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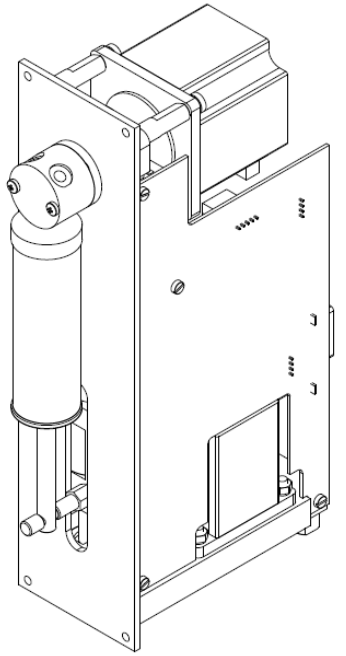
SP1-CX industrial Syringe Pump

LONGER

SP1-CX

Industrial Syringe Pump

Operating Manual



Baoding Longer Precision Pump Co.,Ltd.

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Contents

LONGER SP1-CX Industrial Syringe Pump

Please read this operating manual carefully before using the product.
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● Any damage or failure caused by attempts by personnel other than authorized Longer representatives to install, repair, modify or remove the product.
● Damage or failure caused by not returning pumps in original or adequate packaging
● Syringes
● Syringe seals
● Tubing and tubing connections
● Valves

1 Product Introduction

SP1-CX is compact industry syringe pump, and is mainly used for high precision fluid transfer in OEM application. The pump is controlled by PC or other microprocessor to automate pipetting, diluting and dispensing functions.
This chapter includes below topics:

● SP1-CX main features
● Unpacking SP1-CX
● SP1-CX function
● Tips for setting up the SP1-CX
● Power supply requirement

Note: SP1-CX is not a medical device, and it is not subject to FDA regulatory approval.

1.1 SP1-CX Main Features

● Syringe sized from 50uL to 5mL
● Travel control accuracy:≤1% (Full stroke)
● Travel control precision: ≤±5‰ (Full stroke)
● Full stroke: 60mm (6000steps)
● Control resolution: 0.01mm (1step)
● Applicable valves: 3-Port Valve, 4-Port Valve, T-Valve, 3-Port Distribution Valve, Y-block.
● Wetted material: Borosilicate glass, PTFE, PFA, CTFE, ETFE, UHMW-PE
● Communication interface: RS-232/ RS-485/ CAN
● Time for one stroke: 1.26s-20min (includes time for ramp up/ ramp down)
● Ball screw drive, step loss detection by encoder
● Error reporting
● Programmable storage
● Input/output interface
● Operates using a single 24VDC power supply
● Online upgrades
● Optimize initialization algorithm to reduce dead volume
● Microstep mode
● Pause function
● Self-testing function

1.2 Unpacking

To unpack the device, follow below steps:
1) Take out the pump and accessories from the shipping carton.
2) Check the packing list to make sure all components are present.

1.2.1 ESD considerations

SP1-CX is an electronic device that is sensitive to electrostatic discharge. Static discharge from clothing or other materials can damage the pump. In order to prevent the electrostatic damage, please follow below practices:
● Using antistatic gloves or wrist straps
● Using ESD bench or mat
● Using antistatic floor
Prepare an ESD-free work area before the chassis is grounded.

1.3 SP1-CX Function

SP1-CX uses step motor driven syringe and valve design to aspirate and dispense measured quantities of liquid. The syringe and valve are replaceable. The function and illustration of major components are provided in the following sections.

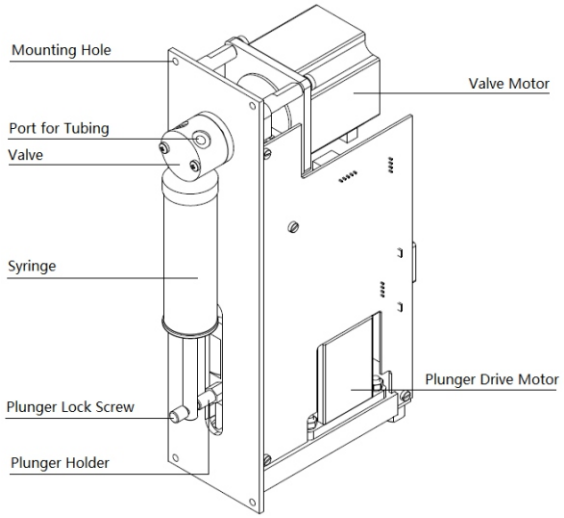


Figure 1-1 SP1-CX Syringe Pump

1.3.1 Syringe and Syringe Drive

The syringe plunger is held to the plunger holder which is also connected to the ball screw drive. The ball screw drive is incorporated with step motor. Then the plunger moved within the syringe barrel driven by the step motor. The plunger block is detected by encoder.

The full stroke of the syringe drive is 30mm, divided into 3000 steps, resolution is 1 step,
and divided into 48000 steps in the microstep mode.
The syringe plunger is held to the plunger holder by a lock screw. The syringe barrel attaches to the pump valve by a 1/4-28 fitting.
Refer to Figure 1-2 for the components of the syringe:

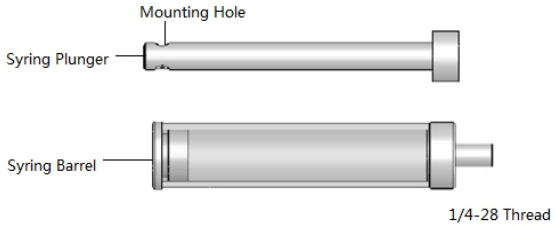


Figure 1-2 Syringe Components

Refer to Figure 1-3 for holding the syringe plunger:

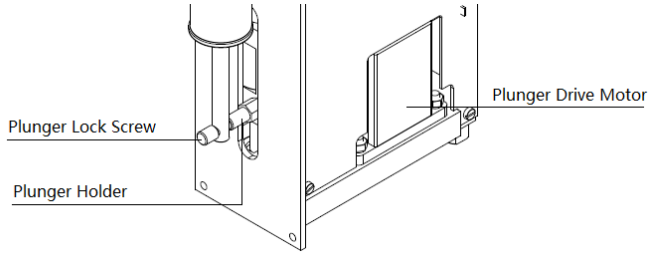


Figure 1-3 Holding the Plunger

Available syringe sizes: 50uL,100uL,250uL,500uL,1.0mL,2.5mL,5.0mL, 10mL, 25mL

1.3.2 Valve and Valve Drive

The valve is made of a PCTFE body and PTFE plug. The plug rotates inside the valve body to connect the syringe port to the various input and output ports. The valve is driven by step motor and the encoder is used to detect the valve position.

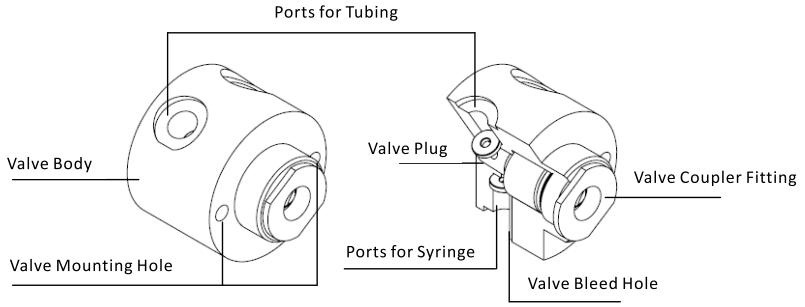


Figure 1-4 3-Port Valve Component (VY32 for Example)

Applicable valves:
3-Port Valve, 4-Port Valve, T-Valve, 3-Port Distribution Valve.

SP1-CX applicable valve:

● 3-Port Valve
There are 3 ports on the valve: input port, output port, syringe port. The port for syringe is the “common” port, connected to input or output port. The angle between adjacent ports is 120 degrees.

● T-Valve
There are 3 ports on the valve: input port, output port, syringe port. The port for syringe is the "common" port, connected to input or output port. The degree of the angle between input/output port and syringe port is 90.
● 3-Port Distribution Valve
There are 4 ports on the valve: input port, output port, syringe port, extra port. The port for syringe is the "common" port. The fluid can be distributed from the syringe to the input port, output port or extra port. The degree of the angle between adjacent ports is 90.
● 4-Port Valve
There are 4 ports on the valve: input port, output, syringe port and extra port. The degree of the angle between adjacent ports is 90.

1.3.3 Control Board

The control board, used to control the syringe plunger and valve, includes microcontroller and circuitry. The external interfaces of control board include DIP dial switch for operating model selection, Address Switch and DB15 external control port. The communication interface can be set through DIP dial switch. Please refer to Chapter 4 "Software Communication" for more details.

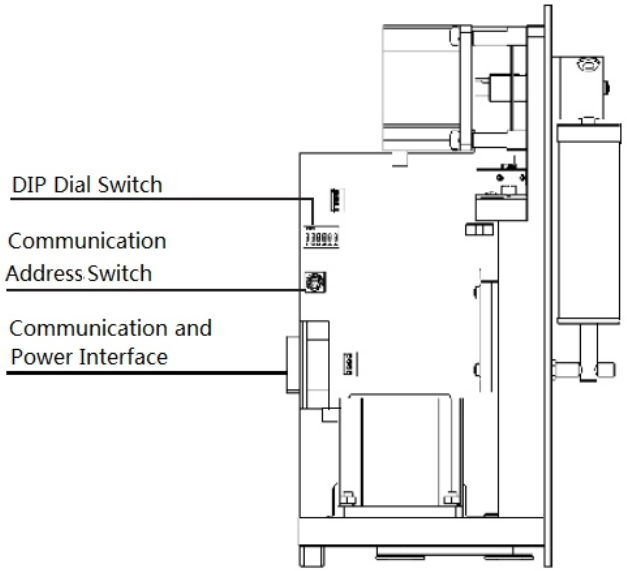


Figure 1-5 The External Interface of the Control Board

Please refer to Chapter 3 "Hardware Setting" for more information about input/output, dial switch, address switch and EEPROM.

1.3.4 Power Supply Interface

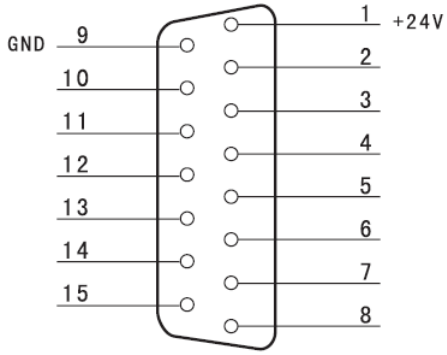


Figure 1-6 Power Supply Interface

1.3.5 Communication Interface

The SP1-CX can communicate In single pump or multi-pump configuration through an RS-232/ RS-485 or CAN bus interface. The baud rate can be 9600bps or 38400bps.
Please refer to Chapter 3, "Hardware Setting" for more information about the communication interface.

1.3.6 Multi-Pump Configuration

Up to 15 SP1-CX pumps can be connected together in a multi-pump configuration. For multi-pump configuration, the RS-485 communications bus is required, although the first pump in the daisy chain maybe connected to PC through either RS-232 or RS-485 interface. The PC can communicate with each pump through the pump's unique address. The pump address can be set through the Address Switch on the back panel of the pump. Please refer to the Chapter 3, "Hardware Setting" for more information about the pump address setting.

