performed with the power turned off!

5 Description of Host Computer Test Software

The host computer software enables combined control of the pipettor and ADPZ-axis of Keyto. Details about the electrical connection are described in Chapter 4.

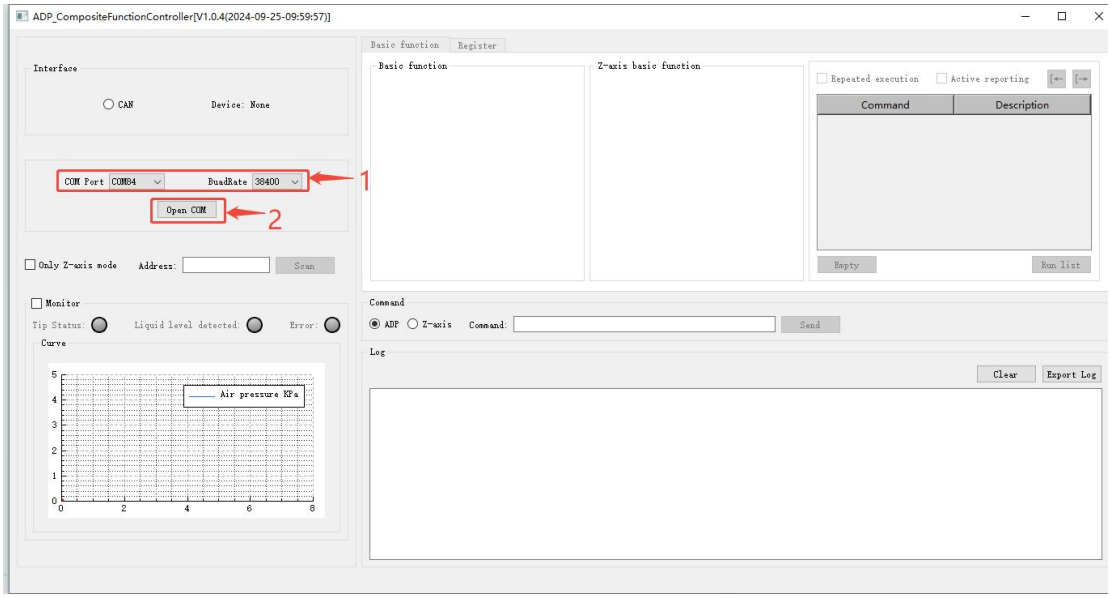
5.1 Opening the ADP Host Computer Test Software

After cable being connected and powered up the device, then open the ADP_CompositeFunctionController.exe test software:



5.2 Serial Port and Baud Rate Selection

1. Select the corresponding serial port number and the baud rate of 38400 (factory default 38400).
2. Click "open serial port" button.

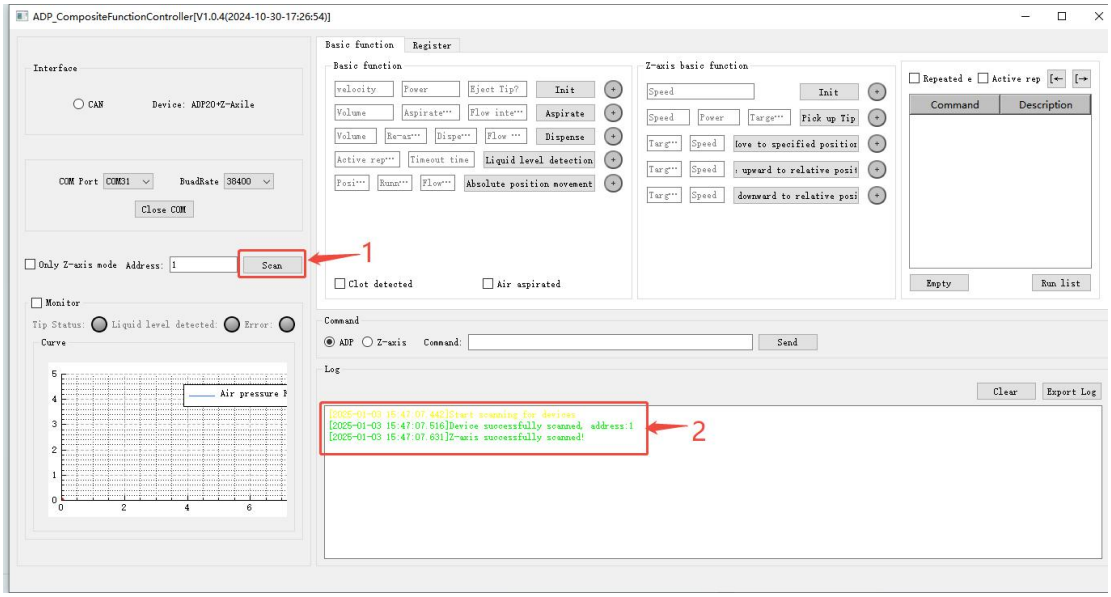


5.3 Scan Device Address

1. Click the "Scan" button, the default address is 1, the address bar will be automatically populated with the scanned address when the scan is

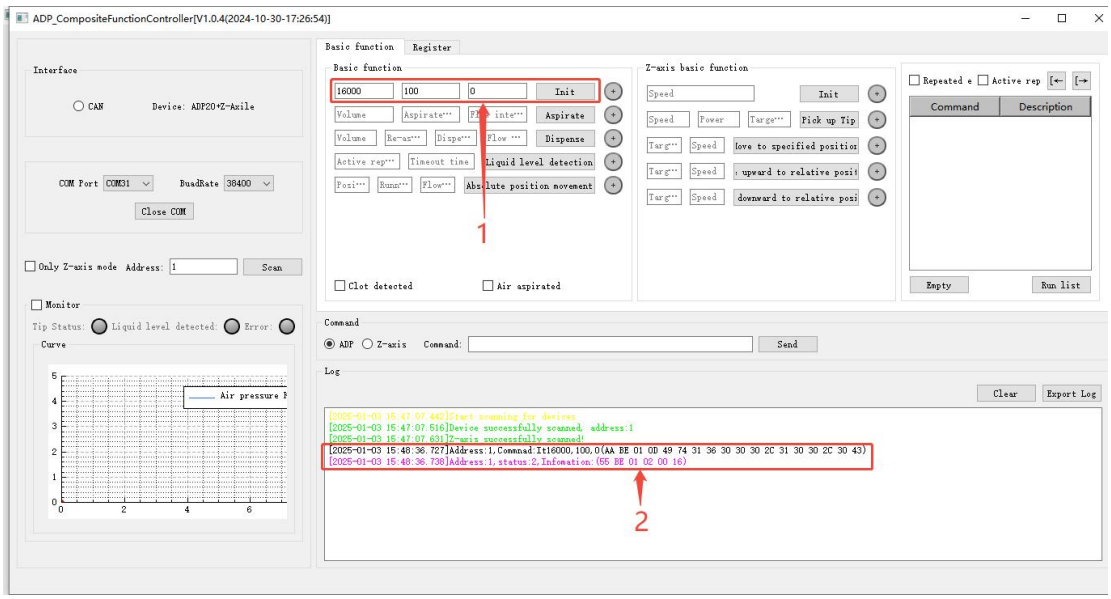
complete. Note that other device operations will only execute after addresses are scanned.

2. The log area will display the successful scanning of the device address..
3. “Device” will show current device model.



5.4 Single-step Command

1. Enter the required initialization parameters and click the ’Init’ button..

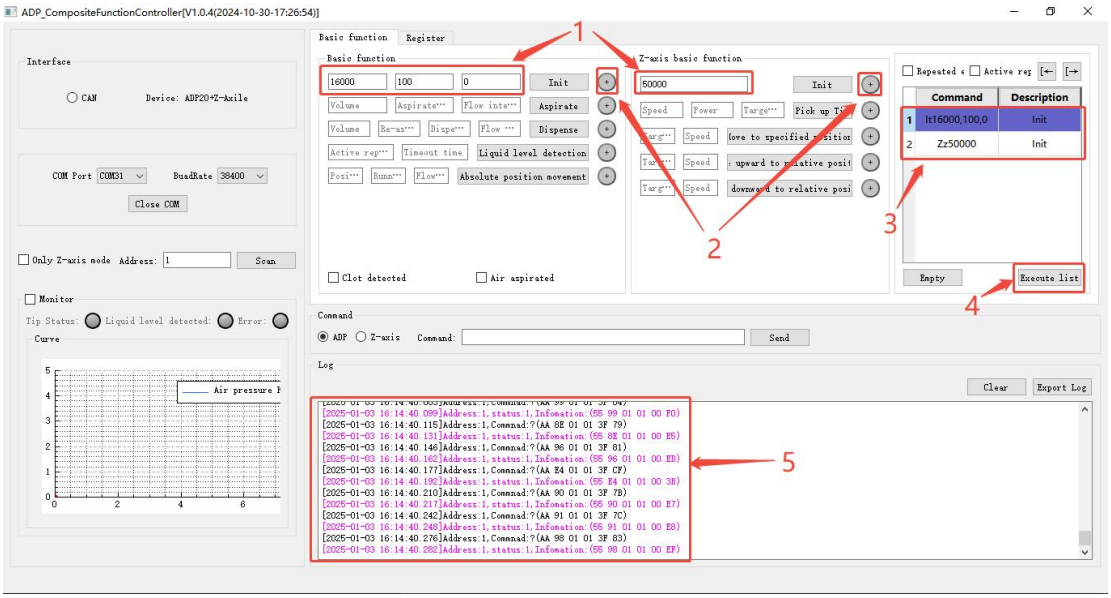


5.5 Combined Execution Command

1. Configure the ADP and ADP Z-axis command parameters separately.
2. Click the "+" button to add the command to the combined command list.
3. The command list displays the added commands, which can be modified by

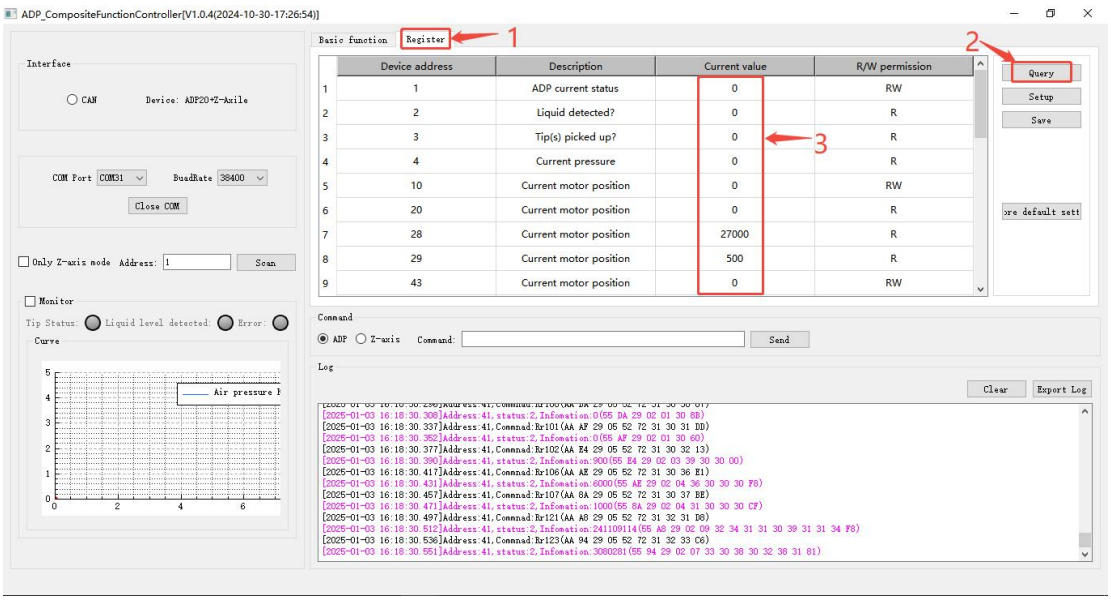
double-clicking on a command.

4. After clicking "Execute List," the host computer sends the commands sequentially. It queries the device status to determine if the current command has completed execution before proceeding to the next command.
5. The host computer checks the device status during operation. Only when the device is idle can it execute the next command.



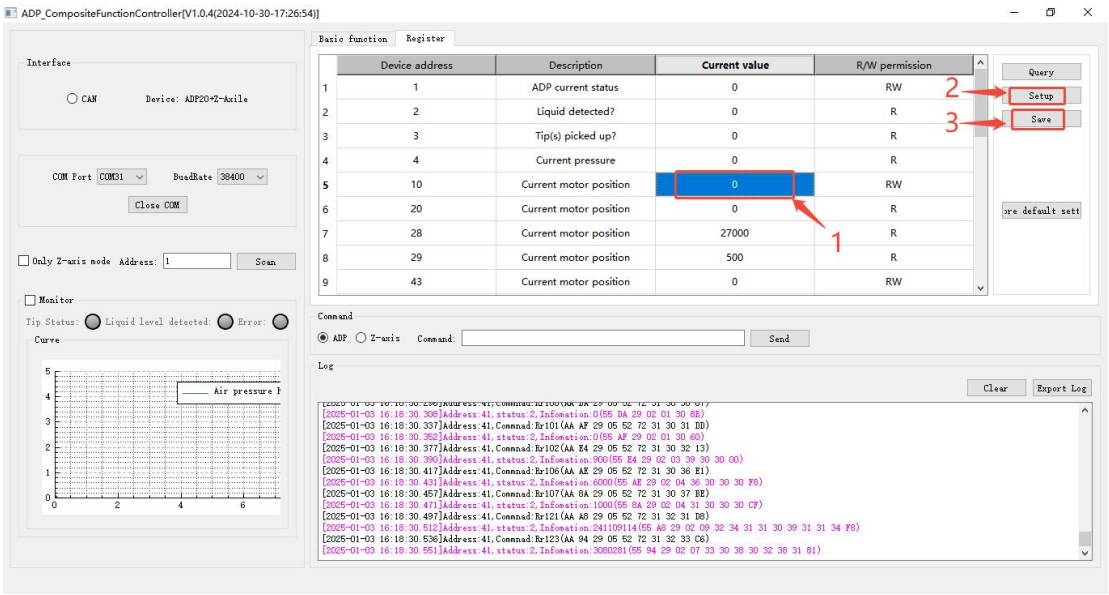
5.6 Register Query

1. Click the 'Register' button to switch to the registration interface.
2. Click the 'Query' button to have the host computer query the device registers sequentially.
3. The value of the device register will be displayed in the 'Current Value' field.



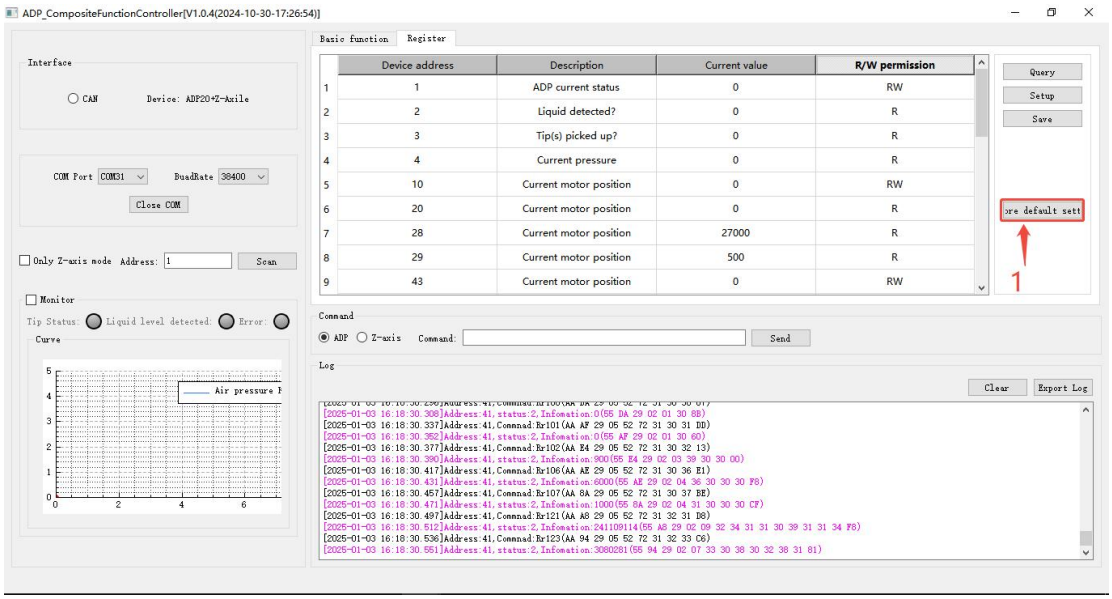
5.7 Register Parameter Settings

1. Double-click the 'Current Value' field in the register parameter line that needs modification (only values with RW permissions can be modified). Enter the new value, then press 'Enter' or click a blank area to confirm.
2. Click 'Setup' to modify the register value.
3. Click 'Save' to store the register value, which will persist after power-off..
4. Power off and restart the device. After restarting, the host computer software will need to reselect the serial port.



5.8 Restore to Factory Settings

1. Click the 'Restore Default Settings' button to reset all register settings to their factory defaults.
2. Power off and restart the device. After restarting, the host computer software must reselect the serial port.