1.4 Tips for Setting Up the SP1-CX

Please refer to Chapter 3 " Hardware Setting" and Chapter 4 " Software Communication" for complete information for setting up the SP1-CX.

To ensure proper operation, follow below tips:

■Always set up and mount the pump in upright position to avoid damaging the syringe barrel and plunger.

■Do not move the plunger and the valve without liquid inside the system to avoid damaging the seal ring and reducing the life time.

■Please refer to the "Chemical Resistance Chart" before pumping any organic solvents.

■Keep fingers out of syringe slot while the pump is running to avoid injury.

■Always power off the pump before connecting or disconnecting the pump.

1.5 Power Supply

1.5.1 Power Supply for a Single Pump

SP1-CX requires 24V DC power supply, provided through the pin 1 and pin 9 of DB-15 connector. The power supply for a single pump should meeting following requirements:

- Output voltage: 24V DC
- Output voltage tolerance: ±10% maximum, ±5% preferred.
- Output voltage regulation: ±1% (within the allowed range of input voltage and load)
- Output current
  - ※ >=1.5A for power supplies with minimal capacitance
  - ※>=850mA for power supplies with internal filter capacitance of at least 1000 uF per amp of output current.
  - ※>=850mA for power supplies with external filter capacitance of at least 1000 uF per amp of output current (aluminum electrolytic capacitor preferred)
- Output voltage ripple: 50mV maximum at full load.
- Conformance to EMI/RFI specifications
- Voltage overshoot at turn-on and turn-off: <2V

To meet above requirements, the power supply must incorporate either linear or switching regulation and must have adequate output filter capacitance.
A current-limiting power supply is recommended. Current limiting above 1.0A is acceptable, assuming that no additional equipment is operated from the supply.

1.5.2 Power Supply for Multi-Pump

When a power supply is used to operate more than one SP1-CX or other device, it must provide the total average current for all devices. The power supply and filter capacitance must satisfy the total peak input current for all devices.

For example, if the system has 6 sets of SP1-CX, and other equipment requiring 4A, then a 10A power supply is satisfactory. And the output filter capacitance in the power supply is at least 10,000uF:

6x0.85=5.1A; 5.1+4=9.1A (choose a 10A power supply)

If the power supply filter capacitance is less than 10,000uF, use either additional external capacitance or a 15A power supply.

6 x 1.5 = 9.0A; 9.0 +4 = 13A (choose a 15 power supply)

In this example, it is assumed that all the pumps and other equipment will sometimes operate at the same time.
Inadequate filter capacitance or current can cause overvoltage transients and sags, and can create unnecessary ripple in SP1-CX. This can result in decreased component life. Additionally, it is possible for a regulated power supply to become unstable with certain loads and oscillate if filter capacitance is inadequate. Some forms of oscillation can cause failures in the SP1-CX. These issues can be avoided by using a proper power supply.
Consideration should also be given to the wiring of the SP1-CX and any additional devices. Wiring should be of sufficient gauge for the current, and as short as possible. Unless otherwise required by safety requirements, the power supply lines to SP1-CX should be 20AWG or thicker. For multiple SP1-CX, make sure the wire size and power supply are adequate for the total current. In the example of the 6 of SP1-CX above, use 18AWG wire if the units are daisy-chained. It is best if each pair is twisted or dressed together for the device to the supply.
Do not use a relay or switch contacts between the 24VDC supply and the SP1-CX.

2 Hardware Setting

This chapter includes below topics:

- Power Supply
- Communication Interface
- Control Board Setting
- SP1-CX without valve
- Installing Component
- Pump Mounting

2.1 Power Supply

SP1-CX requires 24VDC power supply with current rating of at least 1.5A, provided through a DB-15 connector. It is recommended to use one power cable for every two pumps to provide noise immunity. Power cable should not be daisy-chained to more than two pumps.

Please refer to Chapter 1, "Product Introduction", for more information.

2.2 Communication Interface

Each SP1-CX has one external communication interface, which supports power supply and communication with pump.
Each pump has a unique address, refer to "Address Switch Setting" in this chapter, and Chapter 3, "Software Communication" for more information.

Table 2-1. DB15 Connector Pin Definition:

Pin	Function	Remarks
1	DC_24V	Power Supply+
2	TXD	Rs232 Output data
3	RXD	Rs232 Input data
4	COM	Logic ground for input and output
5	CAN-H	CAN High signal
6	CAN-L	CAN Low signal
7	In1	Input 1
8	In2	Input 2
9	GND	Power and logic
10	GND	Power and logic
11	RS-485 A	RS-485 A
12	RS-485 B	RS-485 B
13	OUT1	Output 1
14	OUT2	Output 2
15	OUT3	Output 3

Figure 2-1 shows the pin position of the DB-15 connector on the control board. This is a male connector that requires a female connector on the mating cable.

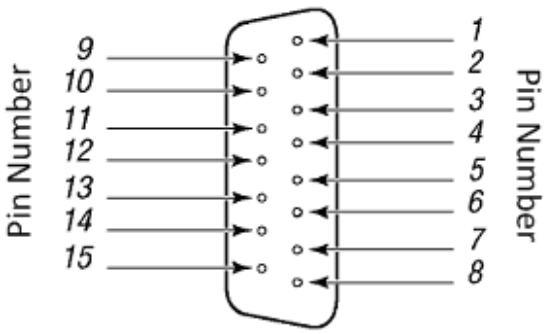


Figure 2-1 DB15 Pins

Communication Interface

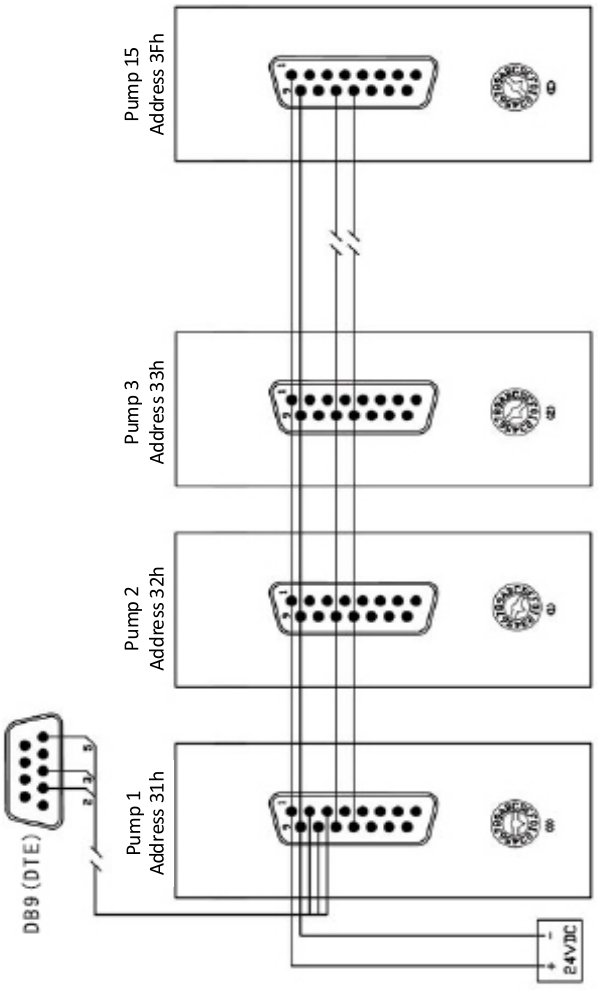
The computer or controller communicates with the SP1-CX through RS232 or RS485 interface.

Note: The RS232 interface does not support hardware handshaking and requires only three lines: RXD, TXD, and Signal Ground.

Examples of cabling connections are shown in Figure 2-2 (RS232) and Figure 2-3(RS485) in following pages.

Note: Power off the pumps before connecting or disconnecting the cable.

RS-232Multi-Pump Cabling



PC Port		Pump Port	
Definition	DB9 pin	Definition	DB15 pin
TXD	3	TXD	3
RXD	2	RXD	2
GND	5	GND	10

Figure 2-2 RS-232 Multi-pump Cabling

RS-485 Multi-Pump Cabling

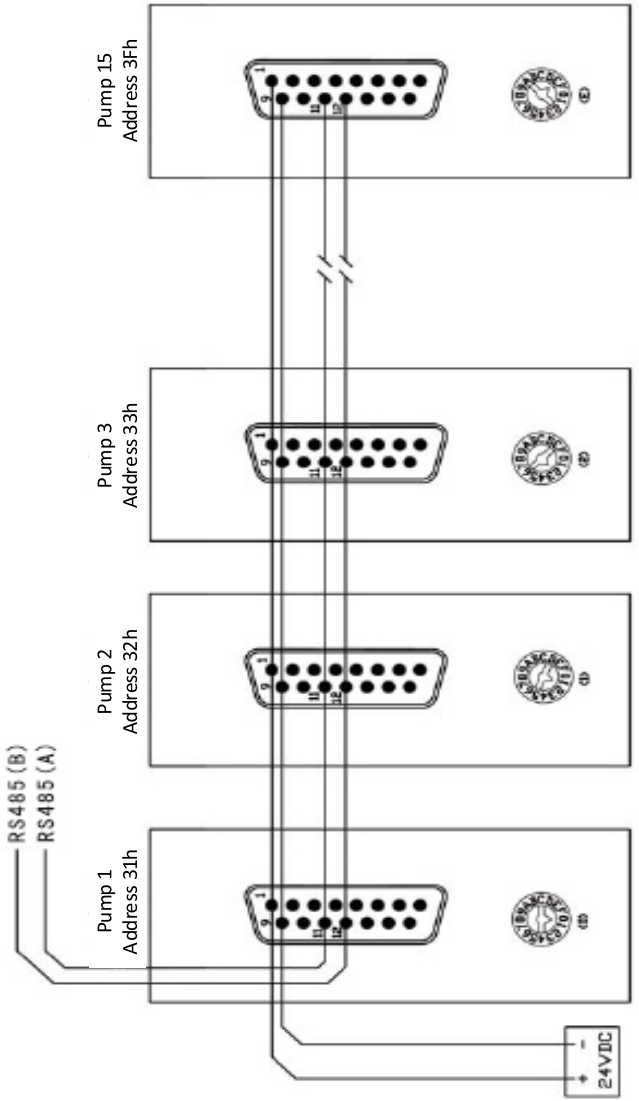
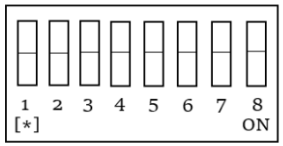


Figure 2-3 RS-485 Multi-pump Cabling

2.3 Control Board Setting

2.3.1 DIP Dial Switch Setting

DIP dial switch is used to set the different working modes and configurations. Refer to Figure 2-4 for the DIP dial switch setting and the corresponding working mode and configuration.



Item	DIP Switch(ON=0, OFF=1) DIP1, DIP2,DIP3	Working Mode and Configuration
1	000	No valve
2	100	3-port valve
3	010	4-port valve
4	110	3-port distribution valve
5	001	Reserved
6	101	T- valve
7	011	Reserved
8	111	Mode for software setting
9	DIP4=0	Turn off the auto mode
10	DIP4=1	Turn on the auto mode
11	DIP5=0	Baud Rate=38400bps
12	DIP5=1	Baud Rate=9600bps
13	DIP6=0	RS232
14	DIP6=1	RS485

Figure 2-4 DIP Dial Switch Setting

Note: Power off the pump when set the DIP switch.

DIP-1 DIP-2 DIP-3: Valve type setting

※ ON，ON，ON No valve
※ OFF，ON，ON 3-port valve (default)
※ ON，OFF，ON 4-port valve
※ OFF，OFF，ON 3-port distribution valve
※ ON，ON，OFF Reserved
※ OFF，ON，OFF T valve
※ ON，OFF，OFF Reserved
※ OFF，OFF，OFF Mode for software setting

DIP-4:Set the auto mode when power on

DIP-4 is used to turn on or turn off the auto mode when power on.

.**DIP-4** **ON** (default)
.**DIP-4** **OFF**

DIP-5: Set the baud rate

DIP-5 is used to set the baud rate:

.DIP-5 ON 38400bps
.DIP-5 OFF 9600bps (default)

DIP-6: Communication interface

DIP-6 is used to set the communication interface:

.DIP-6 ON RS-232
.DIP-6 OFF RS-485 (default)

2.3.2 Address Switch Setting

Address switch (Figure 2-5) is located on lower of the pump back panel. It is used to set the unique address for each pump in the multi-pump system, allowing user to direct commands to specific pump. There are 16 positions (0-F) on the address switch. 15 positions (0-E) are valid pump addresses. F is for self-test function.

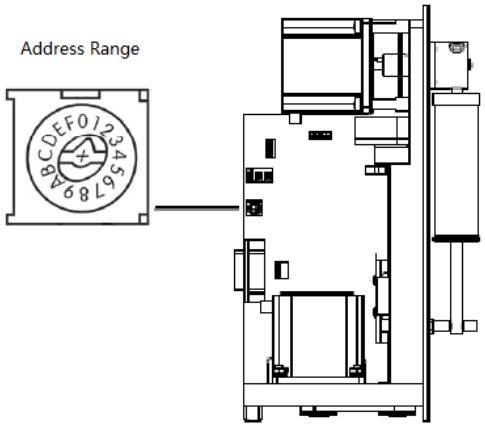


Figure 2-5.Address Switch

To set the address switch:
Power off the pump, then use a small flat head screwdriver and turn the switch in either direction to the desired position.

Note: Restart the pump after re-setting the address switch

Self-test Function

Set the address switch on the "F" position, the pump will run the self-test program when power on. Self-test causes the SP1-CX to initialize, then cycle repeatedly through a series of plunger movements. If an error condition occurs, the pump stops moving.

Caution: Always run liquid through the syringe and valve. Failure to do so can damage the valve and syringe seal.

2.3.3 Input/Output

SP1-CX provides two auxiliary inputs (TTL level signal) and three auxiliary outputs (OC gate signal) that can be accessed through the DB15 connector. The outputs are controlled by the [J] command.

The auxiliary inputs are located on pin7 and pin8 of the DB15 connector. They can be read back using report commands [?13] and [?14]. Additionally, the inputs can be used to externally trigger a command sequence using the [H] command. Refer to Chapter 3 " Software Communication" for commands detail.

The auxiliary outputs are located on pin13, pin14 and pin15 of the DB15 connector.

2.4 SP1-CX without Valve

The pump without valve does not have valve, valve motor and encoder. Other components and plunger operation are same as SP1-CX with valve. There is a PCTFE component instead of the valve to connect with the syringe through 1/4-28 thread port. The input port and output port of the PCTFE component are also 1/4-28 thread.

Input/Output Port	1/4-28 thread
Port Qty/ Angle	3/ 120 degree
Port for syringe	1/4-28 thread
Material	PCTFE/PTFE

Figure 2-6 PCTFE Component

In SP1-CX, the command for no-valve configuration is same as that of the valve configuration except for the initialization command, valve command. Refer to Chapter 3 "Software Communication" for commands detail.

Note: For SP1-CX without valve, an external valve is needed to connect the pump with the system.

For the SP1-CX with valve, the valve will initialize automatically when power on the pump. The valve motor encoder will rotate clockwise until reach the position 0. When valve is in the initialization process, the syringe plunger will not move. The SP1-CX without valve does not perform valve initialization operation.

2.5 Installing Component

Refer to Chapter 5 "Maintenance" for the operation of component maintenance and replacement.

Note: The valve can't be replaced by other types of valve. If other types of valve need to be installed on the pump, please contact with the pump manufacturer.

To install the 3-port valve, 3-port distribution valve, T-valve, and 4-port valve, follow the steps below.

2.5.1 Install the Valve

To install the SP1-CX valve:

1. Set up and mount the pump in upright position.
2. Turn the valve motor shaft and make sure the flat side of the shaft is on the right side.
3. Install the new valve by placing it on the front panel so the screw holes line up. The valve coupler fitting mates to the valve motor shaft. Replace the valve screw. The ports for tubing are on the top, the port for syringe is on the bottom.

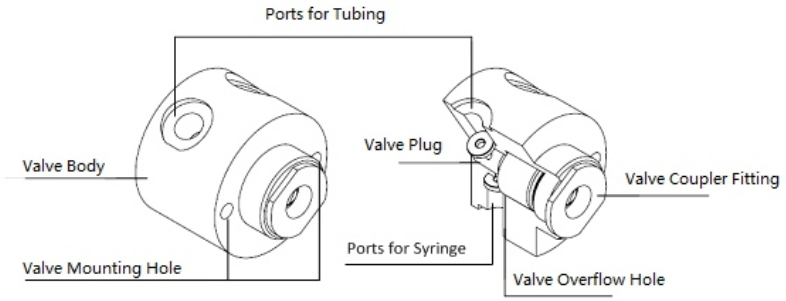


Figure 2-7 SP1-CX Valve Installing (3-Port Valve)

2.5.2 Install the Syringe

To install a syringe:

1. Unscrew the plunger lock screw.
2. Send [ZR] command to initialize the pump. Then send [A6000R] command to lower the plunger holder.
3. To install the syringe (as shown in Figure 2-8)
   a Place the syringe into the fixed hole of the plunger.
   b Place a valve washer on the syringe end of the valve.
   c Pull the syringe plunger down to the plunger holder.

Note: Make sure the plunger lock screw is securely tightened.

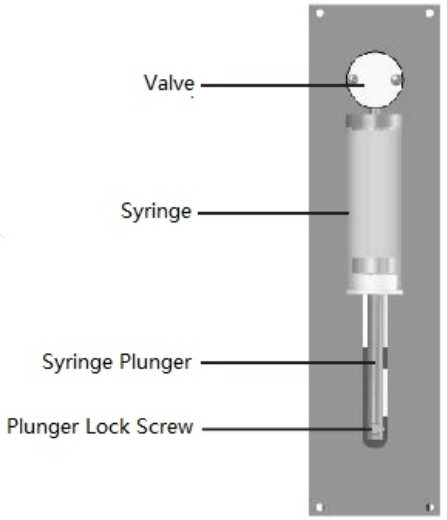


Figure 2-8 Syringe Installing

2.6 Pump Mounting

Numerous M4X0.5 mounting holes provide several mounting methods as below. Refer to Figure 2-9 for the mounting holes position.

> Mounting from the bottom
> Mounting from the top
> Mounting from the sides

Note: Always mount the pump in an upright position. Failure to do so can cause problems in priming the system.

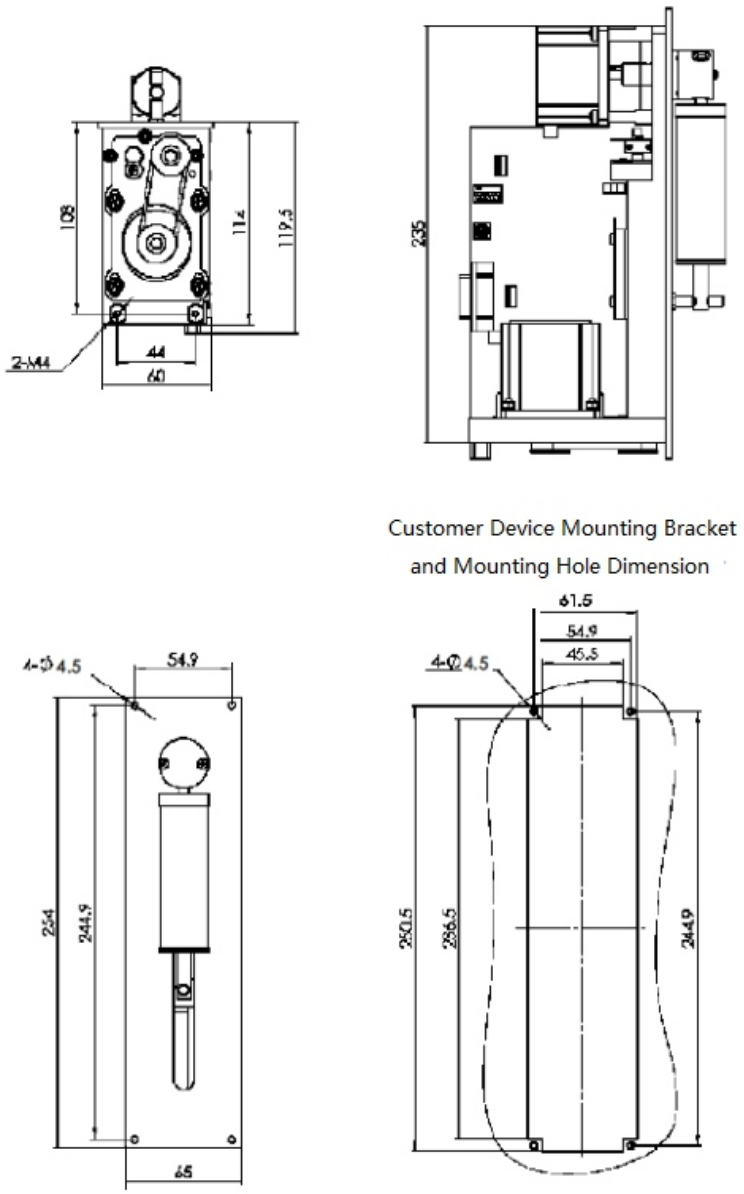


Figure 2-9 SP1-CX Mounting Holes

3 Software Communication

This chapter describes how to communicate with the SP1-CX through RS-232 / RS-485 ,or CAN bus interface.
This chapter includes below topics:
> Address Setting
> Communication Protocols
> Command Set
> Error Codes and Pump Status

3.1 Address Setting

As part of the communication protocol, an address for each pump must be specified. Each physical address set by address switch corresponds to one hexadecimal value. Refer to below table 3-1.

Table 3-1 Address Scheme (Hex)

Address (Hex)	Device
RS-232 / RS-485	
30	Master address (controller, etc.)
31-3F	Pump address
41-4F	Address of dual devices
51-5D	Address of quadruple devices
5F	Broadcast address- all devices on the bus will operate according to the same command when using broadcast address.