ADP_CompositeFunctionController[V1.0.4(2024-10-30-17:26:54)]
Interface
CAN
Device: ADP20+Z-Axile
COM Port COM31
BuadRate 38400
Close COM
Only Z-axis mode Address: 1
Scan
Monitor
Tip Status: Liquid level detected: Error:
Curve
Air pressure
Basic function
Register
Device address
Description
Current value
R/W permission
1 1 ADP current status 0 RW
2 2 Liquid detected? 0 R
3 3 Tip(s) picked up? 0 R
4 4 Current pressure 0 R
5 10 Current motor position 0 RW
6 20 Current motor position 0 R
7 28 Current motor position 27000 R
8 29 Current motor position 500 R
9 43 Current motor position 0 RW
Query
Setup
Save
ore default sett
1
Command
ADP
Z-axis
Command:
Send
Log
Clear
Export Log
[2025-01-03 16:18:30.308]Address:41, status:2, Infomation:0(55 DA 29 02 01 30 8B)
[2025-01-03 16:18:30.337]Address:41, Commnad:Rr101(AA AF 29 05 52 72 31 30 31 DD)
[2025-01-03 16:18:30.352]Address:41, status:2, Infomation:0(55 AF 29 02 01 30 60)
[2025-01-03 16:18:30.377]Address:41, Commnad:Rr102(AA B4 29 05 52 72 31 30 32 13)
[2025-01-03 16:18:30.390]Address:41, status:2, Infomation:900(55 E4 29 02 03 39 30 30 00)
[2025-01-03 16:18:30.417]Address:41, Commnad:Rr106(AA AE 29 05 52 72 31 30 36 E1)
[2025-01-03 16:18:30.431]Address:41, status:2, Infomation:6000(55 AE 29 02 04 36 30 30 30 F8)
[2025-01-03 16:18:30.457]Address:41, Commnad:Rr107(AA 8A 29 05 52 72 31 30 37 BE)
[2025-01-03 16:18:30.471]Address:41, status:2, Infomation:1000(55 8A 29 02 04 31 30 30 30 CF)
[2025-01-03 16:18:30.497]Address:41, Commnad:Rr121(AA A8 29 05 52 72 31 32 31 D8)
[2025-01-03 16:18:30.512]Address:41, status:2, Infomation:241109114(55 A8 29 02 09 32 34 31 31 30 39 31 31 34 F8)
[2025-01-03 16:18:30.536]Address:41, Commnad:Rr123(AA 94 29 05 52 72 31 32 33 C6)
[2025-01-03 16:18:30.551]Address:41, status:2, Infomation:3080281(55 94 29 02 07 33 30 38 30 32 38 31 81)

6 ※Applications

6.1 Application process

The basic liquid aspirate and dispense application process generally includes single aspirate and dispense, single aspirate and aliquot dispense, such as Figure 6-1 provides the recommended single aspirate and dispense, single aspirate and aliquot dispense use of the process, section 8.4 Development Process Examples provides the recommended communication framework and the actual communication data.

Note:

1. Default single aspirate and dispense, single aspirate and aliquot dispense are non-contact dispense.
2. TIP detection :Function enabled via Register 43 configuration. The pipettor is restricted from performing aspiration if no TIP is detected.
3. Liquid aspirate empty/blocked detection: Refer to Table 9-6 register 60 pressure anomaly detection to enable.
4. Liquid level detection delay time: start the ADPZ-axis down 500ms before starting liquid level detection, in order to avoid the pneumatic liquid level detection by the ADPZ-axis jitters at start and stop.
5. Liquid level detection speed: control the liquid level detection speed of ADPZ-axis at about 20mm/s to ensure that the TIP is not more than 3mm below liquid surface.
6. Aspirate 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: A leading air gap helps prevent hanging droplets and improves dispensing precision.
8. Trailing Air Gap: A trailing air gap helps prevent liquid spillage or dripping after dispensing.
9. Leading Air Gap/Trailing Air Gap volume: For 1000ul model, SP28 has a 45ul margin to aspirate the air, the total aspirate volume must less than 1045ul. The aspirated volume depends on the application. When it is less than 1045 μL, a leading air gap of more than 30 μL is recommended.
10. Single aspirate and aliquot dispense data:it is recommended to discard the first and end of the liquid dispense data(accuracy is poor), you can dispense back to the reagent drums or waste tanks.
11. Single aspirate and aliquot dispense parameters: you need to set the volume of Re-aspiration and cut-off speed to achieve a better accuracy and CV, refer to section 6.7.
12. Single aspirate and dispense parameters: do not need to set the volume of liquid aspiration back and cut-off speed, recommend both two parameters to maintain the default value of 0.
13. Liquid dispense: During dispensing, ensure that the TIP remains inside the

container to prevent splashing.

	*Warning: When aspirating, ensure that the aspiration volume does not exceed the capacity of the TIP currently in use.*

14. For example: When use 200ul TIP, SP28 are not allowed to aspirate liquid more than 200ul!
15. Except alarm status, add additional exception handling measures, for example:
    - When failing to pick up TIP, first send TIP eject command to avoid TIP hanging on the nozzle, then try to change the plate position to pick up TIP again(avoid failing to pick up TIP due to TIP difference).
    - When liquid level detecting, need to set the lower limit to avoid hitting bottom. If the same liquid level is used in mulTIPle applications, liquid level height judgement can be added to ensure that the liquid level height of each pipettor is basically the same, to avoid early triggering of liquid level detection due to TIP differences.

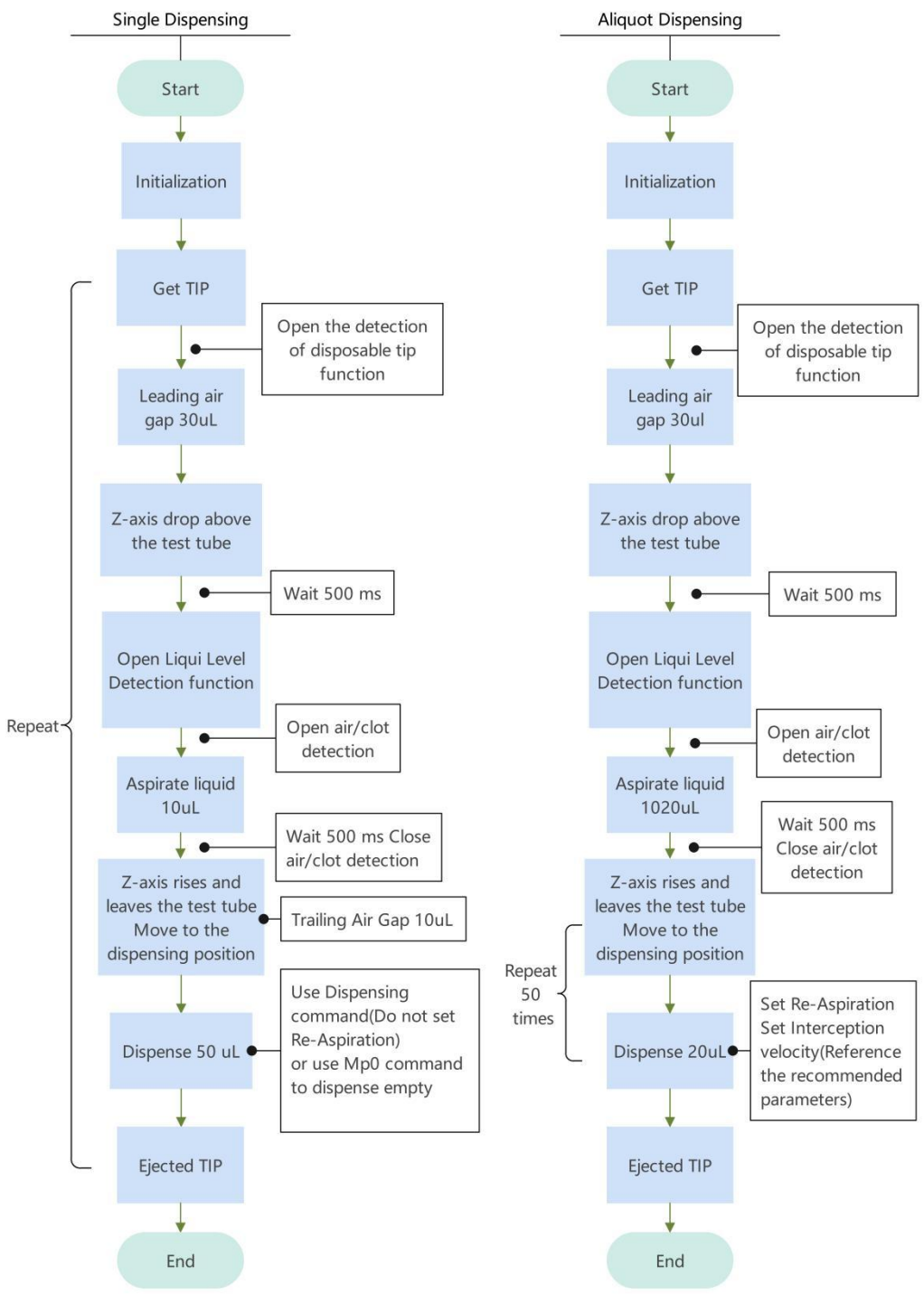


Figure 6-1 Aspiration and Dispense Flow

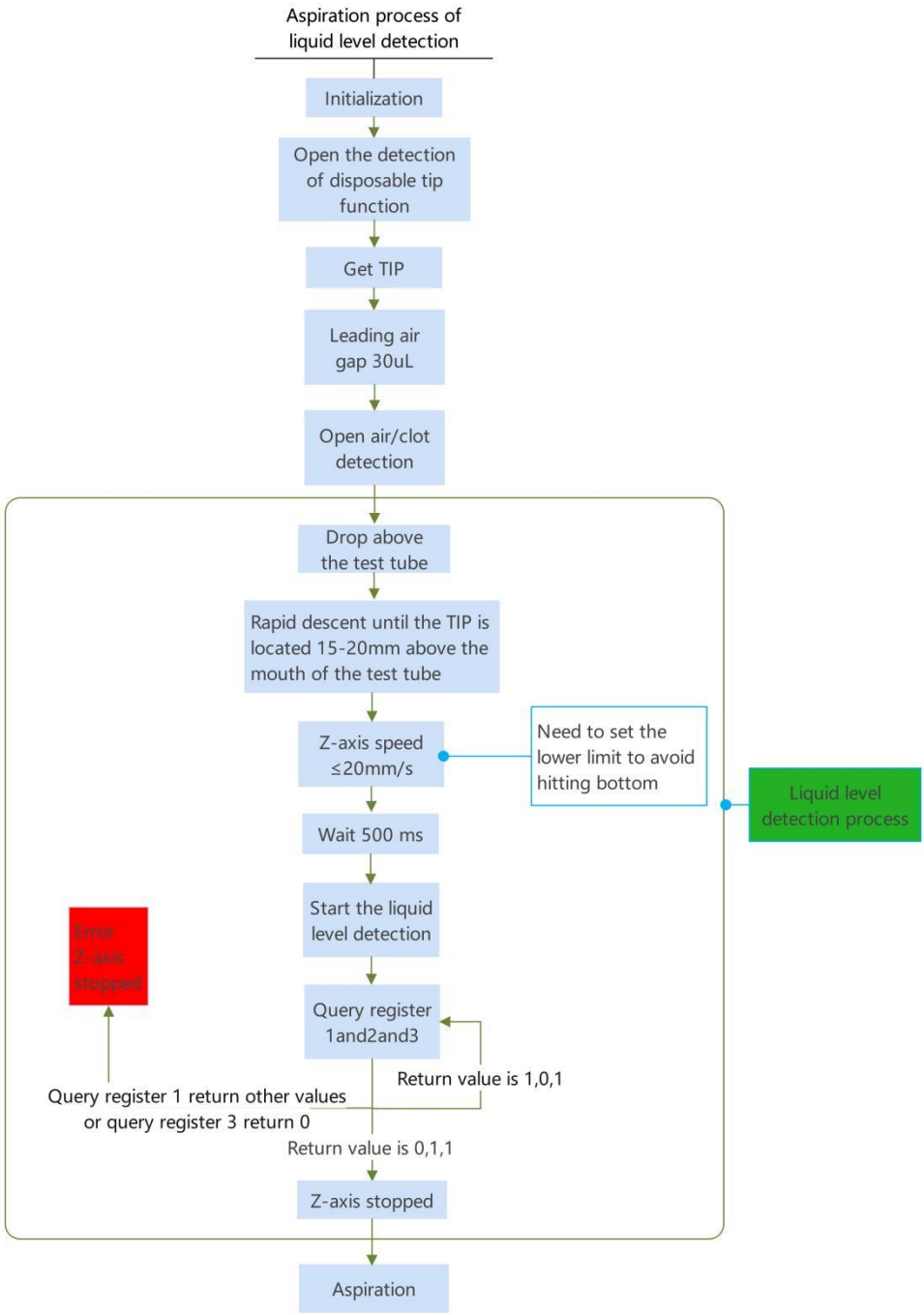


Figure 6-2 The aspiration process with liquid level detection

6.2 TIP Pick Up

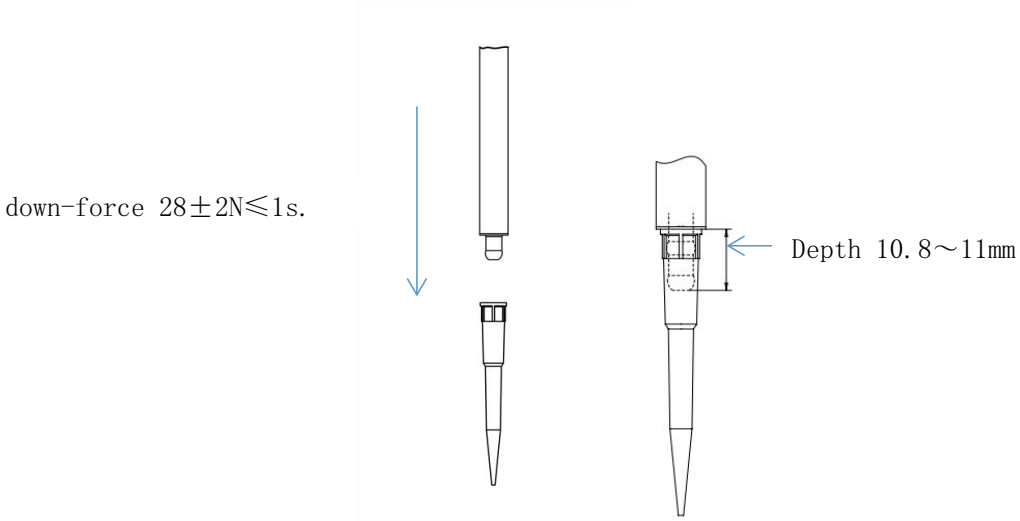


Figure 6-3 Pick up TIP schema

When the nozzle of SP28 move right on top of the TIP, using Keyto ADPZ-axis to pick up TIP can automatically apply the appropriate down-force. ADPZ-axis down-force pressure is recommended to be 28±2N not exceeding 1 second. Please refer to the CAN development process monitoring example in section 8.4.3 CAN Development Process practice or section 8.4.4 Serial Port Development Process practice.

Convenient leakage test method: at Room temperature, uses 1000ul device to pick up non-conductive clean 1000ul TIP with filter and aspirate 1000ul pure water (TIP is inserted into pure water surface not exceeding 3mm), leave the liquid surface and let it stand for one minute to detect if there is any leakage at the TIP. If leakage happen, then the depth of pick up TIP should be appropriately increased.

	*Warning: Too much down-force can lead to failure of TIP ejection or even permanent damage to SP28.*

6.3 Liquid level detection

Move down the SP28 rapidly until the end of TIP is located 15～20mm above the mouth of the test tube, then setting the speed becomes ≤20mm/s (500ms later will start the liquid level detection). When the TIP contact with the liquid level, Keyto ADPZ-axis will be automatically stopped. You also can use SP28 GP01 signals or query register 2 to obtain the liquid level detection status, the details refer to Table 9-6 the register 2 and 10.

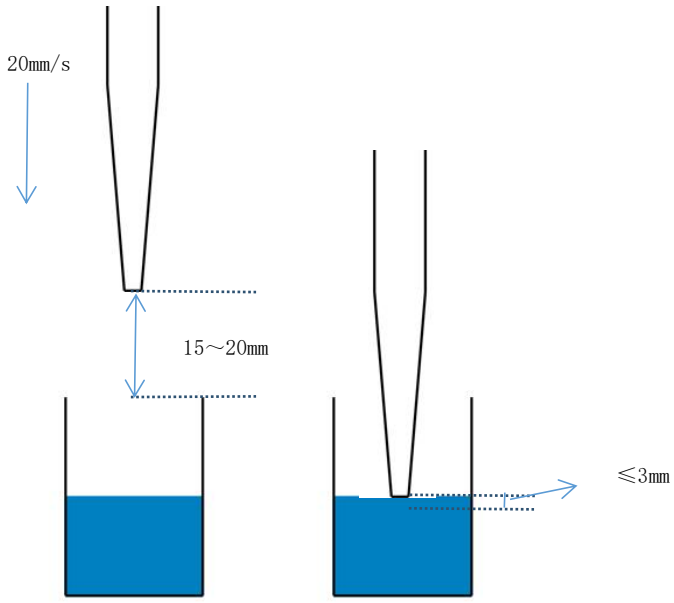


Figure 6-4 Liquid level detection schema

Send the Ld command through the serial port, or CAN dictionary 0x4007 write operation to start the liquid level detection function, after the liquid level detection function is turned on, the SP28 will monitor the change of air pressure in real time. After the SP28 detects the change of air pressure, will inform users the action of detecting the liquid level through mulTIPle ways.