For example: a pump with address switch (hardware address) set to position 0 is addressed as device “31h” in the RS-232 or RS-485 communication protocol. A pump with address switch (hardware address) set to position 1 is addressed as device “32h”, and so on.

In multi-pump configuration, PC or master controller can communicate with all pumps simultaneously by using “5F” (broadcast address), such as initializing all pumps at once. Each pump can be controlled independently by using “31h” to “3Fh”.

Note: When using broadcast address, PC can't read pump's status and the pump can't answer the report commands. Must use specific address to read each pump status.

3.2 Communication Protocol

Two communication protocols are available:

OEM communication protocol

Data Terminal (DT) protocol

The DT protocol can be run through an ASCII data terminal because no sequence numbers or checksums are used. Refer to “Using DT Protocol with Microsoft Windows” in this chapter for instruction.

Note: Recommend to use the OEM protocol, which provides error checking.

3.2.1 OEM Communication Protocol

OEM communication is a robust protocol. Table 3-2 describes each setting within the OEM communication protocol

Table 3-2 OEM Protocol

Parameter	Setting
Frame Format	
Baud rate	9600 or 38400
Data bits	8
Parity	None
Stop bit	1
Command Message Format (Refer to “OEM Communication Protocol Command Format” for details)	
1	STX(^B or 02h)
2	Pump address
3	Sequence number
3+n	Data block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum
Pump Answer Message Format (Refer to “OEM Communication Protocol Answer Format” for details)	
1	STX(^B or 02h)
2	Master address (“0” or 30h)
3	Status code
3+n	Data block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum

OEM Communication Protocol Command Format

The command characters are described as below:

STX is the beginning of the message, checksum (character after the ETX) is the end of the message.

STX(^B or 02h): STX character indicates the beginning of a message

Pump Address: “0” ~” E” (31h~3Fh)

Sequence Number: Fixed value of “1” (31h)

Data Block(length n): The data block consists of the commands and values sent to the pump, using ASCII code, most significant byte first.

Example: A6000R: 6 bytes, ASCII Code: 41 36 30 30 30 52

ETX(^C or 03h): ETX character indicates the end of a command

Checksum: Checksum is the last byte of the message string. The 8-bit checksum is the bit XOR of all bytes (from STX to ETX and includes STX and ETX).

OEM Communication Protocol Answer Format

The answer characters are described as below:

Only the unique answer characters are listed in this section. For the same characters as command message, please refer to “OEM Communication Protocol Command Format”.

Master Address: “0” (30h)

Status and Error Codes: Pump status and error conditions. Refer to “Error Codes and Pump Status” in this chapter.

3.2.2 DT (Data Terminal) Protocol

Table 3-3 DT Protocol

Parameter	Setting
Frame Format	
Baud rate	9600 or 38400
Data bits	8
Parity	None
Stop bit	1
Command Message Format (Refer to "DT Communication Protocol Command Format" for details)	
1	"/" (2Fh)
2	Pump address
2+n	Data block (length n)
3+n	Carriage return ([CR] or 0Dh)
Pump Answer Message Format (Refer to "DT Communication Protocol Answer Format" for details)	
1	"/" (2Fh)
2	Master address ("0" or 30h)
3	Status character
3+n	Data block (length n)
4+n	ETX (03h)
5+n	Carriage return (0Dh)
6+n	Line feed (0Ah)

DT Communication Protocol Command Format

The command characters are described as below:
"/": "/" character indicates the beginning of a message
Pump Address: "0" ~" E" (31h~3Fh)
Data Block(length n): The data block consists of the commands and values sent to the pump, using ASCII code, most significant byte first.
Example: A6000R: 6 bytes, ASCII Code: 41 36 30 30 30 52
Carriage return (0Dh): 0Dh indicates the end of the message.

DT Communication Protocol Answer Format

The answer characters are described as below:
Only the unique answer characters are listed in this section. For the same characters as command message, please refer to "DT Communication Protocol Command Format".
Master Address: "0" (30h)
Status and Error Codes: Pump status and error conditions. Refer to "Error Codes and Pump Status" in this chapter.
Data Block (length n): This is the response from all Report commands with the exception of the [Q] command.
Carriage Return(0Dh)/ Line Feed(0Ah): This character terminates the reply message.

3.2.3 Using DT Protocol with Microsoft Windows

SP1-CX can be controlled in DT protocol mode directly from the Microsoft Windows terminal accessory.
To communicate with the SP1-CX using Windows2000/Win10/Win7/XP, follow these steps:
1. Connect the SP1-CX to a communication port on the PC, first select the Start Programs/Accessories/Communications Hyperterminal menu and choose Run.
2. In the Run dialog box, type Hypertrm.exe. The Connection Description dialog box appears.
3. Enter a name for the connection and select an icon, then click OK. The Phone Number dialog box appears.
4. Select the following in the fields provided:
Connect using: Direct to <communication port> (usually COM1 or COM2 depending on how the hardware is set up)
Click OK. The COM Properties dialog box appears.
5. Select the following in the fields provided:
Bits per second: 9600
Data bits: 8
Parity: None
Stop bits: 1
Flow control: None
Click OK.
6. Select the File menu and choose Properties. The Properties dialog box appears.
7. Select the Settings tab, and enter or select these options:
- Function, arrow, and Control keys act as:
  Select "Terminal keys"
- Emulation:
  Select "Autodetect"
  Enter "500" in Backscroll buffer lines
- Click the ASCII Setup button. The ASCII Setup dialog box appears.

8. Enter or select these options:
   Select “Send line ends with line feed”
   Select ” Echo typed characters locally”
   Enter a Line delay of “0”
   Enter a Character delay of “0”
   Select “Wrap lines that exceed terminal width”
9. Click OK to close the ASCII Setup dialog box, then click OK to close the Properties dialog box.
10. Set the pump address. Factory default address is “0”.
11. Set the DIP switch: DIP1/2/3 for valve type, DIP4 for auto running mode, DIP5 for baud rate, DIP6 for RS232 or RS485.
12. Power on the pump and initialize it by typing /1ZR and pressing Enter.

Refer to “Command Set” in this chapter for pump option details.

3.3 Command Set

SP1-CX has a robust command set allowing a wide range of parameters to be defined by the user. Many of the commands have default values. But the default values may not be the optimum values for specific application.
For a quick glance at summary of all commands, refer to Appendix E, ” Command Quick Reference”.
When problems are detected, SP1-CX sends an error code. Refer to “Error Codes” at the end of this chapter for details.

3.3.1 Command Execution Guidelines

To use the commands properly, pay attention to :
■ All commands must be ended with a [R] character, except Report command and [Q] command.
■ Pump can accept a single command or multiple command string.
Example:
- Single command: [A6000R], moves the plunger to position 6000.
- Command strings such as [IA6000OA0R] moves the valve to the input position, moves the plunger to position 6000, turns the valve to the output position, and finally returns the plunger to position 0.
■ The pump command buffer holds a maximum of 128 bytes. If a command (string) is sent without the [R] command, it is placed into the buffer without being executed.
■ When a command (string) is executing, new commands (strings) are not accepted until the sequence is completed. Exceptions to this rule include Terminate (refer to “T Terminate Command” in this chapter), Report commands and [Q] command.

■ When a command is sent, the pump answers immediately. If an invalid command has been sent in a command string, the pump reports an error immediately. If there was an invalid parameter in the command, the pump will execute up to the invalid parameter, then stop. And the error will be read back to the host computer when receiving the [Q] command.
■ Always run liquid through the syringe and valve when issuing a Move command. Failure to do so may damage the valve and syringe seal.
■ Keep fingers out of the syringe slot while the pump is running. Failure to do so can result in injury.

Command Syntax
The syntax for each command:
<n> Parameter
0..6000 Range of parameter allowed
(n) Default value

Note: In command examples, content in [ ] only indicates the commands and should not be sent as part of the command strings. The sent command string should be in ASCII code.

3.3.2 Control Commands

R Execute Command (String)

[R] command tells the pump to execute the new or previously loaded but unexecuted command (string).
Commands (strings) containing [R] at the end will execute immediately. If the command (string) is sent without [R], it is placed in the command buffer.
Sending the [R] alone, pump will execute the last unexecuted command in command buffer. Sending another [R], the pump will not repeat the command (string).

X Execute Last Executed Command (String)

[X] command repeats the last executed command (string)

G<n> Repeat Command

[G] command repeats a command (string) the specified number of times. The syntax for this command is:
[G<n>], where <n>=0-30000 0=repeated until a Terminate command [T] is issued.
Example: [gA6000A0G10R] moves the plunger to position 6000, then back to position 0. This sequence is repeated 10 times.

g Mark the Start of a Repeat Sequence

[g] command is used in conjunction with the [G] command. [g] indicates the beginning of a repeat sequence within a command string. Both the [g] and [G] commands can be used to nest up to 4 loops.

Example: [A0gP50gP100D100G10G5R], the process as below:

Command	Description
A0	Move the plunger to position 0
g	Outer loop start
P50	Move the plunger down 50 steps
g	Inner loop start
P100	Move the plunger down 100 steps
D100	Move the plunger up 100 steps
G10	Inner loop, repeat 10 times
G5	Outer loop, repeat 5 times.
R	Execute the command string

Note: <n>=0, endless loop, the sequence is repeated until a Terminate command [T] is issued.

M<n> Delay Command

[M] command is used to delay the execution of a command in milliseconds. This command is typically used to allow time for liquid in pump and tubing to stop oscillating, thereby enhancing precision. The syntax for this command is:

[M<n>], where <n>=5..30,000 milliseconds

H<n> Halt Command

[H] command is used within a command string to halt execution of the string. To resume execution, a [R] command or External trigger (TTL signal) must be sent.

The syntax for this command is:

[H<n>]

Two TTL inputs are available, input 1 (DB15 pin7) and input 2 (DB15 pin8). Control the execution as below:

<n>=0 Waits for [R] command, or the rising edge signal on input 1 or input 2 to resume the execution

<n>=1 Waits for [R] command, or the rising edge signal on input 1 to resume the execution

<n>=2 Waits for [R] command, or the rising edge signal on input 2 to resume the execution

Note: If the value of <n> is not specified, the default is 0.

TTL inputs status can be read back by using Report commands [?13] and [?14]. Refer to "Report Command" in this chapter for details.

T Terminate Command

[T] command is used to terminate the plunger movement in progress ([A] [P] [D] [H] [M])

Note: [T] command can't terminate the Valve Command.

[T] command will terminate both single command and command strings.

When a plunger move is terminated by [T] command, lost steps may happen. System reinitialization is recommended after the termination command is executed. If the command was terminated due to a problem or error, the pump must be reinitialized.

J<n> Outputs

[J] command sets the output (OC gate signal)

The syntax is:

[J<n>], Where <n>=0..7

DB15 provides 3 outputs, output 1 (pin13), output 2 (pin14) and output 3 (pin15). They are controlled as shown in below table:

Table 3-4

SP1-CX Command	Output 3 (Pin 15)	Output 2 (Pin 14)	Output 1 (Pin 13)
J0	0	0	0
J1	0	0	1
J2	0	1	0
J3	0	1	1
J4	1	0	0
J5	1	0	1
J6	1	1	0
J7	1	1	1

(0=triode on, 1= triode off)
Note: Initialization command will not reset the <n> of [J] command to default value. The <n> of [J] command will be the default value upon the pump's next power-up.

s<n> Load the Program String into EEPROM

The EEPROM in the pump can store a program string, which provides the user with the option of computer-free operation.