Liquid level detection voltage description:

1. When register 10 is configured to 0, the GPO1 will immediately output a high level pulse(last 10ms) after detecting the liquid level.
2. When register 10 is configured to 1, the GPO1 will immediately output low voltage when it response the command to start liquid level detection, then immediately output high voltage after detecting the liquid level.
3. When register 10 is configured to 2, the GPO1 will immediately output high voltage when it response the command to start liquid level detection, then immediately output a low voltage after detecting the liquid level.

Recommended process for liquid level detection: When detecting liquid level, rapid descent until the end of TIP is located 15～20mm above the mouth of the test tube, with a delay of 500ms (i.e., about 5～10mm above the mouth of the test tube), then send the liquid level detection command and continue to lower it, and then stop the ADPZ-axis when it reserves the liquid level detection output signal from a non-triggered level to a triggered level of 1 ms (the triggered level lasts for 1 ms to filter out interfering signals), or when it reserves the detected liquid level signals.Please refer to the example in section 8.4.3 CAN Development Process practice or section 8.4.4 Serial Port Development Process practice.

Notes:

1. Recommended that the ADPZ-axis falling speed is less than 20mm/s when detecting the liquid level.
2. There should be no foreign objects (including residual reagents) in the TIP during liquid detection, otherwise the foreign objects will slide down

to the TIP when ADPZ-axis goes down and the SP28 will not be able to detect the liquid level accurately.

3. The original factory parameters are only suitable for liquid level detection with certain types of TIP in the reagent kit. If the liquid level detection is triggered prematurely, set the threshold deviation parameter to a positive value; if the liquid level detection penetrates too deeply into the reagent, set the threshold deviation parameter to a negative value. For detailed parameters, refer to Chapter 9 Serial Port Commands and Chapter 10 KT_CAN_DIC Object Dictionary.
4. Due to the structural characteristics of the SP28, the upper limit of the liquid level detection timeout time is the volume divided by 25. For example, the maximum detection time for a 100ul pump liquid level is 4 seconds.

6.4 Mixing process

When using the SP28 to perform aspirate and dispense action for mixing, the following points should be noted:

1. Mixing process: Aspirate leading air gap of 10uL, repeat n times of (Aspirate liquid 20uL-dispense 20uL), move up the TIP above the liquid surface, use Mp0 for dispense the liquid.
2. The reason for using the absolute position command(Mp) is to completely dispense the liquid.
3. It is prohibited to repeat use TIP, otherwise the accumulated liquid film may be sucked into the pipetting barrel and damage the SP28. For application examples, please refer to the example in section 8.4.3 CAN Development Process practice or section 8.4.4 Serial Port Development Process practice.

6.5 Liquid following

SP28 and Keyto ADPZ-axis can realize liquid following function when aspirate and dispense the liquid, the register configuration is shown in Table 9-6, register 101～104. As in Figure 6-5, as the liquid level of the test tube drops when the SP28 is aspirating, the ADPZ-axis controls the SP28 drops with TIP. Please refer to the section 8.4.3 CAN Development Process practice or section 8.4.4 Serial Port Development Process practice.

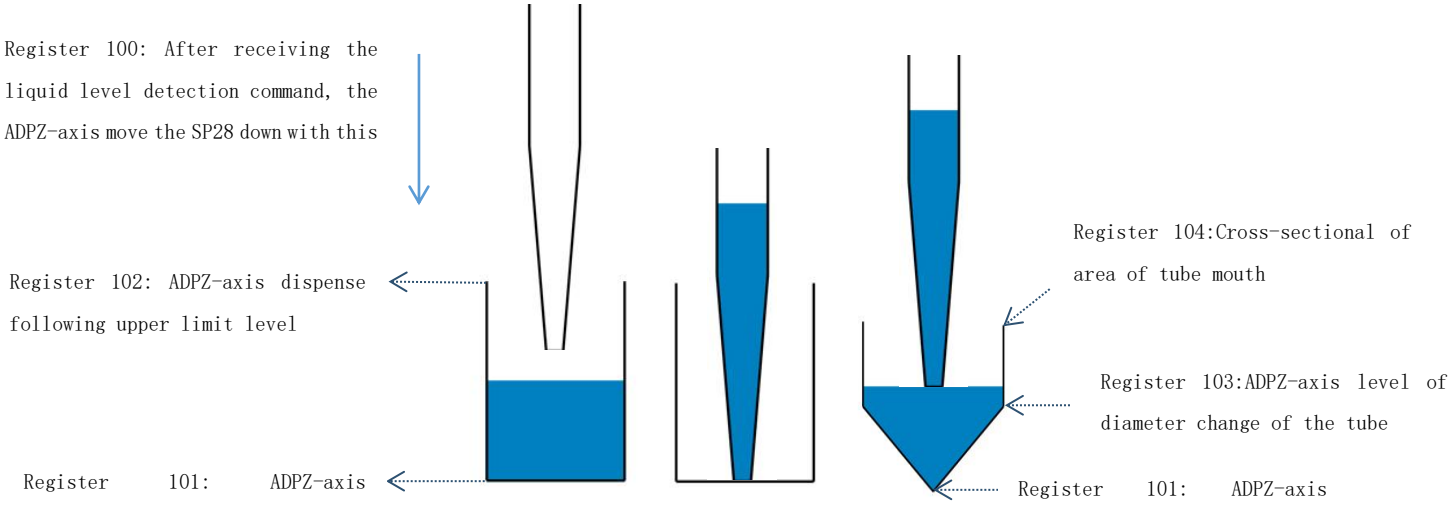


Figure 6-5 liquid following

6.6 Pipetting Abnormality Detection

SP28 has an air pressure sensor, which can monitor the air pressure changes of the real time in the pipetting barrel, and according to the air pressure changes can be very sensitive to achieve the liquid level detection, clot detection.

There will be a series of conditions when aspirating the liquid: aspirate the clot/empty, etc., we can detect these abnormalities through the change in air pressure. By default, these detection functions are disabled, you can set register 60 to open the corresponding function, each bit corresponds to a function, 1 to open, 0 to close. Note: the parameter is decimal, for example, to open the detection of aspirate empty and clot, 60 register should be set to 5 (binary 0b101).

Table 6-1 Pressure Detection Description

register	Description
60	Pressure anomaly detection function, HEX code, set to 1 to enable the function. Bit0: Aspirate liquid clot detection, the minimum volume that aspirate clot detection is 40uL. Bit2: Aspirate liquid empty detection, the minimum volume that aspirate empty detection is 40uL

Note:Only if the aspirate volume is not less than the specified volume, the SP28 will initiate liquid handling abnormality detection function.(If the aspirate volume is too small, the air pressure change is not obvious.) Liquid in TIP when aspirated, the aspiration empty detection and bubble detection are unreliable. If users need to perform aspirate and dispense air operation before aspirating the liquid, please set register 60 to disable the pressure abnormal detection first to prevent error reporting. enable the pressure abnormal detection function during normal aspirating and dispensing, and disable the function after aspirating and dispensing is completed. All abnormal detection results will be reported after the aspiration operation is completed, and the aspiration operation will not be stopped

due to abnormal detection results. More details, please refer to the section 8.4.3 CAN Development Process practice or section 8.4.4 Serial Port Development Process practice.

6.7 Aspiration and Dispensing Parameters

6.7.1 Aspiration and Dispensing Velocity

Follow the principle of "slow aspiration and fast dispensing". The viscosity of the reagent and the type of TIP may affect the velocity. When setting the dispense velocity for single aspiration and dispensing, need to pay attention to whether the reagent is empty or not, and mitigate the reagent splash when dispensing.

6.7.2 Re-aspiration Volume

When single aspirate and dispense, the re-aspiration volume should be set to 0. When single aspirate and aliquot dispense, the re-aspirate volume can be set to refer to Table 6-2:

Table 6-3 Recommended re-aspiration volume for aliquot dispense

TIP \ Dispense Volume / Re-aspiration	5～10ul	10～20ul	20～100ul
50ul	≥5ul	/	/
200ul	≥2ul	≥4ul	/
1000ul	/	≥2ul	≥4ul

6.7.3 Reference of Aspiration and Dispensing Parameter

The following data are based on pure water, the accuracy and CV of the liquid aspirate and dispense can meet performance requirements of the SP28.

Table 6-4 Pure Water Reference Parameters

SP28 model	TIP Type (F: with filter)	Pipetting type	dispense volume uL	Leading Air Gap 0.01ul	Aspirate Parameter			Dispense Parameter			
					volume 0.01ul	velocity 0.01ul	cut-off velocity 0.01ul	Volume 0.01ul	Re-aspirate Volume 0.01ul	velocity 0.01ul	cut-off velocity 0.01ul
1ml	50ul	Single dispense	5	5000	750	100	20	5750	0	1000	10
	200ul	Single dispense	10	5000	1300	100	20	6300	0	1000	10
	1000ul	Aliquot dispense	20	0	20000	250	20	2000	500	500	200
500ul	50ul	Single dispense	5	5000	700	100	20	5700	0	1000	10
	200ul		10	5000	1200	100	20	6200	0	1000	10

	1000ul		20	5000	2200	100	20	7200	0	1000	10
	50ul	Aliquot dispense	5	0	5500	250	20	500	800	500	200
	1000ul		20	0	20000	250	20	2000	500	500	200
250ul	50ul	Single dispense	5	5000	750	100	20	5750	0	500	10
	200ul		10	5000	1300	100	20	6300	0	500	10
	1000ul		20	5000	2200	100	20	7200	0	500	10
	50ul	Aliquot dispense	5	0	5500	50	20	500	800	250	100
	1000ul		20	0	20000	250	20	2000	500	500	100
	50ul		3	0	3000	100	20	300	700	250	100
100ul	50ul	Single dispense	5	5000	700	20	20	5700	0	200	10
	200ul		10	5000	1200	20	20	6200	0	200	10
	1000ul		20	5000	2200	20	20	7200	0	200	10
	50ul	Aliquot dispense	5	0	5500	50	20	500	800	100	50
	1000ul		20	0	20000	50	20	2000	500	100	50

6.8 ※Accuracy and CV Test&Compensation

6.8.1 Accuracy and CV Test

1. Preparation before test

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 dispense process

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

3. Balance leveling and zeroing

Before using the balance, please follow the balance commands for leveling and zeroing.

4. Weigh empty centrifuge tubes

Prepare 10 centrifuge tubes and record the weight and number of the empty tubes.

5. SP28 initialization, TIP installation and aspirate the air

Initialize the SP28 before each test.

Replace and use a new TIP. If the TIP is deformed or contaminated, discard the current data.

To ensure that all reagents are dispensed from the TIP, aspirate 50uL of air before aspirating the liquid.

6. Single aspirate process

Control the Z axis to descend until the end of TIP is ≤3mm below the liquid surface.

Send the SP28 aspirate command, and after the aspirating is completed, raise

the SP28 according to the reagent viscosity with the recommended latency time as shown in the figure below:

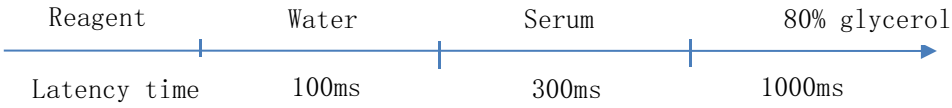


Figure 6-6 Recommended latency time for different reagents

Send a dispense liquid command with the volume: 50ul of leading air gap volume + required liquid volume. Keep the end of the TIP moved to the edge of the centrifuge tube calibre to prevent reagent splashing.

1. Weighing Centrifuge Tubes with Reagent

Repeat step 5 and 6 ten times and weigh the ten centrifuge tubes in sequence. The weight of the reagent is the centrifuge tube with reagent data minus the weight of the empty centrifuge tube.

2. Factors Affecting Accuracy and CV

Accuracy and CV test results are affected by lots of factors, the main ones being:

- Aspirate and dispense parameters, please refer to section 6.7.3.
- Reagent temperature will affect the aspirated liquid volume.
- Reagent density will affect the aspirated liquid volume.
- After TIP is tied into the reagent, the hanging liquid on the outer wall affects the dispense accuracy and CV.
- Leading Air Gap volume, which affects dispense accuracy and CV.
- Whether or not to use the liquid level detection function, which affects the depth of TIP into the reagent.
- Latency time after aspiration and velocity when leaving the liquid level.

6.8.2 Accuracy Compensation

For higher accuracy performance practice, we can do the aspirate calibration for single aspirate and dispense, generally, single aspirate and aliquot dispense do not need to be calibrated. For different aspiration volumes and TIP, segmented calibration is recommended. Below is how to do a segmented calibration for 5～1000ul aspiration volume:

1. Determine the points to be calibrated, for small micro-volume, need more points, we recommend the quantity of calibration points is more than 5. Different volumes of TIP calibrate 5+ points, or different volumes of TIP calibrate 5+ points for each type. Here we use 50ul and 1000ul TIP to calibrate 10 points in the full stroke.

Table 6-5 Calibration Points

Calibration point/ul	50ul TIP	1000ul TIP
	5	50

	8	200
	10	500
	20	700
	50	1000

2. Measure the liquid dispense accuracy 10 times for each point, then average, and compensate according to the difference (the result of subtraction). For example, if the average value of 1000ul point is 990ul and the difference is 10ul, you can set the aspirate volume to 1010ul for compensate.

3. The baseline curves of measured and theoretical values is close to linear, you can do corresponding compensation according to the dispense liquid volume.

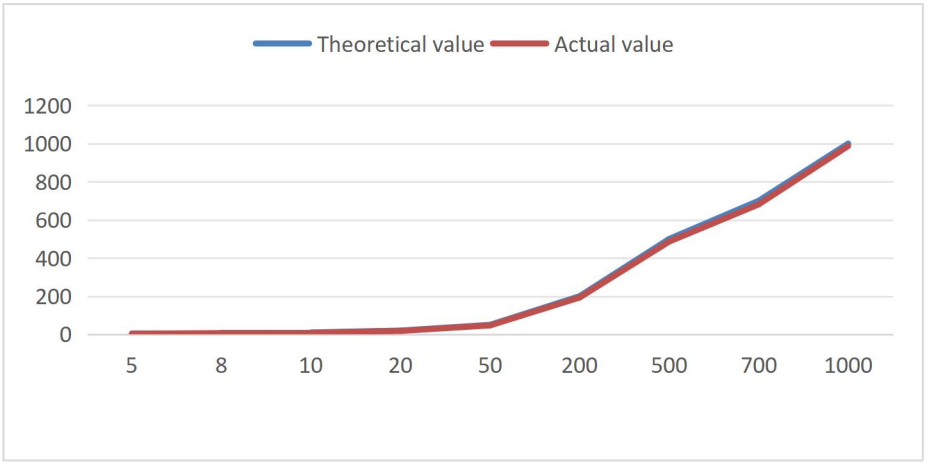


Figure 6-7 Aspiration liquid volume comparison for SP28-1000ul

7 Communication Protocols

7.1 Communication Method

7.1.1 Communication Interface

SP28 supports the following communication methods:

- RS232
- RS485
- CAN

Baud rate:

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

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

7.1.2 Communication Protocol

SP28 supports serial port and KT_CAN_DIC communication, where the serial port supports RS232 and RS485, both of which have the same communication protocol. When using serial port, the send/response interval should be ≥10ms, following the one-send-one-response communication mode, while using the re-send method to ensure the reliability (PLC timing is not accurate, and the interval needs to be extended).

- KT_CAN_DIC Protocol
- KT_OEM Protocol
- KT_DT Protocol

	*Note: The KT_OEM or KT_CAN_DIC Protocol will lock the current protocol, and the protocol will be unlocked after restarting the device.*

KT_CAN_DIC Protocol (recommend)

The KT_CN_DIC protocol is used for CAN communication, controlling SP28 and configuring parameters by reading and writing the KT_CN_DIC object dictionary. During the execution process, there is no need to polling the SP28 status, just wait for the SP28 to automatically report after execution completion. If it is an error state, error handling is required.

KT_OEM Protocol (recommend)

The KT_OEM protocol is based on RS232 and RS485 communication, the communication protocol includes communication sequence numbers and checksum byte, which can effectively detect data loss.During the operating period,it is needed to poll the SP28 status and analyses the status to decide whether there is an error.

KT_DT Protocol

The protocol is based on RS232 and RS485 communication, the communication protocol has no checksum byte, you can easily use the serial port debugging tool to send a string to control the SP28. Data sent and responded as ASCII string, which

is convenient for users to debug. KT_DT Protocol has no checksum byte so there is a risk of data loss.

7.2 ※KT_CAN_DIC Protocol Format

The CAN message type is an extend frame, consisting of ID and data area.

Frame type: data frame

Message identifier type: extended frame

ID: use extended ID, refer to Table 7-1

DLC: data length 8

Data field: the data length is the fixed 8 bytes, including communication sequence number, index, and data, refer to the Table 7-3.

ID format:

Table 7-1 KT_CAN_DIC Message ID Area Format

	bit28～16	bit15～8	bit7～0
Send	Command	Host address	Destination address
Response	Command	Device address	Source address

ID data content includes:

1. Host address.
2. Device address.
3. Command：used to indicate the operation type of the frame message，as shown in Table 7-2 :

Table 7-2 KT_CAN_DIC ID Command List

Command	Function	Description
0x0000	response	response for reading and writing
0x0001	Write	Write object dictionary response value: status, see Table 11-1
0x0002	Read	Read object dictionary, if there is no corresponding object dictionary, no data will be returned.
0x0003	Process data	Used for uploading real time data which does not require an response, e.g. SP28 will automatically upload by using this command if the status change.
0x0004	Heartbeat	Timed uploading heartbeat data, it can be used to detect whether the SP28 is online or not, the heartbeat uploaded data is the node status, the status information see Table 11-1.
0x0080	Alarm	The SP28 will automatically report if error occurs, the error information see status Table 11-1.

Data area data format

Table 7-3 KT_CAN_DIC Data Field Format

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

Data Field detail:

1. Communication sequence number: It is used to distinguish which frame of

data is sent and responded. It is recommended that custom Host adds 1 to the communication sequence number before each frame of data is sent, so that each frame of data is different.

2. Index: The object index is 16-bit address of the object dictionary table, it is shown in the object dictionary table, see section 10.2 for more details.

3. Sub-index: The sub-index number is an 8-bit sub-address, which is used together with the index to define the dictionary table, see section 10.2 for more details.

	*Note: Each control command has a unique index number and mulTIPle sub-index numbers, and frame data with non-zero sub-index numbers are sent first, and frame data with zero sub-index numbers are sent last, and the SP28 starts to move when it reserves a command with zero sub-index numbers.*

4. Data: A data length of 32 bits represents the communication data, which is a signed integer, see section 10.2 for more details.

7.3 KT_OEM Protocol Format

The KT_OEM protocol is based on RS232 and RS485 communication, data area string portion consistent with KT_DT protocol, The protocol contains checksum byte, which can effectively preventing data loss, and the protocol contains sequence numbers, which can simplify communication exception handling,so it is recommended to use KT_OEM protocol to communicate with SP28. The SP28 parses the string in real time, verifies that the address matches, the checksum is correct, and the protocol is formatted correctly, and immediately returns the status of the executed command. During the operating period,the controller polls the SP28 status and analyses the status to decide whether the SP28 executes the completed commands or there is an error.

Table 7-4 KT_OEM command protocol format

Field	Type	Number of bytes	Description
Frame header	Uint8	1	Fixed value 0XAA, indicating the start of command
Sequence number	Uint8	1	Command sequence number ranges from 0x80 to 0xFE. If the current sequence number is the same as the previous one, the current command will not be executed, but will respond with the same response as the previous command.
Address	Uint8	1	Communication address: Each device on a bus should be set to a unique address number, with a range of 0 to 0xFF. Communication will only occur when the address matches, otherwise, the responded command will be ignored.
Data length	Uint8	1	Command Data area length
Data area	Char	n	Command strings in ASCII character format,details see section 9.2.
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 response protocol format

Field	Type	Number of bytes	Description
Frame header	Uint8	1	Fixed value 0X55, indicating the start of response
Sequence number	Uint8	1	Corresponds to the sequence number of the responded command
Address	Uint8	1	Address of this device, Corresponds to the address of the responded command.
Status	Uint8	1	Current status of SP28, see Table 11-1.
Data length	Uint8	1	The length of the Data area. If the Data area is empty, the Data length should be 0.
Data area	Char	n	The response string in ASCII character format, if there is no response, this field does not exist. For details, see Section 9.2.
Checksum	Uint8	1	The 8-bit checksum is calculated from the header of the frame to the end byte of the data area. The value obtained takes the last 8 bits of data.

7.4 KT_DT Protocol Format

Whenever SP28 reserves a string, it will parse the string and verify whether the address matches and the syntax is correct, and response the status of the first command execution.

Table 7-6 KT_DT protocol send format

Field	Type	Number of bytes	Description
Address	Byte	1～3	Communication address: Each device on a bus should be set to a unique address number, with a range of 0～255 in ASCII character format. Communication will only occur when the address matches, otherwise, the responded command will be ignored.
Direction	Byte	1	'>' (0x3E), means from Host to Device
Data area	Byte	n	The string is in ASCII character format and has a length of less than 256. For more details, see Chapter 9.
End character	Byte	1	Carriage Return(0x0D), indicates the end.

Table 7-7 KT_DT protocol response format

Field	Type	Number of bytes	Description
Address	Byte	1～3	The device address that response to the command, with a value range of 0～255 in ASCII character format, must match the command address.

Direction	Byte	1	'<' (0x3C), means from the Device to Host.
Status	Byte	1～3	Device status or command execution status, refer to Table 11-1.
':'	Byte	1	':' (0x3A), this will be empty if there is no response Data area.
Data area	Byte	n	The string is in ASCII character format and has a length of less than 256. For more details, see Chapter 9.
End character	Byte	1	Carriage Return(0x0D), indicates the end.

8 Communication process

Note that when using serial communication, KT_DT protocol has no data verification, so it is recommended to be used only for debugging. For the machine integrating SP28, 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 SP28 address is 1.

	*Note: The KT_OEM or KT_CAN_DIC Protocol will lock the current protocol, and the protocol will be unlocked after restarting the device.*

8.1 Examples of KT_CAN_DIC Protocol

Note: See section 10.2, Each control command with a unique index number and mulTIPle sub-index numbers, sending frame data with non-zero sub-index numbers first, and finally sending frame data with zero sub-index number, SP28 starts to move when it reserves command with zero sub-index number.

Table 8-1 Examples of KT_CAN_DIC Protocol

Function	Direction	ID(HEX)	Data(HEX)	Description
Initialization	First Send	00 01 00 01	01 40 00 01 00 00 00 64	ID: 00 01: write command.00: source device address.01: destination device address. Data:01: communication sequence number.40 00: index number (initialization command).01:sub-index number((Initialization power).00 00 00 64 data((Initialization power set to 100%)
	Response	00 00 01 00	01 40 00 01 00 00 00 02	ID:00 00: response data.01: response device address.00: Host address. Data:01: communication sequence number(consistent with the sequence in the responded command).40 00: index number. 01: sub-index number.00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	02 40 00 02 00 00 00 00	ID: 00 01: write command. 00: source device address.01: destination device address. Data:02: communication sequence number.40 00: index number (initialization command). 02: sub-index number (initialization process eject TIP). 00 00 00 00: data (Regardless of whether the TIP is detected, the TIP will be ejected.)
	Response	00 00 01 00	02 40 00 02 00 00 00 02	ID:00 00: response data. 01: response device address. 00: Host address. Data:02: communication sequence number (consistent with the sequence in the responded commands).40 00: index number. 02: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Last send	00 01 00 01	03 40 00 00 00 00 3E 80	ID:00 01: write command. 00: source device address. 01: destination device address. Data:03: communication sequence number.40 00: index number (initialization command). 00: sub-index number (initialization process speed setting). 00 00 3E 80: data (initialization process speed setting of 16000 micro-steps /s)

Function	Direction	ID(HEX)	Data(HEX)	Description
	Last response	00 00 01 00	03 40 00 00 00 00 00 02	ID:00 00: response data. 01: response device address. 00: Host address. Data:03: communication sequence number (consistent with the sequence in the responded commands).40 00: index number. 00: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
Liquid Level Detection	First Send	00 01 00 01	04 40 07 01 00 00 13 88	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 04: communication sequence number.40 07: index number (liquid level detection). 01: sub-index number (liquid level detection timeout setting). 00 00 13 88: data (liquid level detection timeout setting of 5000 ms)
	Response	00 00 01 00	04 40 07 01 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 04: communication sequence number(consistent with the sequence in the responded commands).40 07: index number. 01: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	05 40 07 00 00 00 00 01	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 05: communication sequence number.40 07: index number (liquid level detection). 00: sub-index number (liquid level detection data reporting type setting). 00 00 00 01: data(automatic reporting of liquid level detection)
	Response	00 00 01 00	05 40 07 00 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 05: communication sequence number(consistent with the sequence in the responded commands).40 07: index number. 00: sub-index number. 00 00 00 02: status (command executed successfully, others see status Table 11-1)
	Response after LLD	00 03 01 00	E2 70 00 00 00 00 00 04	ID: 00 03: process data. 01: response device address. 00: Host address. Data: E2: communication sequence number(consistent with heartbeat sequence, plus one for each transmission). 70 00: index number (liquid level detected).00: sub-index number. 00 00 00 04: status (liquid level detected)
	Response after LLD error	00 80 01 00	E9 00 00 00 00 00 00 16	ID: 00 80: alarm data. 01: response device address. 00: Host address. Data: E9: communication sequence number(consistent with heartbeat sequence, plus one for each transmission). 00 00: index number. 00: sub-index number.00 00 00: 16 status (timeout error)
Aspirate	First Send	00 01 00 01	06 40 01 01 00 00 00 C8	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 06: communication sequence number.40 01: index number (aspirate). 01: sub-index number (aspirate velocity setting). 00 00 00 C8: data (aspirate velocity 200ul/s)
	Response	00 00 01 00	06 40 01 01 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 06: communication sequence number (consistent with the sequence in the responded commands).40 01: index number. 01: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	07 40 01 02 00 00 00 0A	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 07: communication sequence number.40 01: index number (aspirate). 02: sub-index number

Function	Direction	ID(HEX)	Data(HEX)	Description
				(aspiration cut-off velocity setting). 00 00 00 00 0A: data (aspiration cut-off velocity setting of 10ul/s)
	Response	00 00 01 00	07 40 01 02 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 07: communication sequence number (consistent with the sequence in the responded commands).40 01: index number. 02: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Last Send	00 01 00 01	08 40 01 00 00 00 27 10	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 08: communication sequence number.40 01: index number (aspirate). 00: sub-index number (aspirate volume setting). 00 00 27 10: data (aspirate 100uL)
	Last Response	00 00 01 00	08 40 01 00 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 08: communication sequence number (consistent with the sequence in the responded commands).40 01: index number. 00 sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
Dispense	First Send	00 01 00 01	09 40 02 01 00 00 01 F4	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 09: communication sequence number number. 40 02: index number (dispense). 01: sub-index number (re-aspiration volume setting).00 00 01 F4: data (re-aspiration volume setting of 5uL)
	Response	00 00 01 00	09 40 02 01 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 09: communication sequence number (consistent with the sequence in the responded commands).40 02: index number. 01: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	0A 40 02 02 00 00 00 C8	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 0A: communication sequence number. 40 02: index number (dispense). 02: sub-index number (dispense velocity setting).00 00 00 00 C8: data (dispense velocity setting of 200ul/s)
	Response	00 00 01 00	0A 40 02 02 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0A: communication sequence number (consistent with the sequence in the responded commands).40 01: index number. 02: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	0B 40 02 03 00 00 00 64	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 0B: communication sequence number. 40 02: index number (dispense). 03: sub-index number (dispense cut-off velocity setting).00 00 00 64: data (aspiration cutoff velocity setting of 100ul/s)
	Response	00 00 01 00	0B 40 02 03 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0B: communication sequence number (consistent with the sequence in the responded commands). 40 02:index number. 03: sub-index number. 00 00 00 02: status (commands executed successfully, others see status Table 11-1)
	Send	00 01 00 01	0C 40 02 00 00 00 03 E8	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 0C: communication sequence number. 40 02: index number (dispense). 00: sub-index number

Function	Direction	ID(HEX)	Data(HEX)	Description
				(dispense volume setting).00 00 03 E8: data (dispense 10uL)
	Response	00 00 01 00	0C 40 02 00 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0C: communication sequence number (consistent with the sequence in the responded commands).40 02: index number. 00: sub-index number. 00 00 00 02: status (commands executed successfully, other see status Table 11-1)
Read status	Send	00 02 00 01	0D 20 00 01 00 00 00 00	ID: 00 02: read command. 00: source device address. 01: destination device address. Data: 0D: communication sequence number. 20 00: index number (register operation). 01: sub-index number (current state, see section 9.2.4.1). 00 00 00 00: data.
	Response	00 00 01 00	0D 20 00 01 00 00 00 00	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0D: communication sequence number (consistent with the sequence in the responded commands).20 00: index number. 01: sub-index number. 00 00 00 00 status (idle state,others see status Table 11-1)
Read register	Send	00 02 00 01	0E 20 00 02 00 00 00 00	ID: 0002: read command. 00: source device address. 01: destination device address. Data: 0E: communication sequence number. 20 00: index number (register operation). 02: sub-index number (Whether liquid level is detected or not, see section 9.2.4.1). 00 00 00 00: data.
	Response	00 00 01 00	0E 20 00 02 00 00 00 01	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0E: communication sequence number (same sequence as in the responded commands). 20 00: index number.02: sub-index number. 00 00 00 01: data (liquid level detected, if 00 00 00 00 then no liquid level detected)
Write register	Send	00 01 00 01	0F 20 00 36 00 00 00 0A	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 0F: communication sequence number.20 00: index number (register operation). 36: sub-index number (liquid level detection coefficient, see section 9.2.4.1).00 00 00 0A: data (set liquid level detection coefficient to 10)
	Response	00 00 01 00	0F 20 00 36 00 00 00 02	ID: 00 00: response data. 01: response device address. 00: Host address. Data: 0F: communication sequence number (same sequence as in the responded commands). 20 00: index number.36: sub-index number. 00 00 00 02: data (set up successfully, others see status Table 11-1)
Modify and save the pipettor address	Send	00 01 00 01	10 20 00 54 00 00 00 02	ID: 00 01: write command. 00: source device address. 01: destination device address. Data: 10: communication sequence number.20 00: index number (register operation). 54: sub-index number (set the device address, see section 9.2.4.1).00 00 00 02: data (device address set to 2)
	Response	00 00 02 00	10 20 00 54 00 00 00 02	ID: 00 00: response data. 02: response device address. 00: Host address. Data:10: communication sequence number (same sequence as in the responded commands). 20 00: index number.54: sub-index number. 00 00 00 02: data (set up successfully, others see status Table 11-1)
	Send	00 01 00 02	11 50 00 00 00 00 00 00	ID: 00 01: write command. 00: source device address. 02: destination device address. Data:11: communication sequence number.50 00: index number (Power-off save operation). 00: sub-index number .00 00 00 00: data
	Respons	00 00 02 00	11 50 00 00 00 00 00 02	ID: 00 00: response data. 02: response device

Function	Direction	ID(HEX)	Data(HEX)	Description
	e			address. 00: Host address. Data:11: communication sequence number (same sequence as in the responded commands). 50 00: index number.00: sub-index number. 00 00 00 02: data (set up successfully, others see status Table 11-1)

8.2 Example of KT_OEM Protocol(HEX Mode)

Note: The KT_OEM protocol is an encapsulation of the KT_DT protocol, and the command string and return string are described in section 9.2.

Table 8-2 KT_OEM Protocol Single Command Examples

Function	Direction	Data(HEX)	Description
Initialization	Send	AA 80 01 0D 49 74 31 36 30 30 30 2C 31 30 30 2C 30 05	AA: frame header. 80:Sequence number. 01: destination device address. 0D: command string length. 49 74 31 36 30 30 30 30 2C 31 30 30 30 2C 30: string command "It16000,100, 0". 05: frame checksum
	Response	55 80 01 02 00 D8	55: frame header. 80:Sequence number. 01: destination device address. 02: status of successful commands execution (others see status Table 11-1). 00: return string length. D8 frame checksum
Liquid level detection	Send	AA 81 01 08 4C 64 31 2C 35 30 30 30 06	AA:frame header. 81:Sequence number. 01: destination device address. 08: command string length. 4C 64 31 2C 35 30 30 30 30: string command "Ld1,5000". 06 frame checksum
	Response	55 81 01 02 00 D9	55: frame header. 81:Sequence number. 01: destination device address. 02: status of successful commands execution (othera see status Table 11-1). 00: return string length. D9: frame checksum
Aspirate liquid	Send	AA 82 01 0E 49 61 31 30 30 30 30 2C 32 30 30 2C 31 30 21	AA: frame header. 82:Sequence number. 01: destination device address. 0E: command string length. 49 61 31 30 30 30 30 30 2C 32 30 30 2C 31 30: string command "Ia10000,200, 10". 21: frame checksum
	Response	55 82 01 02 00 DA	55: frame header. 82:Sequence number. 01: destination device address. 02: status of successful commands execution (others see status Table 11-1). 00: return string length. DA: frame checksum
Dispense liquid	Send	AA 83 01 12 44 61 31 30 30 30 2C 35 30 30 2C 32 30 30 2C 31 30 30 E2	AA: frame header. 83:Sequence number. 01: destination device address. 12: command string length. 44 61 31 30 30 30 2C 35 30 30 2C 32 30 30 2C 31 30 30 30: string command "Da1000,500,200,100". E2: frame checksum
	Response	55 83 01 02 00 DB	55: frame header. 83:Sequence number.