The [s] command is placed at the beginning of a command string to load the string into the EEPROM. The syntax for this command is:

[s<n>], where<n>=0..14

Up to 15 command strings (numbered 0 through 14) can be loaded into the EEPROM. Each string can use up to 128 bytes. For example, [gA6000A0G5R] requires 11 bytes.

Table 3-5 Example: command string [s8ZS1gIA6000OA0G0R]

Command	Description
s8	Load string into program 8 of EEPROM (Address switch position 8)
Z	Initializes pump
S1	Sets plunger speed
g	Marks start of loop
I	Turns valve to input position
A6000	Moves plunger to position 6000
O	Turns valve to output position
A0	Moves plunger to position 0
G0	Endlessly repeats loop
R	Executes command string

e<n> Execute EEPROM Program String

There are two ways to execute the program strings in EEPROM:
1. Use the Address Switch to select the program string of the EEPROM to be executed when power on. DIP4 needs to be set as OFF. The pump will execute the selected program automatically when power on. Example: DIP4=OFF, and the Address switch is set at position 2. When power on the pump, the pump will execute the program 2 of EEPROM automatically.
This function needs custom design. If you need it, please contact Longer Pump.
2. Use [e] command to execute the program string.

Address Switch determines the program in the EEPROM to be executed when power on the pump.

> Note: An initialization command should always be included in the EEPROM command string if the pump will be used in standalone mode.

EEPROM command strings are executed by sending an [e] command. The executing program string can be terminated using the [T] command.
[e<n>], where<n>=0..14 (the string number)

Linking Program Strings in EEPROM

EEPROM program strings can be linked by ending one program string with an [e] command that refers to a second program string.
Example: [s1ZgIA6000OA0G5e2R]
[s2gIA6000OgHD300G10GR]
DIP4 is set as OFF, and the Address Switch is set as position 1. When power on the pump, the pump will execute the program 1 of EEPROM automatically: initialization, prime sequence. Then links to program 2 of EEPROM. Program 2 will be repeated endlessly until the pump is powered off.

3.3.3 Initialization Commands

Initialization Forces

Initialization moves the plunger to the top of the syringe, which is set to position 0. Also, the input and output positions of the valve are assigned depending on the initialization parameters. The initialization command will set the parameters of all other commands to the default value.

Initialization fails if the plunger can't move to the piston 0 or overload. The plunger force can be set through the initialization command.

Table 3-6 lists the recommended initialization force for each type of syringe.

Caution! To retain the integrity of the seal on the smaller syringes, use a lower initialization force than that for larger syringes. The default initialization speed is 500Hz.

Table 3-6. Recommended Initialization Forces by Syringe

Parameter of the Initialization Command	Plunger Force	Syringes
0, 3-40	Full	10mL, 25mL
1	Half	1mL，25mL，5mL
2	Quarter	50μL, 100μL, 250μL, 500μL

Initialization Commands for Plunger and Valve

Z<n> Initialize Plunger and Valve Drive (Output Port on the Right Side)

Z<n> command initializes the plunger and valve drive and moves the valve to set the output port on the right side (look from the front of pump). Refer to below description on the parameters:

Table 3-7.

Command	Parameter/Value	Description
Z	<n>=0 (default) <n>=3～9	Initializes at full plunger force and at default initialization speed (500Hz)
	<n>=10~40	Initialization at full plunger force and at speed code <n>. Refer to command [S] for a list of speed codes (S10~S40)
	<n>=1	Initializes at half plunger force and at default initialization speed (500Hz)
	<n>=2	Initialization 1/4 plunger force at speed (500Hz)

Y<n> Initialize Plunger and Valve Drive (Output Port on the Left Side)

Y<n> command initializes the plunger and valve drive and moves the valve to set the output port on the left side (look from the front of pump). Refer to below description on the parameters:

Table 3-8

Command	Parameter/Value	Description
Y	<n>=0 (default) <n>=3～9	Initializes at full plunger force and at default initialization speed (500Hz)
	<n>=10~40	Initialization at full plunger force and at speed code <n>. Refer to command [S] for a list of speed codes (S10~S14)
	<n>=1	Initializes at half plunger force and at default initialization speed (500Hz)
	<n>=2	Initialization 1/4 plunger force and at speed (500Hz)

Initialization Commands for Plunger Only (without Valve)

W<n> Initialize Plunger Drive

W<n> command initializes the plunger drive of pump without valve.

Table 3-9.

Command	Parameter/Value	Description
W	<n>=0 (default) <n>=3～9	Initializes at full plunger force and at default initialization speed (500Hz)
	<n>=10~40	Initialization at full plunger force and at speed code <n>. Refer to command [S] for a list of speed codes (S10~S14)
	<n>=1	Initializes at half plunger force and at default initialization speed (500Hz)
	<n>=2	Initialization 1/4 plunger force and at speed (500Hz)

Caution! The valve commands are invalid after the [W] command. The valve commands will be valid after re-initialized by using [Z] or [Y] command.

Note: Refer to Table 3-11 for the speed setting.

3.3.4 Plunger Movement Command

A<n> Absolute Position

[A] command moves plunger to the absolute position <n>, where <n>=0..6000.

For example: [A300R] moves plunger to the absolute position 300.

P<n> Relative Pickup

[P] command moves plunger down the number of steps commanded. The new absolute position= previous absolute position + <n>, where <n>=0..6000.

For example:

The plunger is at position 0. [P300R] moves plunger down 300 steps to absolute position of 300. Then [P600R] moves plunger down 600 steps to absolute position of 900.

D<n> Relative Dispense

[D] command moves plunger upward the number of steps commanded. The new absolute position= previous absolute position - <n>, where <n>=0..6000.

For example:

Plunger is at position 6000. [D300R] moves the plunger up 300 steps to an absolute position of 5700.

3.3.5 Valve Command

Note: The valve command sent to the pump without valve is invalid, which will return error 2 (invalid command).

I Move Valve to Input Position

[I] command moves the valve to input position, which connects the input port and syringe port.

The input port is defined by initialization command [Z] or [Y]. [Z] command defines the left port as the input port. [Y] command defines the right port as the input port.

For example: if the [I] command is sent after the [Z] command, the left port (look from the front of the pump) will connect to the syringe port.

O Move Valve to Output Position

[O] command moves the valve to output position, which connects the output port and syringe port.

The output port is defined by initialization command [Z] or [Y]. [Z] command defines the right port as the output port. [Y] command defines the left port as the output port.

For example: if the [O] command is sent after the [Z] command, the right port (look from the front of the pump) will connect to the syringe port.

Below figure indicates the valve position following the initialization and valve command.

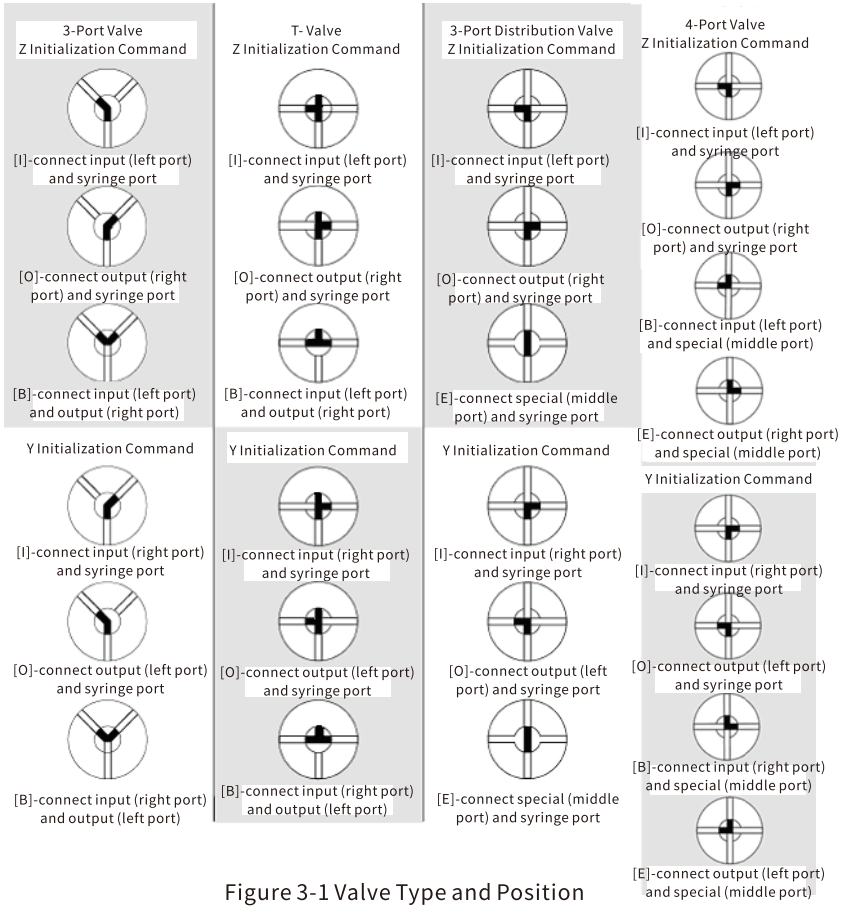


Figure 3-1 Valve Type and Position

B Move Valve to Bypass Position

[B] command connects the input port and output port, bypassing the syringe.

E Move valve to Extra Position (Only Applicable to 3-Port Distribution Valve and 4-Port Valve)

[E] command moves the valve to special position. For 4-port valve, the [E] command is similar as [B] command, bypassing the syringe.

> Caution! When the valve is in the bypass position, the syringe plunger will not move. Sending a Plunger Movement command causes an error 11 (plunger move not allowed).

3.3.6 Set Command

Set commands are used to control the speed of the plunger, set the backlash compensation and syringe dead volume.
Plunger movement is divided into three phases:

- **Ramping Up.** Plunger movement begins with the start speed and accelerates with the programmed slope to the constant or top speed.

- **Constant or Top Speed.** The plunger moves at the constant or top speed. Plunger constant or top speed can be programed in Hz (half-step/second) or in preprogrammed Set Speeds. The actual time the plunger travels is dependent on the ramping up and down. If the plunger move is short, it may never reach top speed.

- **Ramping Down.** The plunger will decelerate based on the programmed slope. To enhance fluid breakoff, the Cutoff command [c] can be used to define the end speed of the plunger just before it stops.

The total steps plunger moves after each Plunger Movement command can be calculated based on the steps needed in each phase.

> Note: Unless the top speed is less than the start or cutoff speed, always program the pump in order of the move: start speed [v], top speed [V], cutoff speed [c].