Function	Direction	Data(HEX)	Description
			01: destination device address. 02: status of successful commands execution (others see status Table 11-1). 00: return string length. DB: frame checksum
Read status	Send	AA 84 01 01 3F 6F	AA : frame header. 84:Sequence number. 01: destination device address. 01: command string length. 3F: string command "? ". 6F: frame checksum
	Response	55 84 01 00 00 DA	55: frame header. 84:Sequence number. 01: destination device address. 00: idle status (others see status Table 11-1). 00: return string length. DA: frame checksum
Read register	Send	AA 85 01 03 52 72 33 2A	AA: frame header. 85:Sequence number. 01: destination device address. 03: command string length. 52 72 33: string command "Rr3". 2A: frame checksum
	Response	55 85 01 02 01 30 0E	55: frame header. 85:Sequence number. 01: destination device address. 02: status of successful commands execution (others see status Table 11-1). 01: return string length. 30: return data of register: "0". 0F: frame checksum
Write register	Send	AA 86 01 07 57 72 35 34 2C 31 30 F7	AA: frame header. 86:Sequence number. 01: destination device address. 07: command string length. 57 72 35 34 2C 31 30: string command "Wr54,10". F7: frame checksum
	Response	55 86 01 02 00 DE	55: frame header. 86:Sequence number. 01: destination device address. 02: status of successful commands execution (others see status Table 11-1). 00: return string length. DE: frame checksum
Modify and save the pipettor address	Send	AA 87 01 06 57 72 38 34 2C 32 CB	AA: frame header. 87:Sequence number. 01: destination device address. 06: command string length. 57 72 38 34 2C 32: string command "Wr84,2". CB: frame checksum
	Response	55 87 02 02 00 E0	55: frame header. 87:Sequence number. 02: destination device address. 02: status of successful commands execution (others see status Table 11-1). 00: return string length. E0: frame checksum
	Send	AA 88 02 01 53 88	AA: frame header. 88:Sequence number. 02: destination device address. 01: command string length. 53: string command "S". 88: frame checksum
	Response	55 88 02 02 00 E1	55: frame header. 88:Sequence number. 02: destination device address. 02: status of successful commands execution (others see status Table 11-1).

Function	Direction	Data(HEX)	Description
			00: return string length. E1: frame checksum

8.3 Example of KT_DT Protocol(String Mode)

Table 8-3 Examples of KT_DT Protocol Single Command

Function	Direction	Data(String)	Description
Initialization	Send	1>It16000,100,0	1: destination device address. 16000: initial operating speed is 16000 micro-steps/s. 100: initial operating power is 100%. 0: In initialization process, disposable TIP will be ejected regardless of whether it is detected or not
	Response	1<2	1: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
Liquid level detection	Send	1>Ld1,5000	1: destination device address. 1: automatic reporting status after detecting the liquid level. 5000: detection timeout is 5000 ms
	Response	1<2	1: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
	Response	1<4	1: destination device address. 4: liquid level status detected. while the blue LED on the SP28 is always on
Aspirate liquid	Send	1>Ia10000,200,10	1: destination device address. 10000: aspirate volume is 100uL. 200: aspirate velocity is 200ul/s. 10: aspirate cutoff velocity is 10ul/s
	Response	1<2	1: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
Dispense liquid	Send	1>Da1000,500,200,100	1: destination device address. 1000: dispense 10uL. 500: re-aspiration volume is 5uL. 200: dispense velocity is 200ul/s. 100: dispense cutoff velocity is 100ul/s
	Response	1<2	1: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
Read status	Send	1>?	1: destination device address. ?: used to query the status of SP28, equivalent to read the register 1
	Response	1<0	1: destination device address. 0: idle state (Others see status Table 11-1)
Read register	Send	1>Rr3	1: destination device address. 3: check whether there is a disposable TIP (other register refer to section 9.2.4.1)
	Response	1<2:0	1: destination device address. 2: status of successful commands execution (others see status Table 11-1). 0: no disposable TIP
Write register	Send	1>Wr54,10	1: destination device address. 54: set the liquid level detection coefficient. 10: liquid level detection coefficient set to 10
	Response	1<2	1: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
Modify and save the pipettor address	Send	1>Wr84,2	1: destination device address. 84: set the device address. 2: device address set to 2
	Response	2<2	2: destination device address. 2: status of successful commands execution (Others see status Table 11-1)
	Send	2>S	2: destination device address.

		S: save data when power-off.
Response	2<2	2: destination device address. 2: status of successful commands execution (Others see status Table 11-1)

Note: send means from the Host to Device(SP28), and the response means from Device(SP28) to the the Host.

8.4 Development Process Practice

8.4.1 CAN Communication Flow

	Note: Recommend the communication method be in one command-one response mode, i.e. each time you send a command, wait until it is responded before sending a new command.

Configure automatically response via index number 0x2000 sub-index number 0x52.

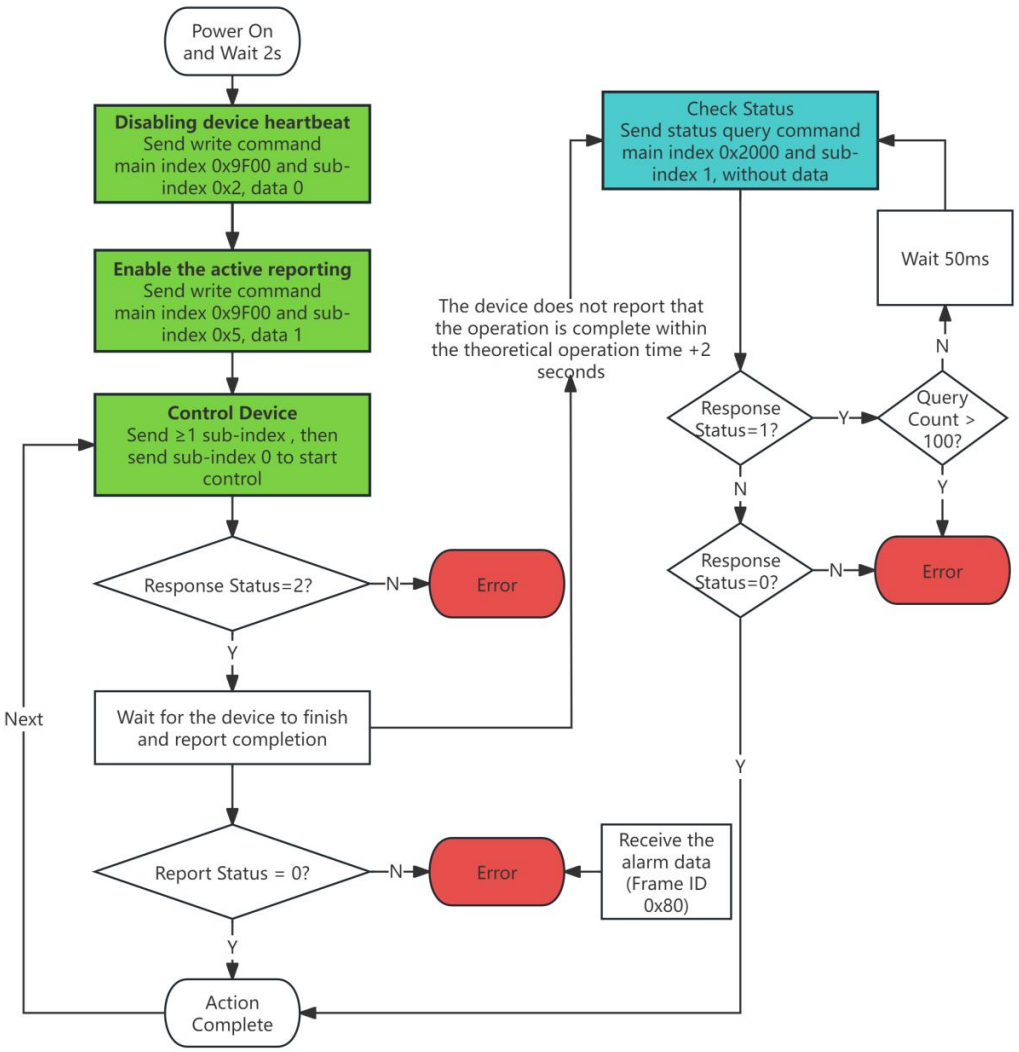


Figure 8-1 KT_CAN_DIC Protocol Communication Framework

The green box indicates writing registers and controlling SP28 operation, see Figure 8-2 for details. The blue box indicates querying the status of SP28 and reading the registers, see Figure 8-2 for details.

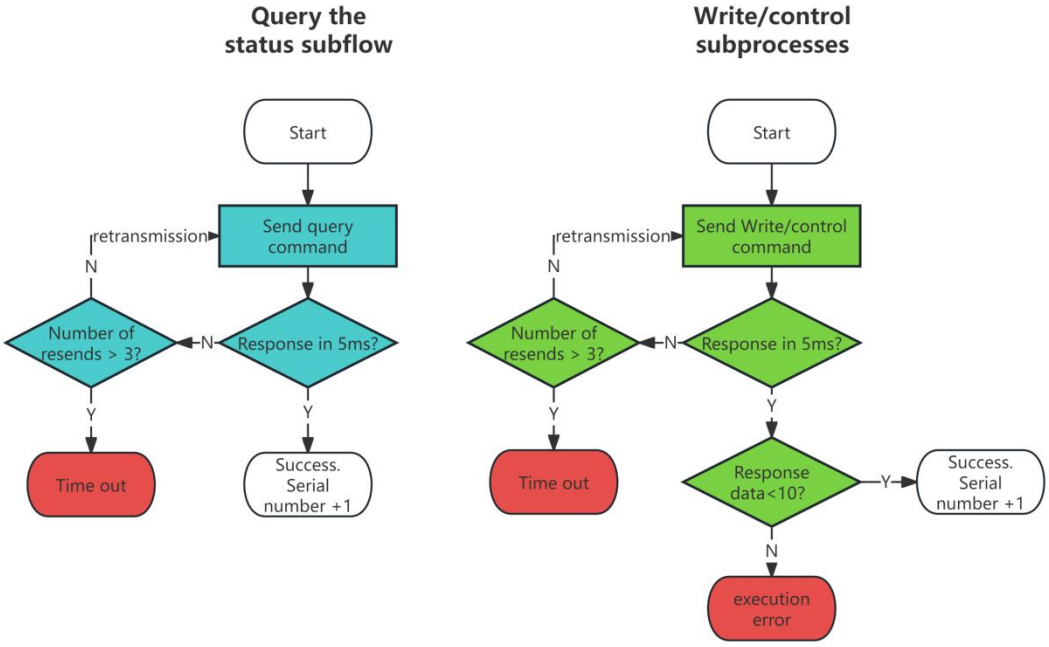


Figure 8-2 KT_CAN_DIC Protocol Communication Sub-flow Framework

8.4.2 Serial Port Communication Flow

	Note: When using serial port communication, it is recommended to send the next frame of data in ≥10ms interval after the command is responded to avoid bus interference. the communication mode adopts one command-one response mode, i.e., each time you send a command, wait until it is responded before sending a new command.

See Figure 8-3 for a one command-one response model:

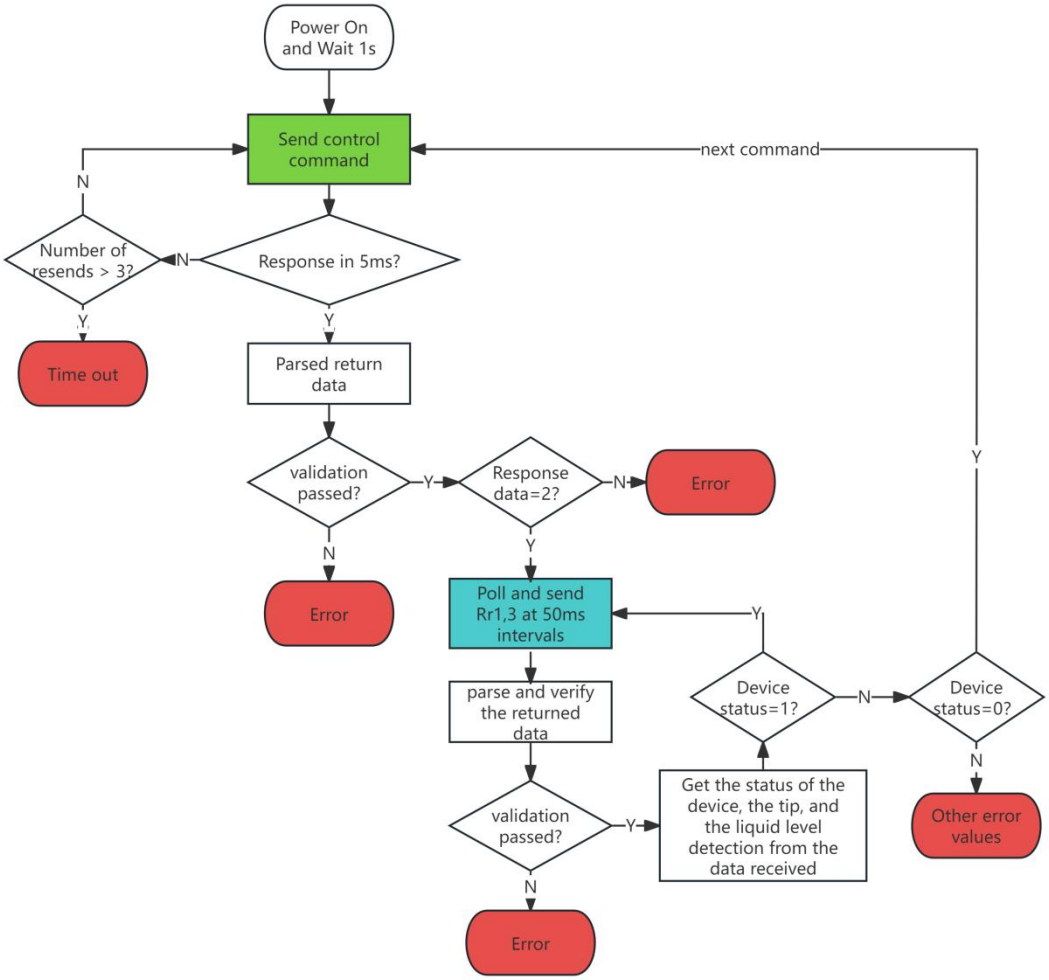


Figure 8-3 KT_OEM Protocol Communication Framework

The green box indicates writing registers and controlling SP28 operation, see Figure 8-4 for details. The blue box indicates querying the status of SP28 and reading the registers, see Figure 8-4 for details.

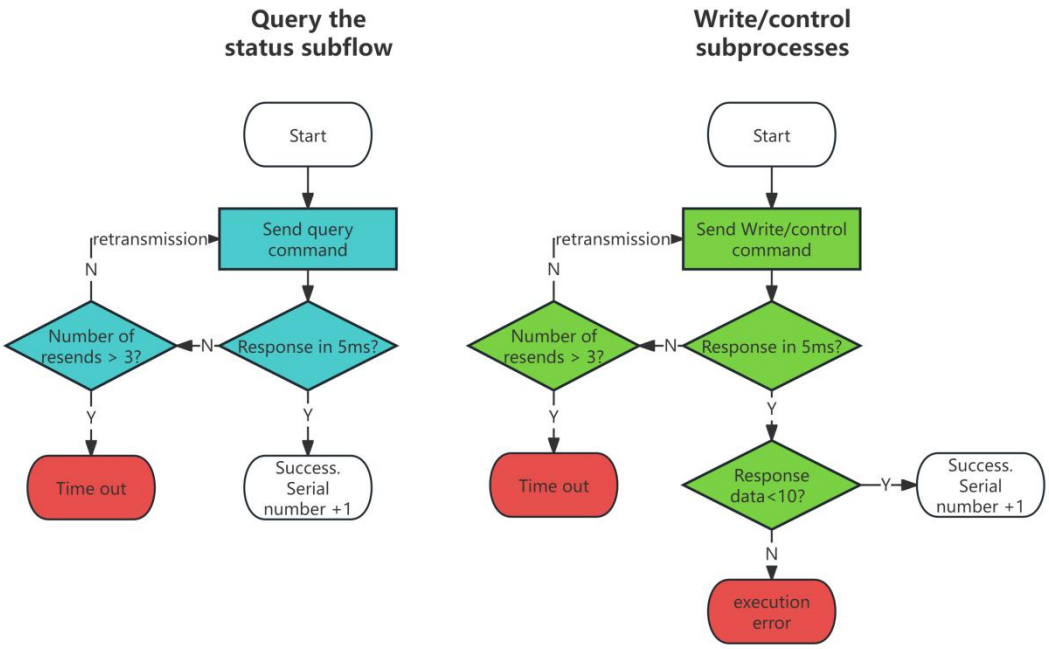


Figure 8-4 KT_CAN_DIC Protocol Communication Sub-flow Framework

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-up default upload heartbeat	0x00040100	Data frame	Extended frame	0x08	00 00 00 00 00 00 00 00
1	Response	Power-up default upload heartbeat	0x00040100	Data frame	Extended frame	0x08	00 00 00 00 00 00 00 00
2	Response	Power-up default upload heartbeat	0x00042900	Data frame	Extended frame	0x08	01 00 00 00 00 00 00 00
3	Response	Power-up default upload heartbeat	0x00040100	Data frame	Extended frame	0x08	01 00 00 00 00 00 00 00
4	Response	Power-up default upload heartbeat	0x00042900	Data frame	Extended frame	0x08	02 00 00 00 00 00 00 00
5	Send	Turn off ADPZ-axis 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	Turn off SP28 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 SP28 automatically feedback after execution	0x00010001	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 01

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
		done					
10	Response		0x00000100	Data frame	Extended frame	0x08	02 20 00 52 00 00 00 02
11	Send	Enable Axis Z automatically feedback after execution done	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	ADPZ-axis initialization	0x00010029	Data frame	Extended frame	0x08	03 41 00 00 00 00 C3 50
14	Response		0x00002900	Data frame	Extended frame	0x08	03 41 00 00 00 00 00 02
15	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
16	Send	Configure SP28 initialization power to 100%	0x00010001	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 64
17	Response		0x00000100	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 02
18	Send	Configure SP28 initialization to eject TIP	0x00010001	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 00
19	Response		0x00000100	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 02
20	Send	Perform SP28 initialization	0x00010001	Data frame	Extended frame	0x08	05 40 00 00 00 00 FA 00
21	Response		0x00000100	Data frame	Extended frame	0x08	05 40 00 00 00 00 00 02
22	Response	SP28 operation completion frame	0x00030100	Data frame	Extended frame	0x08	02 70 02 00 00 00 00 00
23	Send	Configure ADPZ-axis to pick up TIP of 80% power	0x00010029	Data frame	Extended frame	0x08	01 41 04 01 00 00 00 50
24	Response		0x00002900	Data frame	Extended frame	0x08	01 41 04 01 00 00 00 02
25	Send	Execute ADPZ-axis to pick up TIP	0x00010029	Data frame	Extended frame	0x08	01 41 04 00 00 00 4E 20
26	Response		0x00002900	Data frame	Extended frame	0x08	01 41 04 00 00 00 00 02
27	Response	SP28 with TIP	0x00030100	Data frame	Extended frame	0x08	00 70 01 00 00 00 00 01
28	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
29	Send	Configuration ADPZ-axis move speed 80000um/S	0x00010029	Data frame	Extended frame	0x08	04 41 01 01 00 01 38 80
30	Response		0x00002900	Data frame	Extended frame	0x08	04 41 01 01 00 00 00 02
31	Send	ADPZ-axis positioning at 0um	0x00010029	Data frame	Extended frame	0x08	05 41 01 00 00 00 00 00
32	Response		0x00002900	Data frame	Extended frame	0x08	05 41 01 00 00 00 00 02
33	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
34	Send	Configure SP28 liquid level detection ADPZ-axis following speed 20000um/s	0x00010001	Data frame	Extended frame	0x08	0C 20 00 64 00 00 4E 20
35	Response		0x00000100	Data frame	Extended frame	0x08	0C 20 00 64 00 00 00 02
36	Send	Configure ADPZ-axis aspiration following lower limit	0x00010001	Data frame	Extended frame	0x08	0D 20 00 65 00 01 FB D0
37	Response		0x00000100	Data frame	Extended frame	0x08	0D 20 00 65 00 00 00 02
38	Send	Configure ADPZ-axis position of the TIP TIP when it is in the mouth of the test tube	0x00010001	Data frame	Extended frame	0x08	0E 20 00 66 00 00 AF C8
39	Response		0x00000100	Data frame	Extended frame	0x08	0E 20 00 66 00 00 00 02
40	Send	Configure the ADPZ-axis position of the TIP TIP when the diameter of the test tube changes	0x00010001	Data frame	Extended frame	0x08	0F 20 00 67 00 01 9A 28
41	Response		0x00000100	Data frame	Extended frame	0x08	0F 20 00 67 00 00 00 02
42	Send	Configure the cross-sectional area of the inner cavity of the test tube	0x00010001	Data frame	Extended frame	0x08	10 20 00 68 00 00 00 4E
43	Response		0x00000100	Data frame	Extended frame	0x08	10 20 00 68 00 00 00 02
44	Send	Configure SP28 aspiration velocity to 100ul/s	0x00010001	Data frame	Extended frame	0x08	06 40 01 01 00 00 00 64
45	Response		0x00000100	Data frame	Extended frame	0x08	06 40 01 01 00 00 00 02
46	Send	Configure SP28 with a aspiration cut-off velocity of 0	0x00010001	Data frame	Extended frame	0x08	07 40 01 02 00 00 00 00
47	Response		0x00000100	Data frame	Extended frame	0x08	07 40 01 02 00 00 00 02
48	Send	aspiration 30ul	0x00010001	Data	Extended	0x08	08 40 01 00 00 00 0B B8

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
				frame	frame		
49	Response		0x00000100	Data frame	Extended frame	0x08	08 40 01 00 00 00 00 02
50	Response	SP28 operation completion frame	0x00030100	Data frame	Extended frame	0x08	03 70 02 00 00 00 00 00
51	Send	Configuring SP28 liquid level detection without detecting timeout	0x00010001	Data frame	Extended frame	0x08	09 40 07 01 00 00 00 00
52	Response		0x00000100	Data frame	Extended frame	0x08	09 40 07 01 00 00 00 02
53	Send	Perform SP28 liquid level detection	0x00010001	Data frame	Extended frame	0x08	0A 40 07 00 00 00 00 00
54	Response		0x00000100	Data frame	Extended frame	0x08	0A 40 07 00 00 00 00 02
55	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
56	Response	SP28 operation completion frame	0x00030100	Data frame	Extended frame	0x08	04 70 02 00 00 00 00 00
57	Response	SP28 return to detected liquid level	0x00030100	Data frame	Extended frame	0x08	00 70 00 00 00 00 00 04
58	Response	Configuration of SP28 aspiration anomaly detection	0x00010001	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 05
59	Response		0x00000100	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 02
60	Send	Configure SP28 for a aspiration speed of 100ul/s	0x00010001	Data frame	Extended frame	0x08	0C 40 01 01 00 00 00 64
61	Response		0x00000100	Data frame	Extended frame	0x08	0C 40 01 01 00 00 00 02
62	Send	Configure SP28 aspiration cut-off velocity 0	0x00010001	Data frame	Extended frame	0x08	0D 40 01 02 00 00 00 00
63	Response		0x00000100	Data frame	Extended frame	0x08	0D 40 01 02 00 00 00 02
64	Send	Perform aspiration liquid 100ul	0x00010001	Data frame	Extended frame	0x08	0E 40 01 00 00 00 27 10
65	Response		0x00000100	Data frame	Extended frame	0x08	0E 40 01 00 00 00 00 02
66	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
67	Response	SP28 operation completion frame	0x00030100	Data frame	Extended frame	0x08	05 70 02 00 00 00 00 00

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
68	Send	Configuration ADPZ-axis relative upward speed 80000um/S	0x00010029	Data frame	Extended frame	0x08	06 41 02 01 00 01 38 80
69	Response		0x00002900	Data frame	Extended frame	0x08	06 41 02 01 00 00 00 02
70	Send	ADPZ-axis Move up relative to the current position10000um	0x00010029	Data frame	Extended frame	0x08	07 41 02 00 00 00 27 10
71	Response		0x00002900	Data frame	Extended frame	0x08	07 41 02 00 00 00 00 02
72	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
73	Send	Configure SP28 re-aspiration volume 0ul during dispensing liquid	0x00010001	Data frame	Extended frame	0x08	10 40 02 01 00 00 00 00
74	Response		0x00000100	Data frame	Extended frame	0x08	10 40 02 01 00 00 00 02
75	Send	Configure SP28 for a dispensing velocity of 100ul/s	0x00010001	Data frame	Extended frame	0x08	11 40 02 02 00 00 00 64
76	Response		0x00000100	Data frame	Extended frame	0x08	11 40 02 02 00 00 00 02
77	Send	Configure SP28 aspiration cut-off velocity 0ul/s	0x00010001	Data frame	Extended frame	0x08	12 40 02 03 00 00 00 00
78	Response		0x00000100	Data frame	Extended frame	0x08	12 40 02 03 00 00 00 02
79	Send	Perform dispensing liquid 130ul	0x00010001	Data frame	Extended frame	0x08	13 40 02 00 00 00 32 C8
80	Response		0x00000100	Data frame	Extended frame	0x08	13 40 02 00 00 00 00 02
81	Response	SP28 operation completion frame	0x00030100	Data frame	Extended frame	0x08	06 70 02 00 00 00 00 00
82	Response	ADPZ-axis operation completion frame	0x00032900	Data frame	Extended frame	0x08	00 70 02 00 00 00 00 00
83	Send	Disable SP28 aspiration liquid anomaly detection	0x00010001	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 00
84	Response		0x00000100	Data frame	Extended frame	0x08	01 20 00 3C 00 00 00 02
85	Send	Turn off SP28 liquid level detection ADPZ-axis following	0x00010001	Data frame	Extended frame	0x08	22 20 00 64 00 00 00 00
86	Response		0x00000100	Data	Extended	0x08	22 20 00 64 00 00 00 02

No.	direction	Description	Frame ID	Format	Type	DLC	Data(HEX)
				frame	frame		
87	Send	Disable SP28 aspiration liquid level following function	0x00010001	Data frame	Extended frame	0x08	23 20 00 68 00 00 00 00
88	Response		0x00000100	Data frame	Extended frame	0x08	23 20 00 68 00 00 00 02
89	Send	Configure SP28 initialization power to 100%	0x00010001	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 64
90	Response		0x00000100	Data frame	Extended frame	0x08	03 40 00 01 00 00 00 02
91	Send	Configure SP28 initialization to eject TIP	0x00010001	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 00
92	Response		0x00000100	Data frame	Extended frame	0x08	04 40 00 02 00 00 00 02
93	Send	Perform SP28 initialization	0x00010001	Data frame	Extended frame	0x08	05 40 00 00 00 00 FA 00
94	Response		0x00000100	Data frame	Extended frame	0x08	05 40 00 00 00 00 00 02
95	Response	SP28 operation completion frame	0x00030100	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 Flow

Direction	Command(HEX)	Function	Command String ASCII
Send	AA8029075A7A31303030301F	ADPZ-axis initialization	Zz10000
Response	558029020000		
Polling	AA8129013F94	Polling ADPZ-axis status	
Response	558129010000	ADPZ-axis status 01 busy	
	.....	Omitted (continue polling status until idle)	
Send	AA8329013F96	Read ADPZ-axis status	
Response	558329000001	ADPZ-axis state 0 idle	
Send	AA84010D4974363430303032C3130302C300C	SP28 initialization	It64000,100,0
Response	5584010200DC		
Polling	AA8501013F70	Polling SP28 Status	
Response	5585010100DC	SP28 status 01 busy	
	.....	Omitted (continue polling status until idle)	
Send	AA8701013F72	Read SP28 status	

Direction	Command(HEX)	Function	Command String ASCII
Response	5587010000DD	SP28 state 0 idle	
Send	AA88290A5A6735303030302C3830AF	ADPZ-axis downward movement pick up TIP	Zg50000,80
Response	558829020008		
	.....	Omitted	
Send	AA8A29013F9D	Read ADPZ-axis status	
Response	558A29000008	ADPZ-axis state 0 idle	
Send	AA8B290A5A70302C313830303030B7	ADPZ-axis moves upward to the zero position	Zp0,180000
Response	558B2902000B		
	.....	Omitted	
Send	AA8D29013FA0	Read ADPZ-axis status	
Response	558D2900000B	ADPZ-axis state 0 idle	
Send	AA8E010352723333	Read TIP status	Rr3
Response	558E0102013118		
Send	AA8F012257723130302C32303030302C3133303030302C34353030302C3130353030302C373836	Configure SP28 liquid level detection and aspiration/dispensing ADPZ-axis follow parameters.	Wr100,20000,130000,45000,105000,78
Response	558F010200E7		
Send	AA90010C4961333030302C3130302C30CD	Aspirate 30ul Leading Air Gap	Ia3000,100,0
Response	5590010200E8		
	.....	Omitted	
Send	AA9201013F7D	Query SP28 status	
Response	5592010000E8	Idle	
Send	AA9301054C64302C307F	Turn on SP28 liquid level detection	Ld0,0
Response	5593010200EB		
	.....	Omitted	
Send	AA9501013F80	Query SP28 status	
Response	5595010000EB	Idle	
Send	AA9601065772363O2C35D7	Setting of aspiration abnormality detection	Wr60,5
Response	5596010200EE		
Send	AA97010D4961313030303O2C3130302C3003	SP28 aspiration 100ul liquid	Ia10000,100,0
Response	5597010200EF		
	.....	Omitted	
Send	AA9901013F84	Query SP28 status	
Response	5599010000EF	Idle	
Send	AA9A29095A70302C383030303094	ADPZ-axis rises to position 0	Zp0,80000
Response	559A2929020043		

Direction	Command(HEX)	Function	Command String ASCII
	.....	Omitted	
Send	AA9C29013FAF	Query ADPZ-axis status	
Response	559C2900001A	Idle	
Send	AA9D010F4461313330303030 2C302C3130302C3065	SP28 dispense liquid 130ul	Da13000,0,100,0
Response	559D010200F5		
	.....	Omitted	
Send	AA9F01013F8A	Query SP28 status	
Response	559F010000F5	Idle	
Send	AAA00106577236302C30DC	Turn off aspiration anomaly detection	Wr60,0
Response	55A0010200F8		
Send	AAA1010F57723130302C302C302C302C302C3081	Turn off SP28 liquid level detection and aspiration/dispensing ADPZ-axis follow.	Wr100,0,0,0,0,0
Response	55A1010200F9		
Send	AAA2010D4974363430303030 2C3130302C302A	SP28 ejects TIP	It64000,100,0
Response	55A2010200FA		
	.....	Omitted	
Send	AAA401013F8F	Query SP28 status	
Response	55A4010000FA	Idle	

9 Serial Port Commands

This chapter describes the data format in Data area of the KT_OEM and KT_DT protocol, i.e. the format of the operation commands. The data is an ASCII string and mulTIPle commands set can be sent at the same time, and SP28 will parse and execute the commands set one by one. These commands are classified by function as follows:

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

9.1 Commands Syntax

Send mulTIPle commands to SP28, and the format is as follows:

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

The SP28 returns 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 9.2.

<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.*

9.2 Commands Details

	*Note:* *[] represents an optional parameter, if the optional parameter is empty it will be executed according to the default parameter in the protocol.* *The content inside <> is a command, the mark <> does not need to be sent, it is just used to distinguish between letters and commands.*

9.2.1 Command Parameter Range Coefficient K

there are four models of SP28 with volumes of 100uL, 250uL, 500uL, and 1000uL. For the 100uL pipettor, the coefficient K is 10. for the 250uL pipettor, K is 4. for the 500uL pipettor, K is 2. and for the 1000uL pipettor, K is 1.

9.2.2 Initialization Command

9.2.2.1 <It>n1,[n2],[n3] Initialize

Used to initialize the SP28, control the SP28 piston to position 0.

Table 9-1 It command

Command	Parameters	Data range	Unit	Default	Description
It	n1	200～64000	ustep/s	/	**Mandatory parameter,** Initialization velocity
	[n2]	0～100	%	100	The power of the initialization process. Percentage of maximum power
	[n3]	0	/	0	TIP will be ejected Regardless of whether there is a TIP
		1			TIP will be ejected if there is a TIP
		2			Don’t eject the TIP

Response: Refer to Table 11-1.

	*Note: To ensure picking up the TIP successfully, please apply a downward force of 28±2N and hold for at least 1 second when picking up the TIP. Insufficient downward force may cause the TIP to fall off during movement, while excessive force may damage the pipettor.*

9.2.3 Control Commands

9.2.3.1 <Ia>n1,[n2],[n3] Aspiration

Used to aspirate the liquid, automatically converting the parameters corresponding to the volume to the distance of the piston movement and controlling the upward movement of the piston to aspirate.

Table 9-2 Ia command

Command	Parameters	Data range	Unit	Default	Description

Ia	n1	4～100000/K	0.01ul	/	**Mandatory parameter**, Aspiration volume
	[n2]	1～2000/K	1ul/s	500/K	Aspiration velocity
	[n3]	0～2000/K	1ul/s	10	cut-off velocity

n1 Aspiration volume:

Mandatory parameter, aspiration volume refers to the volume that are theoretically aspirated to the disposable TIP, but the aspiration volume and target volume are different due to different physical factors. For high precision aspiration, it is necessary to combine the physical characteristics such as aspiration velocity, liquid viscosity, aspiration volume, and disposable TIP model to make the corresponding calibration curve.

[n2] Aspiration velocity:

The velocity should be set according to the physical properties of the liquid. for example, viscosity and surface tension. Too fast a flow rate for different liquids may result in low pressure in the SP28 pipetting barrel and may also cause the liquid to continue to flow into the disposable TIP when the plunger stops, leading to mis-aspiration. A reasonable approach is to set the liquid velocity to match the aspiration velocity.

[n3] cut-off velocity:

This parameter is used to control the final stop speed of aspiration and is set according to the different physical properties of the liquid.

Response data： See status Table 11-1.