K<n> Backlash Steps

[K] command sets the number of backlash steps. The syntax is:
[K<n>], where <n>=0..31 (0 is the default)
Note: Initialization command will not reset the parameter of the [K] command to default value 24. The parameter will be default value of 0 upon the pump's next power-up.
When the plunger drive motor reverses direction, the plunger will not move until the backlash is compensated, the backlash is caused by the mechanical clearance in the system. To provide this compensation, during aspiration, the plunger moves down additional steps, then backs up the set number of backlash steps. This ensures that the plunger is in the correct position to begin a dispensing move. Note that, during this operation, a small volume of fluid will discharge from the input of the valve.

L<n> Set Slope

During the beginning and end of a move, the plunger speed ramps up and down respectively. The ramp is programmed using the Slope command. It is calculated as <n>x2.5kHz/sec. The syntax for this command is:
[L<n>], where <n>=1..20 (11 is the default)
Note: Initialization command will reset the parameter of [L] command to default value.

Table 3-10 (Slope list)

Slope Code	Pulse/sec² (kHz/s)	Ramp Time T(ms) (Speed from 0Hz to 5000Hz with the slope)
1	2.5	2000
2	5	1000
3	7.5	667
4	10	500
5	12.5	400
6	15	333
7	17.5	286
8	20	250
9	22.5	222
10	25	200
11	27.5	182
12	30	167
13	32.5	154
14	35	143
15	37.5	133
16	40	125
17	42.5	118
18	45	111
19	47.5	105
20	50	100
Ramp up time calculation: t1=T*(Vr-Vs)/Vtop Vr: top speed, Vs: start speed, Vtop: 5000Hz		
Ramp down time calculation: t1=T*(Vr-Ve)/Vtop Vr: top speed, Ve: cutoff speed, Vtop: 5000Hz		

v<n> Set Start Speed

[v] command sets the speed at which the plunger begins its movement, in pulses/sec. The plunger will then ramp up (slope) to the top speed. The start speed should always be less than the top speed. The syntax for this command is:

[v<n>], where <n>=50-1000Hz (500 is the default)

Note: Initialization command will reset the parameter of [v] command to default value.

V<n> Set Top Speed

[V] command sets the top speed in pulses/second. The syntax for this command is:

[V<n>], where <n>=5…5000Hz (1400 is the default)

Note: Initialization command will reset the parameter of [V] command to default value.

Note: Syringes 2.5mL and larger may require slower speeds. Users must determine the appropriate speeds for their applications.

S<n> Set Speed

[S] command sets a predefined top plunger speed, in pulses/sec. As <n> increases, the plunger speed decreases. The syntax for this command is:
[S<n>], where <n>=0…40 (11 is the default). Refer to table 3-11 for the correspondence between the speed code <n> and speed.
Note: Initialization command will reset the parameter of [S] command to default value.
These speed settings do not cover the full range of speeds the plunger can travel. They are commonly used speeds provided for the convenience of the user.
The [S] command sets top speed without changing start speed, slope and cutoff speed, except under the following conditions:

- If the start speed is higher than the top speed, the start speed equals to the top speed .
- If the cutoff speed is higher than the top speed, cutoff speed is equals to the top speed .

Table 3-11 Speed Code and Speed

Speed Code（n）	Speed（Hz）	Speed（rpm/min）	Linear Speed（mm/s）
0,1,2	5000	750.00	50.00
3	4400	660.00	44.00
4	3800	570.00	38.00
5	3200	480.00	32.00
6	2600	390.00	26.00
7	2200	330.00	22.00
8	2000	300.00	20.00
9	1800	270.00	18.00
10	1600	240.00	16.00
11	1400	210.00	14.00
12	1200	180.00	12.00
13	1000	150.00	10.00
14	800	120.00	8.00
15	600	90.00	6.00
16	400	60.00	4.00
17	200	30.00	2.00
18	190	28.50	1.90
19	180	27.00	1.80
20	170	25.50	1.70
21	160	24.00	1.60
22	150	22.50	1.50
23	140	21.00	1.40
24	130	19.50	1.30
25	120	18.00	1.20
26	110	16.50	1.10
27	100	15.00	1.00
28	90	13.50	0.90
29	80	12.00	0.80
30	70	10.50	0.70
31	60	9.00	0.60
32	50	7.50	0.50
33	40	6.00	0.40
34	30	4.50	0.30
35	20	3.00	0.20
36	18	2.70	0.18
37	16	2.40	0.16
38	14	2.10	0.14
39	12	1.80	0.12
40	10	1.50	0.10

c<n> Cutoff Speed

[c] command sets the speed at which the plunger ends its movement, in pulses/sec. The plunger will ramp down (slope) from the top speed. The syntax for this command is:

[c<n>], where <n>=50…2700Hz (500 is the default)
Note: Initialization command will reset the parameter of [c] command to default value.

k<n> Syringe Dead Volume Command

[k] command allows the setting of the number of steps that the plunger travels after initialization. The syntax for this command is:

[k<n>],
Where:
<n>= the offset in steps from zero position
<n>= 0…80 (20 is the default)

When initialize the plunger drive, the plunger moves upward until it contacts the top of the syringe, then plunger moves downward <n> steps to leave a small gap between the syringe seal and the top of the plunger. This small gap was designed so that the seal does not hit the top of the plunger each time the syringe moves to the “home” position. This maximizes the life of the syringe seal.

Note: Initialization command will not reset the parameter of [k] command to default value. The parameter of [k] command will be default value of 20 upon the pump's next power-up.

Summary of the Set Commands:

S<n> Set Speed [<n>=0..40] Default：11
V<n> Set Top Speed Hz [<n>=5..5000] Default：1400
v<n> Set Start Speed Hz [<n>=50..1000] Default：500
c<n> Set Cutoff Speed Hz [<n>=50..2700] Default：500
L<n> Set Slope [<n>=1..20] Default:7
Where slope=n*2500(Hz/s)
K<n> Set Backlash Step [<n>=0..31] Default:0
k<n> Set Dead Volume [<n>=0..80] Default：20

3.3.7 Report Commands

? Report Absolute Plunger Position

[?] command reports the absolute target position of the plunger in steps, returns [0…6080].
Note: The position returned by pump includes the syringe dead volume set through [k] command. Example: send [?] after [k80A6000R], pump will return plunger target position as 6080.

?1 Report Start Speed

[?1] command reports the start speed set through [v] command, in pulses/sec, returns [50…1000]Hz.

?2 Report Top Speed

[?2] command reports the top speed set through [V] or [S] command, in pulses/sec, returns [5…5000]Hz.

?3 Report Cutoff Speed

[?3] command reports the cutoff speed set through [c] command, in pulses/sec, returns [50…2700]Hz.

?4 Report Actual Position of Plunger

[?4] command reports the actual position of the plunger, returns [0…6000].
Note: The position returned by pump does not include the syringe dead volume set through [k] command.

?5 Report the Slope Code

[?5] command reports the slope code set through [L] command, returns [1…20]. Refer to the table 3-10 for the correspondence between the slope code and slope.

?6 Report Valve Position

Command	Valve	ZR Initialization		YR Initialization	
		current position	report	current position	report
?6	3-Port	IR	“4”	IR	“0”
		OR	“0”	OR	“4”
		BR	“8”	BR	“8”
	3-Port Distribution	IR	“3”	IR	“9”
		OR	“9”	OR	“3”
		ER	“6”	ER	“6”
	4-Port	IR	“3”	IR	“0”
		OR	“0”	OR	“3”
		BR	“6”	BR	“9”
		ER	“9”	ER	“6”
	T	IR	“3”	IR	“0”
		OR	“0”	OR	“3”
		BR	“9”	BR	“9”

?8 Report the Plunger Force

[?8] command reports the plunger force.
Returns code 0=full force, code 1= half force, code 2= quarter force

?10 Report Command Buffer Status

[?10] command reports the command buffer status. If the buffer is empty, the status code is 96. If the buffer is not empty, the status code is 64. If a program string is sent to the pump without an [R] command, the string is loaded into the buffer and the buffer status becomes status 64. An [R] command will then execute the command stored in the buffer.

?12 Report Number of Backlash Steps

[?12] command reports the number of backlash steps as set through [K] command. Returns [0…31].

?13 Report Status of Auxiliary Input 1 (DB15, Pin8)

0=high; 1=low

?14 Report Status of Auxiliary Input 2 (DB15, Pin7)

0=high; 1=low

?15 Report Pump Address

[?15] command reports the pump address. Returns in Hex [31…3F], in Dec [49…63] corresponding to Address Switch [0…E].

?23 Report Firmware Version

[? 23] command reports the firmware version in ASCII characters.
Most significant 4 bits= software version,
least significant 4 bits= hardware version.

?24 Report Syringe Dead Volume

[?24] command reports the syringe dead volume set through [k] command, in steps, returns [0…80].

3.3.8 Error Codes and Pump Status

Q command reports the error codes and pump status (refer to table 3-12.)
Table 3-12: Error Code and Pump Status

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
76543210	0	or 1	0	or 1	Number	Error
01X00000	40h	60h	64	96	0	No Error
01X00001	41h	61h	65	97	1	Initialization Error
01X00010	42h	62h	66	98	2	Invalid Command
01X00011	43h	63h	67	99	3	Invalid Parameter
01X00100	44h	64h	68	100	4	Reserved
01X00101	45h	65h	69	101	5	Reserved
01X00110	46h	66h	70	102	6	Reserved
01X00111	47h	67h	71	103	7	Device Not Initialized
01X01001	49h	69h	73	105	9	Plunger Overload
01X01010	4Ah	6Ah	74	106	10	Valve Overload
01X01011	4Bh	6Bh	75	107	11	Plunger Move Not Allowed
01X01111	4Fh	6Fh	79	111	15	Command Overflow

[Q] command reports error codes and pump status (ready or busy). The user should send a [Q] command before sending a program string or individual command to ensure that the pump has completed the previous command successfully.

Note: [Q] command is the only valid methods for obtaining status.

The response to the [Q] command (the status byte) provides two items of information:
Pump status (bit 5) and error code (bits 0-3).

Status Bit

Bit 5 is the status bit. It indicates when the pump is busy or not busy. The designations for bit 5 are listed below:

Table 3-13.

Status Bit 5	Description
X=1	Pump is ready to accept new commands
X=0	Pump is busy and will only accept Report commands, [Q] command and Terminate command.

In response to Move commands ([A], [P] and [D]), the [Q] command reports that the pump is busy. Commands addressed to multiple pumps at once can't be used to obtain pump status. Pumps must be queried separately.

> Note: Although the answer message for other commands contains a status bit, it should not be used for determining pump status. A [Q] command is the only valid method to determine if the pump is busy. The error information in the status byte of the answer message is always valid.

Error Codes

Error codes describe problem conditions that may be detected in the MSP1-CX. Error codes are returned in the least significant 4 bits of the status byte. If an error occurs, the pump stops executing commands, clears the command buffer, and inserts the error code into the status byte.
Some errors continue to appear, such as syringe overloads, until they are cleared by the Initialization command. On a plunger overload, the device will not execute another valve or plunger Movement command until it is reinitialized. The last error has precedence in the status byte. For example, if a command overflow occurs, an error 15 results. If the next command causes an error 3, the status byte reflect the error 3 (invalid parameter).

Table 3-14.

Error Code	Description
0(00h)	Error Free Condition.
1(01h)	Initialization error. This error occurs when the pump fails to initialize.
2(02h)	Invalid Command. This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally.
3(03h)	Invalid Parameter. This error occurs when an invalid parameter <n> is given with a command. Correct the parameter and pump operation will continue normally.
4(04h)	Reserved.
5(05h)	Reserved.
6(06h))	Reserved.
7(07h)	Device Not Initialized. This error occurs when the pump is not initialized. To clear the error, initialize the pump.
9(09h)	Plunger Overload. This error occurs when movement of the syringe plunger is blocked by excessive backpressure. The pump must be reinitialized before normal operation can resume. This error can only be cleared by reinitializing the pump.
10(0Ah)	Valve Overload. This error occurs when the valve drive loses steps by blockage or excess backpressure. The pump must be reinitialized before normal operation can resume. Sending another Initialization command reinitializes the pump to clear the error and set it to the correct location. Continual valve overload errors are an indication the valve should be replaced.
11(0Bh)	Plunger Move Not Allowed. When the valve is in the bypass or throughput position, Plunger Movement commands are not allowed.
15(0Fh)	Command Overflow. This error occurs when the command buffer contains too many characters, or Plunger Movement command, Set command, Valve command is sent while the plunger is moving, or new command is sent while 'M'/'H' is executing.

Error Types

The pump handles errors differently, depending on the error type. There are four error types, which are described below.

Immediate Errors

These include “Invalid Command” (error 2), “Invalid Parameter” (error 3), “Plunger Move Not Allowed” (error 11). After the command is sent, the answer message immediately returns an error. Once a valid command is sent, the pump will continue to function normally.

Initialization Errors

These include “Initialization Error” (error 1) and “Device not Initialized” (error 7). If the pump fails to initialize or if an Initialization command has not been sent, subsequent commands will not be executed.

To ensure that the pump initializes successfully, send a [Q] command after the Initialization command.

- If the [Q] command indicates both a successful initialization and that the pump is ready, subsequent Move commands can be sent.

- If the [Q] command indicates the pump has not been initialized, the pump must be reinitialized until the [Q] command indicates successful initialization.

- If initialization is not successful, a “Device Not Initialized” error is returned as soon as the next Move command is sent. A successful reinitialization must be executed before subsequent commands can be sent.

Overload Errors

These include the “Plunger Overload” and “Valve Overload” errors (errors 9 and 10). If the pump returns either a plunger or valve overload, the pump must be reinitialized before continuing. If a successful initialization has not occurred, an initialization error is returned.

Command Overflow Error

This is error 15. This error occurs when the command buffer contains too many characters, or Plunger Movement command, Set command, Valve command is sent while the plunger is moving, or other new command is sent while 'M'/'H' is executing. The [Q] command allows the controller to determine when the command is complete and the pump is ready to accept new commands.

Error 15 will not be returned after Report command and [T] command.

Error Reporting Examples

[A7000R] Not return an error immediately after the command. A [Q] command returns "Invalid Parameter" error. The error code will not be cleared but will be overwritten after receiving a new command.

[A6000A6500R] Moves plunger to position 3000, then stops. A [Q] command returns "Invalid Parameter" error.

[x2000R] Returns an "Invalid Command" error immediately. The pump status is "Not Busy".

[A6000x2000R] Returns an "Invalid Command" error immediately. The pump is "Not Busy".
Valve in Bypass [A1000R] Not return an error immediately. A [Q] command returns "Plunger Move Not Allowed" error.

4 Setting Up the SP1-CX for Your Application

SP1-CX is capable of providing precision pumping in a wide variety of hardware and fluid system. The interplay of fluid viscosity, aspiration and dispense speeds, and system geometry (syringe size, tubing inner diameter, and valve inner diameter) determine the behavior of the SP1-CX in a particular application. Following is a description of the hardware, fluid and pump control parameters to be evaluated and optimized in managing these interdependencies for optimal pump performance.

4.1 Glossary

Air Gap
A small volume of air at the end of the output tubing or sandwiched between two fluids in the pump system tubing. Air gaps may be created by aspirating air (programmed air gaps) or by the spring action of the fluid system (inertial air gaps).

Aspirate/Dispense Tubing
Connects the valve output port (1/4-28 thread) to a sample source and destination. To ensure good breakoff, aspirate/dispense tubing tends to have a smaller ID than reagent tubing, and a necked-down or tapered end.

Backlash
Mechanical play in the syringe drive created by accumulated mechanical clearances.

Backpressure
The pressure which must be exceeded to move fluid through tubing. Backpressure is generated by a combination of fluid inertia and friction.

Breakoff
Describes how the last droplet of fluid exits the end of the output tubing following a dispense. Rapid or sharp breakoff means that the droplet exits cleanly with high inertia.

Breakup
Undesired air gaps created by overly rapid aspiration.

Carryover
Contamination of a volume of fluid by residual fluid from a previous aspiration or dispense. Carryover causes variability in final volume and concentration.

Cavitation
Formation of air bubbles due to rapid pressure changes. Often caused by aspirating fluid into the syringe too quickly.

Dilution effect
Reduction in sample or reagent concentration, caused by contact with system fluid or residual fluid from a previous aspiration or dispense.

I.D. (Inner Diameter)
Diameter of the constraining wall of a fluid path.

Priming
Completely filling the pump tubing and syringe with bubble-free fluid to allow sustained, reproducible pumping action. The air in an unprimed line acts as a spring, adversely affecting accuracy and precision.

Reagent Tubing
Connects the valve input port (1/4-28 thread) to a reagent source. Reagent tubing is used to fill the pump syringe; it tends to have a larger I.D. than aspirate/dispense tubing, and a blunt-cut end which extends into the reagent.

System Fluid
A fluid used to prime the pump system that does not act as sample or reagent. Typically the system fluid is de-ionized water or a wash buffer and is isolated from sample or reagent fluid by an air gap to avoid intermixing.

Syringe Speed Profile
Typically, the syringe plunger begins moving slowly, then ramps up to top speed. This allows the plunger to start moving gradually, without overloading the motor, and still provide maximum flowrate. The syringe plunger stops by ramping down in speed. This results in the most reproducible fluid breakoff for accurate dispensing.

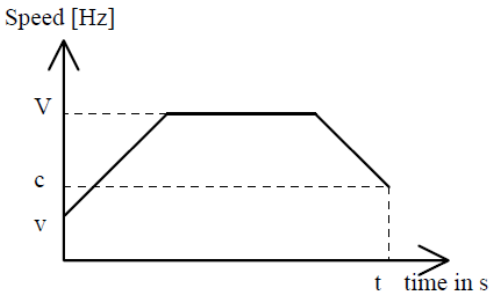


Figure 4-1 Syringe Speed

Start speed (v)
The speed at which the syringe plunger starts moving.

Top speed (V)
The maximum speed at which the syringe plunger moves.

Cutoff speed (c)
The speed of the syringe plunger just before stopping.

Slope (L)
Acceleration (deceleration) of the syringe plunger between start speed, top speed, and cutoff speed.

The volume aspirated or dispensed when the syringe plunger moves a specified number of steps depending on the syringe size. To determine the number of steps required to aspirate or dispense a given volume, use the following formula:

$$\#\text{of steps} = \frac{(\text{pump stoke steps}) \times \text{volume}}{(\text{syringe size})}$$

For example: to aspirate 100uL using an SP1-CX with 1mL syringe, move the plunger as follows:

$$\#\text{of steps} = \frac{6000 \text{ steps} \times 100\text{uL}}{1\text{mL} \times 1000\text{uL/mL}} = 600 \text{ steps}$$

4.2 Optimizing SP1-CX Performance

> Note: Run the pump only in the upright position. Do not move the pump valve or syringe plunger without first wetting or priming the pump.

For command details, refer to Chapter 3" Software Communication"
To optimize SP1-CX performance, follow these steps:

1 Check chemical compatibility

Check the chemical compatibility chart in Appendix C, "Chemical Resistance Chart", to determine if the fluids in your application are compatible with the SP1-CX syringe and valve materials. If not, a system fluid is required. Complete the optimization procedure with the fluids you will use in your final system.

Note that the system fluid is used to prime the syringe and tubing from inlet to outlet. After the tubing is primed (and before any sample or reagent is aspirated), an air gap must be taken into the aspirated/dispense tubing to separate the system fluid from subsequently aspirated sample or reagent. Air gaps should be aspirated slowly to avoid break-ups, and the air gap volume should be one-tenth the volume of the aspirated fluid- or at least 10uL- to avoid any dilution effect. Similar air gaps should separate each aspirated fluid when performing multiple aspirates with no intervening dispenses, in order to prevent premature mixing and/or contamination. In addition, the aspirate/dispense tubing must be long enough to hold the total aspirate volume without coming in contact with the valve or syringe.

2 Select syringe size

Determine your volume and flowrate requirements. Select a syringe that accommodates the smallest and largest volumes to be dispensed without refill, as well as the desired flowrate (refer to Flowrate Ranges). While smaller syringes allow better accuracy and precision, a larger syringe allows more aliquots when multiple aspirations or multiple dispenses are required, and they allow better breakoff and longer seal life.

Table 4-1 Flowrate Ranges

Syringe Size	Minimum Flowrate	Maximum Flowrate
50uL	0.0025 mL/min	2.5 mL/min
100uL	0.0050 mL/min	5 mL/min
250uL	0.0125 mL/min	12.5 mL/min
500uL	0.025 mL/min	25 mL/min
1mL	0.050 mL/min	50 mL/min
2.5mL	0.125 mL/min	125 mL/min
5mL	0.25 mL/min	250 mL/min
10mL	0.5 mL/min	500 mL/min
25mL	1.25 mL/min	1250 mL/min

Note: The flowrate does not include the aspiration process and ignores the time for ramp up and ramp down.
When the fluid is liquid, aspirating the fluid into the syringe too quickly will lead to air bubbles in the system, which will affect the flowrate of dispense. Table 4-2 lists the max aspirating/dispensing speed for the specific syringe volume with water.

Table 4-2 Max Aspirating/Dispensing Speed (Temp：26℃；Humidity：65%)

Tubing	Syringe Size (uL)	Max Dispensing Speed (Hz)	Max Aspirating Speed (Hz)
0.5mm(I.D.)	50	5000	5000
	100	5000	5000
	250	5000	1700
	500	5000	700
	1000	5000	300
	2500	4300	150
	5000	1500	80
	10000	690	30
	25000	400	—
1.0mm(I.D.)	50	5000	5000
	100	5000	5000
	250	5000	5000
	500	5000	5000
	1000	5000	4000
	2500	5000	1600
	5000	5000	800
	10000	4600	380
	25000	1200	120
1.5mm(I.D.)	50	5000	5000
	100	5000	5000
	250	5000	5000
	500	5000	5000
	1000	5000	5000
	2500	5000	2000
	5000	5000	1500
	10000	4800	500
	25000	1700	230

Conclusion: when using syringe larger than 1ml., the air bubble will be formed due to rapid pressure changes. This will affect accuracy and precision. And more bubbles with larger cross-sectional area of syringe. Therefore, the max aspirating speed for larger size syringe will decrease, less than 5000Hz.