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

Used for liquid dispense, automatically converts the parameter corresponding to the volume to the piston movement distance, controls the piston movement to dispense the liquid, and according to the parameter whether re-aspiration occurs to prevent hanging liquid.

Table 9-3 Da command

Command	Parameters	Data range	Unit	Default	Description
Da	n1	4～100000/K	0.01ul	/	**Mandatory parameter**, Dispense volume
	[n2]	0～10000	0.01ul	0	Re-aspiration volume
	[n3]	1～2000/K	1ul/s	500/K	Dispense velocity
	[n4]	0～2000/K	1ul/s	10	cut-off velocity

n1 Dispense volume:

Dispense volume refers to the volume theoretically dispensed from the disposable TIP, but the dispense volume and target volume are different due to different physical factors. For high precision dispense, it is necessary to combine the physical characteristics such as dispense velocity, liquid viscosity, dispense volume, and disposable TIP model to make the corresponding calibration curve.

[n2] Re-aspiration volume:

To avoid the droplet of the disposable TIP affecting the accuracy and causing

cross-contamination, we design the function of automatically re-aspirating specified volume of liquid after the dispense is completed, which can well avoid the droplets issue. The re-aspiration volume is affected by the dispense volume,disposable TIP type, reagent viscosity, etc. The dispense accuracy is affected by the dispense volume, for different dispense volumes, users need to debug and change the parameters to achieve anti-droplets and ideal dispense accuracy.

[n3]Dispense velocity:

The flow rate should be set according to the physical properties of the liquid, such as viscosity and surface tension. Too fast a flow rate for different liquids may lead to high pressure in the SP28 pipetting barrel. A reasonable method is to set the liquid velocity to match the dispense velocity.

[n4]cut-off velocity:

It is used to set the velocity at the moment of dispense completion, decelerate to stop velocity after the final stage of dispense completion and then stop, note that the stop velocity must be less than or equal to the dispense velocity. Higher stop velocity can quickly cut-off the dispensed fluid, which has some improvement on droplets issue of the disposable TIP.

Response data: See status Table 11-1.

	Note: *Parameter n1 is the target volume of dispense, <n2> does not affect the target volume of liquid dispense, only affects the hanging of liquids for aliquot dispense.* *Keep <n2> = 0 and <n4> =25 for single aspirate and dispense.* *The cut-off velocity <n4> must be less than the dispense speed <n3> in aliquot dispense.*

9.2.3.3 <Ld>n1,[n2] Liquid level detection

Used to detect the liquid level. When the liquid level detection, the SP28 loaded with the disposable TIP is first lowered to 5mm from the top surface of the reagent container, then the liquid level detection command is sent and the lowering continues, when the disposable TIP touches the liquid surface, the SP28 will send out a signal that the liquid level has been detected. the user can view the signal of the detected liquid level in three ways: monitoring the communication data, monitoring the GPO1 and querying the register status.

Table 9-4 Ld command

Command	Parameters	Data range	Unit	Default	Description
Ld	n1	0～1	/	/	**Mandatory parameter** 0: After the SP28 detected the liquid level, don't automatically reported the data, it is needed confirm whether the liquid level is detected by querying

				whether the status value is 1 or not. 1: Automatically report the status after detecting the liquid level, if detected, the status value is 1.
	[n2]	0～20000	ms	10000	0: No timeout. Other values: timeout duration, timeout time without detecting pressure change will report timeout error
	[n3]	-10000～10000	/	0	Liquid level detection pressure threshold deviation
	[n4]	1～100	ms	5	Duration for which the liquid level detection pressure reaches the threshold
	[n5]	1～2000	ul/s	25	Liquid level detection aspiration velocity

Response data: See status Table 11-1.

[n3]Liquid level detection pressure threshold deviation:

Adjust the parameter for triggering liquid level detection anomalies. The smaller the value of this parameter, the more sensitive the liquid level detection will be. If the liquid level detection is triggered prematurely, set this parameter to a positive value. If the liquid level detection probe penetrates the reagent too deeply, set this parameter to a negative value.

[n4]Duration for which the liquid level detection pressure reaches the threshold:

It can have a filtering effect, mainly dealing with detection anomalies caused by sudden changes in air pressure.

[n5]Liquid level detection aspiration velocity:

Adjust the parameter for triggering liquid level detection anomalies. The larger the value of this parameter, the more sensitive the liquid level detection will be, and this parameter will also limit the maximum duration of liquid level detection.

Note: Generally, the parameters n3 to n5 can be used with their default values and do not need to be modified.

9.2.3.4 <Mp>n1,[n2],[n3] Absolute position move command

Control the plunger moves to the absolute position.

Table 9-5 Mp command

Command	Parameters	Data range	Unit	Default	Description
Mp	n1	0～maximum stroke	ustep	/	**Mandatory parameter** Target position
	[n2]	1～64000	ustep/s	8000	Moving velocity
	[n3]	0～32000	ustep/s	160	cut-off velocity

9.2.4 Parameter Read/Write Commands

9.2.4.1 Register

The registers are used for customer Host writing and reading the parameters of SP28.

Table 9-6 Register Table

Register address	R/W	Data range	Unit	Default	Description
1	R/W	/	/	0	Current status(see Table 11-1 status table),write 0 to clear the error, return value is the same as Query status command: '?'
2	R	0～1	/	0	Whether the liquid level is detected 0:No, the liquid level is not detected 1:Yes,the liquid level is detected
3	R	0～1	/	0	The TIP is picked up? 0:No, no TIP 1:Yes, with TIP
4	R		/	/	Current pressure ADC value
…					
10	R/W	0～2		0	GPO1 output configuration: 0: Output 10 ms high-level pulse when liquid level is detected 1: Output high-level voltage when liquid level is detected 2: Output low-level voltage when liquid level is detected
…					
20	R	0～32000	ustep		Current piston position
…					
28	R		ustep		Maximum stroke
29	R	1000/K	ul		Maximum volume
…					
32	R/W	0～3200	ustep		Backlash
33	R/W	0～2300	mA	1000	Rated current
…					
36	R/W	0～1			0: Disable the pressure sensor 1: Enable the pressure sensor
…					
42	R/W	0～64000	ustep		The distance of ejecting the TIP
43	R/W	0～2		0	0: SP28 has TIP detect optocoupler, Host determines whether there is a TIP by reading the register 3. 1: SP28 has TIP detect optocoupler, SP28 will detect whether there is a TIP before aspirate, dispense and liquid level detection, report an error if no TIP. 2: 1)SP28 doesn't have TIP detect optocoupler; 2)SP28 has TIP detect optocoupler but doesn't use it

Register address	R/W	Data range	Unit	Default	Description
…					
54	R/W	1～100		60	Liquid level detection coefficient, the smaller the value, the more sensitive
…					
60	R/W	0～0x1F		0	Pressure abnormality detection, HEX code, corresponding bit 1 to enable the function Bit0: Aspiration of clot detection enable Bit2: Aspiration of empty detection enable Bit4: Dispense clot detection enable
…					
70	R/W	0～100		10	Aspirating clot detection coefficient, the bigger the value, the more sensitive
72	R/W	0～100		60	Aspirating empty detection coefficient, the bigger the value, the more sensitive
73	R/W	0～1000		10	Dispense clot detection coefficient, the smaller the value, the more sensitive
…					
80	R/W			38400	Serial port baud rate
81	R/W			500	CAN baud rate
82	R/W	0～1		0	Automatic data upload after exercise completion 0: No upload 1: Upload
83	R/W	0～10000	ms	1000	Heartbeat interval time 0: No heartbeat data Other values: Heartbeat interval time in ms
84	R/W	0～255		1	Device address
…					
90	R				Firmware version
91	R				Device model
92	R				Device serial number, each SP28 is unique
…					
100	R/W	0～50000	um/s	0	The speed of ADPZ-axis when liquid level detection, ADPZ-axis is automatically controlled during liquid level detection. When set to 0, ADPZ-axis does not move. This parameter doesn’t support saving after power down

Register address	R/W	Data range	Unit	Default	Description
101	R/W	0～180000	um		The position of the ADPZ-axis when the end of TIP moves to the bottom of the test tube, it is used when the liquid level detection and liquid level following. This parameter doesn't support saving after power down
102	R/W	0～180000	um		The position of the ADPZ-axis when the end of TIP moves to the mouth of the test tube, it is used when the dispensing following. This parameter doesn't support saving after power down
103	R/W	0～180000	um		The position of the ADPZ-axis when the end of TIP moves to where the diameter changes of the test tube, it is used when the liquid following. This parameter doesn't support saving after power down
104	R/W	0～180000	mm2		Cross-sectional area of test tube, it is used when the liquid following. This parameter doesn't support saving after power down, when it is 0, ADPZ-axis does not move

Note: Registers 100～104 are only available when using with Keyto ADPZ-axis together.

9.2.4.2 <Wr>n1,n2 Write register command

Table 9-7 Wr register Command

Command	Parameters	Data range	Unit	Default	Description
Wr	n1	1～100	/	/	**Mandatory parameter** Register Address
	n2		/	/	**Mandatory parameter** Data

9.2.4.3 <Rr>n1,[n2] Read register command

Read register, read the specified number of register from the starting address, when reading register number is larger than 1, return data separated by ','.

Table 9-8 Rr register Command

Command	Parameters	Data range	Unit	Default	Description
Rr	n1	1～100	/	/	**Mandatory parameter** Start reading Register Address
	[n2]	1～255	/	1	Number of reading

Response data: The status is shown in the Table 11-1, read the specified number of register from the starting address, read register larger than 1, return data separated by ','.

9.2.5 System operation commands

9.2.5.1 <?> Query Status

Send commands "?" to query status.

Table 9-9 ? Command

Command	Parameters	Data range	Unit	Default	Description
?	/				Query status

Response data: The status is shown in the Table 11-1.

9.2.5.2 <{}>[n1] Loop control command

The loop control command is used to control the loop of a command set. Loops can be nested, and a command string can support up to 20 loops, including nested loops.

Table 9-10 {} command

Command	Parameters	Data range	Unit	Default	Description
{	/	/	/	/	Loop starting
}	[n1]	0～2147483647		0	0: infinite loop Other value: repeat times

9.2.5.3 <L>[n1] Delay

The delay is used for SP28 internal delay, mainly as a delay between two command executions.

Table 9-11 L Command

Command	Parameters	Data range	Unit	Default	Description
L	[n1]	0～2147483647	ms	/	Delay time

Response data: The status is shown in the Table 11-1.

9.2.5.4 <T> Stop command

Stops the command currently being executed by SP28.

Table 9-12 T Command

Command	Parameters	Data range	Unit	Default	Description
T	/				Stops the command currently being executed by SP28.

9.2.5.5 <U> Reset command

The commands are used as a device reset operation.

Table 9-13 U Command

Command	Parameters	Data range	Unit	Default	Description

U	/	0	Device reset

9.2.5.6 <M>[n1] Restore factory settings command

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

Table 9-14 M command

Command	Parameters	Data range	Unit	Default	Description
M	/			0	Restore factory settings

9.2.5.7 <S> Save after power off command

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

Table 9-15 S command

Command	Parameters	Data range	Unit	Default	Description
S	/				The modified register parameters will be saved even after power off

10 KT_CAN_DIC Dictionary

The object dictionary includes 16-bit index number and 8-bit sub-index number, different operations are indicated by ordered sequence number, all data including read and write permissions. The control commands include initialization, aspirate and dispense liquid, etc., all follow different index number to indicate different commands, and sub-index numbers are different parameters, the number of parameters is the same as the number of serial command parameters, for example, the serial port command <It>n1[n2][n3], where 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 number and several sub-index numbers, and frame data with non-zero sub-index numbers are sent first, and frame data with zero sub-index numbers are sent last, and the SP28 starts to move when it reserves a command with zero sub-index numbers.*

10.1 Command Parameter Range Coefficient K

there are four models of SP28 with volumes of 100uL, 250uL, 500uL, and 1000uL. For the 100uL pipettor, the coefficient K is 10. for the 250uL pipettor, K is 4. for the 500uL pipettor, K is 2. and for the 1000uL pipettor, K is 1.

10.2 Control Commands

Table 10-1 CAN Control Commands

Function	Index	Sub-index	R/W	Data range	Default	Description
Initialization	0x4000	0	W	200～64000 (ustep/s)	/	**Mandatory parameter** Initialization velocity
		1	R/W	0～100(%)	100	Power during initialization
		2	R/W	0～2	0	Eject TIP mode: 0: Eject TIP regardless of whether there is a TIP 1: Eject TIP if there is a TIP 2: Don’ t eject the TIP
Aspirate	0x4001	0	W	4～100000(0.01ul)/K	/	**Mandatory parameter** Aspiration volume, for example, aspirate 100ul parameter value is 10000
		1	R/W	1～2000/K (ul/s)	500/K	Aspiration velocity, ul/s
		2	R/W	0～2000/K (ul/s)	10	cut-off velocity, ul/s
Dispense	0x4002	0	W	4～100000(0.01ul)/K	/	**Mandatory parameter** Dispense volume, resolution 0.01ul, for example, aspirate 100ul parameter value is 10000

Function	Index	Sub-index	R/W	Data range	Default	Description
		1	R/W	0～10000(0.01ul)/K	0	Re-aspiration volume, resolution 0.01ul, e.g. 200 for 2ul
		2	R/W	1～2000/K（ul/s）	500/K	Dispense velocity, ul/s
		3	R/W	0～2000/K（ul/s）	10	cut-off velocity, ul/s
Absolute position move	0x4003	0	W	0～32000	/	**Mandatory parameter** Position value,ustep
		1	RW	1～64000	16000	Running velocity,ustep/s
		2	RW	0～32000	160	cut-off velocity,ustep/s
Liquid level detection	0x4007	0	W	0～1	/	**Mandatory parameter** Liquid Level Detection Reporting Type: 0: no automatic reporting after detecting liquid level. need to check whether status bit is 1 or not. 1：Automatic reporting after detecting liquid level, and the status is 1
		1	R/W	0～20000(ms)	0	Timeout detection time 0: No detection of timeout. Other values: timeout duration, timeout time without detecting pressure change will report a timeout error
		2	RW	-10000～10000	0	Liquid level detection pressure threshold deviation: Adjust the parameter for triggering liquid level detection anomalies. The smaller the value of this parameter, the more sensitive the liquid level detection will be. Generally, the default value can be used and there is no need to modify it.
		3	RW	1～100 ms	5	The duration for which the liquid level detection pressure reaches the threshold can have a filtering effect, mainly dealing with detection anomalies caused by sudden changes in air pressure. Generally, the default value can be used and there is no need to modify it.
		4	RW	1～2000 ul/s	25	Liquid level detection aspiration speed: Adjust the parameter for

Function	Index	Sub-index	R/W	Data range	Default	Description
						triggering liquid level detection anomalies. The larger the value of this parameter, the more sensitive the liquid level detection will be. Generally, the default value can be used and there is no need to modify it. This parameter will also limit the maximum duration of liquid level detection.
Stop	0x4008	0	W	0	0	Stop moving and liquid level detection
Save	0x5000	0	W		0	Save parameters after power off
Restore Factory Settings	0x5000	1	W	123456	/	**Mandatory parameter** Restore Factory Settings
Reset and restart	0x9F00	3	W		0	Reset and restart

10.3 Register Read and Write

It is specified that the index number 0x2000 for the SP28 internal register, the sub-index number is the register address, the register address is shown in Table 9-6.

10.4 Process Data

The SP28 automatically uploads process data via command 0x0003, and the process data dictionary is as below:

Table 10-2 CAN Process Data

Function	Index	Sub-index	R/W	Data range	Default	Description
Liquid level detected	0x7000	0	R	4	/	After the liquid level is detected, automatically upload this status value 4
TIP detection status	0x7001	0	R	0～1	/	TIP detection status Automatic uploading of the disposable TIP status when it is picked up or ejected 0: No disposable TIP 1: With disposable TIP
Movement complete	0x7002	0	R	0～255	/	After moving done then automatically upload the status

d	0: normal Other data:Error status, see Table 11-1

10.5 Heartbeat Data

The SP28 sends heartbeat data via index number 0x0004, the custom Host can use it to detect whether the device is online.

10.6 Alarm Data

The SP28 sends alarm messages via index number 0x0080. The alarm messages are shown in the status Table 11-1.

11 Device Status and LED

11.1 Device Status

Each command has a return status, which indicates whether the commands are executed successfully, whether the device is error, busy, idle, etc. The status is 1 byte of hexadecimal data.

Rules:

0～9：Working status.

10～19：Commands execution error code.

>=20：Device failures error code

Table 11-1 Status Table

Value	Status	Description
0	Idle	Device is in idle status
1	Busy	The device is busy and does not accept the commands
2	Executed successfully	Commands executed successfully
3	Execution complete	Command execution completed
4	Liquid level detected	When the automatic reporting function is enabled, the status is automatically uploaded after the liquid level is detected
…		
10	Parameter over range	Commands parameters out of range
11	Parameter error	Commands parameter error
12	Syntax error	Commands syntax error
13	Invalid commands	Command not supported, invalid
14	Address error	Read and write register address error
15	Prohibit writing	This address is inhibited from being written
16	Prohibit reading	This address is inhibited from being read
17	Uninitialized	Uninitialized
18	ADPZ-axis not initialized	ADPZ-axis is not initialized
19	ADPZ-axis not connected	ADPZ-axis is not connected
20	Disposable TIP not detected alarm	Allow aspirate and dispense of liquid after alarm
21	Eject disposable TIP failure alarm	Allow aspirate and dispense of liquid after alarm
22	Timeout alarm	Allow aspirate and dispense of liquid after alarm
23	Aspiration of clot detection alarm	Allow aspirate and dispense of liquid after alarm
25	Aspiration of empty detection	Allow aspirate and dispense of liquid after alarm

	alarm	
27	Dispense of colt detection alarm	Allow aspirate and dispense of liquid after alarm
…		
50	Motor stall error	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize
51	Drive failure	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize
52	Zero position optocoupler error	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize
53	Disposable TIP optocoupler error	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize
54	Atmospheric pressure sensor error	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize
55	Storage error	Prohibit the aspiration and dispense of liquid, need to troubleshoot and re-initialize

11.2 LED Indicator

LED has 2 color: green and blue, blue: indicates whether the motor is working or not, green:indicates whether the TIP is detected or not, Blue light flashing: error.

Table 11-2 LED Status Description

LED Status	Description
LED off	idle
Blue light always on	Busy/ Liquid level detected
Green light always on	TIP detected
Blue flashing	Error,The number of flashes corresponds to different errors

Table 11-3 LED Flashing times Description

Flashing times	error	Description
1	Alarm when no disposable TIP is detected	Set the register 43 to enable, this alarm will happen when aspirating/dispensing/liquid level detecting and no TIP is detected, it is recommended that stop the SP28 to prevent reagents from being sucked into the pipetting barrel.
2	Alarm when fail to eject disposable TIP	After executing the TIP ejection instruction, if the TIP presence feedback indicates an error, check whether the TIP is installed too tightly and avoid reusing TIP.
3	Alarm when time out	If the liquid level is not detected within the specified time after executing the liquid level detection instruction, report this error. Ensure that the pipettor TIP can make contact with the reagent during the descent process.

4	Alarm for aspirate clot detected	Enable the alarm function in register 60. During aspiration or dispensing, if abnormal pressure is detected, report this type of error. Troubleshoot as adjusting according to the process, and allow continued control of the device when an error is reported.
6	Alarm when aspirate empty detected	
7	Alarm when dispense clot detected	
9	Motor blockage error	Contact our sales and engineer
10	Drive error	
11	Zero position optocoupler error	
12	Disposable TIP optocoupler error	
13	Sensor error	
14	Storage error	

12 Troubleshooting and Q&A

12.1 Common Issues and Troubleshooting

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

Table 12-1 Communication Issue

Issue	Possible causes	Recommended Solutions
ADP power on but the indicator doesn't flash	The cable plug part is not fixed. ADP moves up and down causing the cable to bend and break at the terminal connection.	Consider replacing the cable if poor contact occurs when wiggling the cable, and ensure that the cable cover is properly pressed against the cable sheath. For more details, refer to section 4.1, "ADP Installation."
	short circuit of power cables	Use a multi-meter to check if the ADP power supply is short-circuited. If a short circuit is detected, please return the device to Keyto for repair.
	Loose cable joint	Power off then reconnect. For more details, refer to section 4.1, "ADP Installation"
	Incorrect cable connection	Connect the cables correctly as described in "Lead Definition"
Failed to communicate with ADP	Incorrect baud rate	The baud rate defaults to 38400, please test the communications in accordance with Chapter 5, "Composite Function Controller Tool Usage Instructions."
	Incorrect wiring sequence	Check RS232 cables: Rx→Tx, Tx→Rx, GND →GND.
	Incompatible serial port tool	Replace the USB to serial cable or RS485 adapter with a different brand.
	Incorrect instruction format	Check the instruction format in accordance with Chapter 8 "Communication Process ".
Unstable communication	Noise on communication lines	1. Make sure the communication cable is as short as possible. 2. Dial terminating resistor to ON if necessary.

		3. Separate the communication cable from the high-current cable. 4. Keep the resistance between the two phases of CAN and RS485 at 60Ω.
	Unstable communication mode	1. Communicate at a lower baud rate. 2. Adopt the question-and-response communication mode, make sure transmission interval is≥10ms. 3. Use of re-transmission mechanisms to ensure communication reliability.

Table 12-2 TIP Issues

Issue	Possible causes	Recommended Solutions
Liquid drip out from TIP after aspiration	Loose TIP	Rotate the TIP to check the TIP connection. If the TIP is loose, please follow Section 6.2, “Picking Up the TIP,” to secure the TIP using 28±2N down-force.
	Gravity	Keyto’s leakage testing equipment can detect air pressure leakage with an accuracy of up to the Pa level. Each ADP undergoes this testing before it leaves the factory.
	Reagents	Organic reagents or certain solvents to which certain substances have been added will leak more quickly than normal reagents. Refer to Section Figure 6-1, “Anti-droplet ” for instructions on how to use anti-droplet function.
	Reagent temperature	Higher reagent temperatures can lead to faster leakage, which can be solved by aspirating the liquid and then aspirating some air.
TIP has been picked up but indicator doesn’t flash	TIP size doesn’t match, poor conformity of production	If it is a lot sizing problem, it is recommended to change the TIP brand or install the TIP using more down-force but no more than 30N. If it is occasional, it may because of a poor conformity of production, please change the TIP brand or increase the down-force to pick up the TIP.

Repeated use of the TIP can cause residue on the inner wall, resulting in worse accuracy and CV	TIP are for single use only.	If the TIP are used repeatedly, the accuracy and CV values for both aspiration and dispensing, as well as the success of level detection, will be affected. Therefore, repeated use of the TIP is not recommended.
Failed to eject the TIP	TIP are still hanging on the nozzle after an eject TIP command has been executed	If it is a lot sizing problem,it is because the TIP size does not match, therefore, it is recommended to change the TIP brand. If it is occasional, it may because of a poor conformity of production, please change the TIP brand.3
	Failed to eject the TIP	Please follow Section 6.2, “Ejecting the TIP,” to secure the TIP using 28±2N down-force and eject the TIP within the recommended pressure range.

Table 12-3 Liquid Level Detection Issues

Issue	Possible causes	Recommended Solutions
Detects deeper levels	Water in the pipettor cylinder	Dry the pipettor and wait for a 48-hour natural drying, then check that the level detection is working properly, if not, please return the device to Keyto for repair.
	pipettor liquid level detection drops too quickly.	Please follow Section 6.3 “Liquid level detection” to control the liquid level detecting speed to about 20mm/s.
Liquid level detection triggered in advance/ Liquid level detected just after	Water in the pipettor cylinder	Dry the pipettor and wait for a 48-hour natural drying, then check that the level detection is working properly, if not, please return the device to Keyto for repair.
	Repeated use of the TIP	If the TIP are used repeatedly, the accuracy and CV values for both aspiration and dispensing, as well as the success of level detection, will be affected. Therefore, repeated use of the TIP is not recommended.
	Poor quality of TIP	Replace the TIP with another brand or test

activation of this function	filter, low permeability	with a non-filter TIP, modify the level detection factor or replace the TIP with another brand if it is related to the filter.
	Liquid level detection activated when the TIP head is below the liquid level	Liquid level detection only can be activated in air.
GPO1 signal of liquid level detection can't activate the external device	GPO1 provides signal only, no driving capability	The GPO1 output signal has a current lower than 1 mA and cannot be used to drive external devices.

Table 12-4 Accuracy and CV Issues

Issue	Possible causes	Recommended Solutions
CV OK but poor accuracy when aspirate and dispense	Need to compensate for accuracy	Refer to Section 6.8.2, "Compensation Accuracy" to set the appropriate compensation.
	Incorrect setting of aspiration and dispensing parameters	Refer to Section 6.7, "Aspirate and dispense parameters" to set the appropriate parameters.
	Incorrect testing method	Refer to the recommended test process in Section 6.8.1, "Accuracy and CV test" to conduct the accuracy and CV test.
Failed to completely dispense the liquid in the TIP, leaving residue behind	Not aspirate air before or the air volume is not enough	30ul air volume is sufficient for most scenarios. Air volume can be increased depending on the types of reagent and the pipettor allowance.
	Special reagent properties	1. Some types of reagents are more viscous and cannot be fully dispensed at one time, please dispense slowly in several times. 2. Some organic reagents tend to adhere to the inner wall of the TIP. After dispensing, residue may slowly flow down.
	Poor TIP quality	If the residue problem persists, test with another brand of TIP. If the problem is with the current TIP, replace the TIP with another brand.

Poor CV and accuracy	Liquid touched without liquid level detection when aspirating	1. Aspirate using liquid level detection, or ensure the TIP head remains ≤ 3mm below the liquid surface to avoid submerging too deeply. 2. Consider taking aspiration following according to the actual aspiration volume to avoid air aspiration.
	Not aspirate air before or insufficient air aspiration, leading to the residue in TIP	Generally, 30ul of air aspiration can meet most applications. Please add the air aspiration volume based on the reagent type, TIP size and pipettor allowance.
	Incorrect testing method	Please refer to section 6.8.1, "Accuracy and CV Test" to conduct the accuracy and CV test according to the recommended test procedure.

12.2 Q & A

Q1: **Why did the ADP work yesterday and suddenly stop working today? /Why the communication doesn't work after being connected?**

1. Check the wire connection, supply voltage or power.
2. Measure the resistance between the 24V(read) and GND(black), if it is short-circuited, it means the board is damaged, please contact Keyto for further maintenance.
3. Check the wire sequencing and configuration for serial port or CAN.
4. Refer to Chapter 5, using correct address(default address 1)to send command.
5. Please keep the resistance between two phrase of CAN and RS485 as 60Ω, minimizing the transmitting distance.
6. Ensure proper RS232 wiring as Rx→Tx, Tx→Rx, GND→GND

Q2: **What can I do if water or reagent get into the pipettor?**

1. Stop use the ADP immediately, dry the ADP and wait for a 48-hour natural drying,
2. Verify if the level detection is functioning properly. If not, please return the device to Keyto for repair.

Q3: **How can I use the SP28 with the ADPZ-axis?/How does liquid level detection work?**

1. When using our Composite Function Controller Tool to control both the pipettor and ADPZ-axis, the tool will automatically detect if the ADPZ-axis is connected after device scanning.
2. Enter the required parameters step by step. Send "pipettor initialization, ADPZ-axis initialization, ADPZ-axis descent, ADPZ-axis descent", after 500ms,

then click to execute the liquid level detection command.

3.There are currently no command for ADPZ-axis to follow descent when liquid detecting and aspirating in the Controller tool.

4.The ADPZ-axis will automatically stop once the pipettor detects the liquid surface.

Q4: **How to use TIP presence detection, clog detection or air aspiration function?**

1.Please refer to the details provided in Section 9.2.4.1, specifically Register 43 and Register 60, for further information.

2.Once the TIP presence detection function is activated, executing an aspiration, dispense or liquid level detection command without a TIP picked up will trigger a warning and return a device response status of error code "20".

Q5: **Liquid level detection not sensitive/not possible/invalid?**

1.Suggest to execute the liquid level detection command 500ms after starting the ADPZ-axis descent

2.During debugging, water entering the device can cause liquid level detection to malfunction.

3. Do not use the TIP repeatedly.

4. Poor quality of the filter in TIP may impact detection performance.

Q6: **What's the difference between single and aliquot dispense?/ How to set aspiration parameters?**

1.When the application goes: aspirate 100ul and dispense the full 100ul into a target tube, this is called single aspirate and single dispense. The sequence of "aspirate air→aspirate liquid→dispense all" is recommended for this kind application, and at the same time, please use the default value of aspiration cut-off velocity, the re-aspirate volume after dispense, the dispense cut-off velocity, and please do not change arbitrarily to avoid the poor accuracy and CV of liquid dispense accuracy.

2.When the application goes: aspirate 1000ul, then dispense smaller aliquot of 20ul into different tubes(maximum of 50 times), this is called single aspirate and multi dispense. For this kind of application, it is a must to set up the re-aspirate volume and cut-off velocity, parameters can be referred to Table 6-4 for pure water.

Q7: **How to empty all reagent?**

1.Recommended operation: first aspirate 30ul of air→aspirate 20ul of liquid →dispense 50ul(this air aspiration volume is unfixed, just and example, users can adjust up to a maximum stroke of 1050ul.)

2.It96000,,2 or Mp0 command can help with emptying and positioning the system to zero.

3.Appropriately increasing the dispense speed can help completely empty the liquid from the TIP.

Q8: Why can't I eject the TIP or execute a command?

1.Ensure that the command is sent successfully and the device reserves it successfully.

2.Check the return message and status for error report/LED indicator blinking.

3.The question-and-response communication mode is recommended, please send the next frame after receiving the command response.

Q9: Is there a DEMO database?

1.STM32 MCU and C/C# controller tool reference source code are available currently.

Q10: Which communication is recommended?

1.Suggest to use CAN communication. After setting the active report mode at motion completion, motion completion and abnormal status will be reported actively.

2.If the serial port is used, it is recommended to use KT_OEM protocol. When the communication reserves the response, please send the next frame at least 10ms interval.

Q11: How can I make sure each command is successfully responded?

1.The CAN command sequence number response and the send command should correspond to each other.

2.Wait for a response to each command before sending the next frame. If a timeout occurs without a response, re-send the command.

Q12: How to determine motion completion? /Can the flag bit be reported when the movement is complete?

1.The query status is "busy" when the device is in motion, and "idle" when the motion is complete.

2.The CAN heartbeat status changes from 1 (busy) to 0 (idle).

3.Refer to Register 82 for report after motion completion.

Q13: Why do the parameters remain the same after restarting the controller tool after parameter setting?

1.Refer to 5.7 Register Parameter Setting Instructions for the steps of setting parameters (please do not modify the system parameters arbitrarily)

2.If you use a switch power supply, make sure the power is completely off before restarting.

3. Part of the parameters do not support the power-down save.

Q14: How can I determine/ensure the reagent has been aspirated?

1.It is recommended that the ADPZ-axis follow the descent when aspirating to ensure the TIP touches the reagent during the aspiration process.
2.Set Register 60 to 1 to enable air aspiration. If the aspirated air volume reaches the inspection threshold, the device will return an error status (25).

Q15: What should I do when an error is reported?

Record the status of the device response and the current execution process when an error is reported. If the following solution measures do not provide effective help, please contact us. Below are some of the status trigger scenarios and their corresponding solutions:
1. Error status 10～16 (DEC the same below): Check the text-transform parameters and the writable range of the parameters.
2. Error status 17～18: Initialize the device before operating aspiration, dispensing, or movement
3. Register 43 enables the alarm function. If an aspirate, dispense, or liquid level detection command is sent when no TIP is detected, this function will report an error. It is recommended to stop the operation to prevent reagents from being aspirated into the pipettor.
4. Error status 21: An error will occur if the TIP is detected after executing the TIP ejection command. Please check if the TIP is installed too tightly and avoid repeated use of the TIP.
5. Error status 22: An error will occur if the liquid level is not detected within the specified time during liquid level detection. Please ensure that the TIP can contact the reagent during the pipettor’s descent.
6. Error status 23～25: Register 60 enables the alarm function, which will trigger an error if abnormal air pressure is detected during aspiration. Adjustments can be made according to the user’s process, allowing the device to continue operating when the error is reported.
7.Error status 50～55: It is recommended to contact our company for assistance.

Q16: How to test the leakage of the pipettor?

1.Keyto leakage testing equipment can accurately test air pressure leakage at the Pa level.
2.Convenient test method: At room temperature, with the pipettor on standby, install a (non-conductive) clean, non-filter 1000ul TIP. Aspirate 1000ul of pure water, let it stand for 30 seconds, and then check for leakage from the TIP.
3.Please note: the TIP must be securely attached during the testing process. Avoid submerging the TIP too deeply into the liquid during aspiration, as this may cause liquid to cling to the outer wall of the TIP and lead to test failure.
4.Please note: leakage of organic reagents, such as ethanol, is normal.

Q17: How to write Register 60?/How to enable the abnormal aspiration function?

1.Table 12-5, write Wr60,5 to only active the aspiration of air and clog detection.

Table 12-5 Register 60 Function Description

DEC	Bit4	Dispensing clot detection	Bit2	Aspiration of air	Bit0	Aspiration Clog Detection
0(default)	0	off	0	off	0	off
1	0	off	0	off	1	on
4	0	off	1	on	0	off
5	0	off	1	on	1	on
16	1	on	0	off	0	off
21	1	on	1	on	1	on

Q18: What’s the function of terminating resistor for RS485/CAN?

1.If no terminating resistor is added, self-excited oscillations are likely to occur. Adding terminating resistor will improve the reliability or stability of communication.

Q19: What’s the function of terminating resistor for RS485/CAN?

1. KT_OEM or KT_CAN_DIC Protocol will lock the current protocol after communication, and the protocol will be unlocked after restarting the device.

13 Environmental Conditions

Table 13-1 Environmental Conditions

Item	Unit	Value
Operating environmental temperature	℃	+15℃～+35℃
Operating environmental humidity	RH%	40%～80% non-condensing
Storage temperature	℃	-20℃～+55℃
Storage humidity	RH%	40%～80% non-condensing

14 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 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 valve 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.

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