3 Select tubing

In tubing selection, the general rule is that smaller syringes work best with smaller I.D. tubing and larger syringes with larger I.D. tubing. The 3-Port valve has an internal I.D. of 1/16”. For aspirate/dispense tubing a thermal-drawn tip or tapered tip is most common, providing good breakoff and excellent accuracy and precision for most applications. A necked-down tip may be used when aspirating very small volumes of sample, i.e., 1-5uL. A blunt-cut tip is better suited for large volume applications. For tubing recommendations, refer to Table 4-3, Tubing Recommendations.

Table 4-3 Tubing Recommendations

SP1-CX Applicable Tubing	
Part No.	Description
008T16-050	1.6mm (1/16") O.D. x 0.5mm (.02") I.D.
008T16-100	1.6mm (1/16") O.D. x 1.0mm (.039") I.D.
008T32-150	3.2mm (1/8") O.D. x 1.5mm (.059") I.D.

4 Connect the pump

Connect power and communication cables to the pump, install syringe and tubing. Place the end of the input tubing in a reservoir of particle-free fluid, place the end of the output tubing in a waste reservoir.

5 Check communication to the pump

a) Open the pump application program.
b) Send the command [?23] to read the pump's firmware revision number. Successful communication will return the revision number and a Ready status.
Possible errors:
No response. Check if the cable connection is loose or wrong, or the cable is connected to the wrong port on the computer. Retry.

6 Initialize the pump and set initialization speed

The following information assumes that your input tubing connects to the left valve port. IF your input tubing connects to the right valve port, exchange [Y] for all instances of [Z] in the following commands.
Send the command [ZR] to initialize the pump. Successful initialization will move the syringe plunger to the position 0 (fully dispensed) and return a Ready status.
Possible errors:
Error 1 (initialization error). Check for tubing blockage and reinitialize. If you are using very narrow I.D. tubing or pumping a viscous fluid, the initialization speed may need to be reduced.

7 Prime the syringe

a) Send the command [IA6000OA0R] to pull fluid through the valve input position and into the syringe.
b) Inspect the pump tubing and syringe for bubbles and re-prime until all bubbles are completely gone.
If bubbles remain after several priming strokes, disassemble the syringe and clean it with alcohol. Also check to ensure the fittings are tight and the syringe is tight within the valve port.
c) Re-prime.
Possible errors: Error 9 (plunger overload). Refer to step 8.

8 Check aspirate/dispense

Send the command [IA6000OA0R] to aspirate a full syringe stroke (6000 steps) from input and dispense it to output. Successful execution will move the syringe plunger to position 6000 then back to position 0, then it will return a Ready status.
Possible errors:
Error 9 (plunger overload). The stepper motor is unable to move the syringe plunger, probably because of excessive backpressure caused by excessive flowrate, narrow tubing I.D., or valve or tubing blockage. Note whether the error occurred during aspiration or dispensing. To differentiate between blockage and flowrate limitation, reduce syringe plunger speed by sending the command [S12IA6000OA0R]. Repeat with decreasing plunger speed (increase S_ value) until the pump aspirates and dispenses successfully.

9 Set start speed and top speed

The SP1-CX plunger speed can be controlled from 1.2 seconds per stroke to 20 minutes per stroke (top speed) using the [S] or [V] commands. (The [V] command allows a slightly larger speed range.) As a general rule, aspiration should be slow (to avoid cavitation) and dispense fast (to promote breakoff). Since cavitation and breakoff will affect both accuracy and precision, speed settings may be optimized separately for aspiration and dispense.
Using aspirate/dispense commands, set start speed [v] and top speed [V] to meet application throughput goals.
a) Send the command [v50IA6000OA0R]. Repeat with increasing start speed (increase v_ value) to find the maximum value.
b) Send the command [vxVxIA6000OA0R] to set top speed equal to start speed (x). Repeat with increasing top speed (increase V_ value) to the maximum value that does not overload the plunger or cause cavitation.

10 Set cutoff speed and slope

Using aspirate/dispense commands, set slope [L] and cutoff speed [c] to attain reproducible breakoff. Note that cutoff speed controls only dispensing.
To optimize the slope, send the command [vxVxL14IA6000OA0R]. Repeat with modified slope (L_ value) to achieve the overall time suited to your application without plunger overload.
To optimize the cutoff speed, start with the maximum cutoff speed allowed for your application (the lower of 2700Hz or the top speed). Send the command [cxIA6000OA0R] and monitor the dispense for plunger overload or any splattering of the fluid dispensed outside of the dispense vessel. If any of these conditions occur, lower the cutoff speed until the pump can dispense the fluid with clean breakoff.
Another condition that affects breakoff is the formation of inertial air gaps. This is seen as a small air gap inside the tubing at the tip. This occurs to a greater extent on larger reagent syringes, and it enhances the breakoff of liquid from the tip of the tubing. If an inertial air gap is not desired in the application, lowering the cutoff speed and/or the top speed will remove the inertial air gap. However, this may not give a clean breakoff of the fluid.
In some instances it may not be possible to improve fluid breakoff. Clean breakoff is important to accuracy and precision. It is a concern especially when using slow speeds because drops will usually adhere to the tip.
For example, using a 2.5mL syringe, dispense tubing and de-ionized water with a surfactant added

*[S24IA6000OA0R]- will leave a drop on the tip

*[S24IA6000OA5S1A0R]- no drop will be left

*[V100IA6000OA0R]- will leave a drop on the tip

*[V100IA6000OA5V5000A0R]- no drop will be left

Increasing the cutoff speed and slope may also improve the fluid breakoff. Smaller I.D. tubing may improve breakoff, especially for smaller syringes.

> Note: It may not be possible to achieve good fluid breakoff under any circumstance, especially with syringes smaller than 500uL or with some fluids.

11 Set the backlash compensation

When the plunger drive motor reverses direction, the plunger will not move until the backlash due to mechanical clearance within the system is compensated. To provide this compensation, during aspiration, the plunger moves down additional steps, then backs up the set number of backlash steps. This ensures that the plunger is in the correct position to begin a dispensing move, which will improve the dispensing accuracy.

4.3 Helpful Hints

To maintain pump performance, keep the following in mind when operating the pump:

- Wipe up all spills immediately.
- Pumping cold fluids may cause leaks, the result of differing coefficients of expansion of PTFE and glass. Leaks my occur when pumping fluids that are at or below 15°C.
- Before pumping any organic solvent, please refer to the Chemical Resistance Chart in Appendix C. Using organic solvents may reduce tubing and seal life.

5 Maintenance

Although required maintenance may vary with your application, the following procedures are recommended for optimal performance and maximum life of the SP1-CX.

Perform maintenance tasks in these intervals:

- daily
- weekly
- periodically

5.1 Daily Maintenance

To ensure proper operation of the SP1-CX, perform these tasks daily:

- Inspect the pump for leakages, and correct any problems.
- Wipe up all spills on and around the pump.
- Flush the pump thoroughly with distilled or deionized water after each use and when the pump is not in use.

> Note: Do not allow the pump to run dry for more than a few cycles.

5.2 Weekly Maintenance

The fluid path of the SP1-CX must be cleaned weekly to remove precipitates such as salts, eliminate bacterial growth, and so on. Any of the three cleaning procedures below:

- Weak detergent
- Weak acid and base
- 10% bleach

The procedures using these solutions are described in the following sections.

5.2.1 Weak Detergent Cleaning

To clean the pump with weak detergent, follow these steps:

1 Prime the pump with a weak detergent solution (e.g., 2% solution of CONTRAD®, or RoboScrub) and allow the solution to remain in the pump with the syringe fully lowered for 30 minutes.
2 After the 30 minutes, remove the reagent tubing from the detergent and cycle all the fluid from the syringe and tubing into a waste container.
3 Prime the pump a minimum of 10 cycles with distilled or de-ionized water. Leave the fluid pathways filled for storage.

5.2.2 Weak Acid-Base-Sequence Cleaning

To clean the pump with weak acid and base, follow these steps:

1 Prime the pump with 0.1N NaOH and allow the solution to remain in the pump for 10 minutes with the syringes fully lowered.
2 Flush the pump with distilled or de-ionized water.
3 Prime the pump with 0.1N HCl, and allow the solution to remain in the pump for 10 minutes with the syringes fully lowered.
4 After a 10 minutes period, remove the reagent tubing from 0.1N HCl solution and cycle all the fluid from the syringes and tubing into a waste container.
5 Prime the pump a minimum of 10 cycles with distilled or de-ionized water.

5.2.3 10% Bleach Cleaning

To clean the pump with 10% bleach, follow these steps:

1 Make a solution of 10% bleach by adding one part of commercial bleach to nine parts of water.
2 Prime the pump with the 10% bleach and allow the solution to remain in the pump with the syringes fully lowered for 30 minutes.
3 After the 30 minutes, remove the reagent tubing from 10% bleach solution and cycle all the fluid from the syringes and tubing into a waste container.
4 Prime the pump a minimum of 10 cycles with distilled or de-ionized water.

5.3 Periodic Maintenance

Tubing, syringe seals, and valves require periodic maintenance. If they become worn, you are likely to notice these symptoms:

- Poor precision and accuracy
- Variable or moving air gap
- Leakage

If any of these symptoms occurs and it is not obvious which component is causing the problem, it is easiest and most economical to replace one component at a time in the following order:

- input and output tubing
- plunger seal
- valve

The frequency of replacement will depend on the duty cycle, fluids used, and instrument maintenance.

5.3.1 Quality Control Assurance

Check the accuracy and precision of the SP1-CX on a regular basis.

It is recommended to check both accuracy and precision gravimetrically, using an analytical balance with the capability to measure to 0.1mg. Gravimetric measurements should be corrected for the specific gravity of water at the ambient temperature.

The syringe can be checked by programming in the desired volume and determining the weight of fluid dispensed.

To determine precision and accuracy, run a minimum of 20 replicates. The Mean, Standard Deviation and Coefficient of Variation (see formula below) can then be calculated. The calculations to determine accuracy must take into account the specific gravity of water, which is dependent upon temperature. In addition, to prevent a false reading caused by fluid adhering to the tip of the aspirate tubing, a small amount of surfactant should be added to the water (e.g., Fluorad® at a 0.01% concentration)

% Coefficient of Variation= (Standard Deviation/Mean)*100

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

$$\%Accuracy = \left[\frac{|\frac{\bar{X}}{sg}| * 100}{Vol_{expected}} \right] - 100$$

Where:

sg=specific gravity of water @25°C=0.99707
Vol=expected volume to be dispensed
n= number of replicate
X= individual result
$\bar{X}$ = mean of all results

5.3.2 Replacing Dispense or Reagent Tubing

To replace dispense or reagent tubing, follow these steps:

1 Unscrew the fittings, remove the tubing.
2 To install new tubing, insert the fitting into the valve and tighten it.

5.3.3 Replacing a Syringe

To replace a syringe, follow these steps:

1 Remove as much fluid as possible from the system by cycling the pump and using air as the system fluid.
2 Initialize the pump. Lower the plunger drive by sending the command [A6000R].
3 Loosen the plunger lock screw approximately three full turns.
4 Unscrew and remove the syringe from the valve.
5 To install the syringe (as shown in Figure 5-1)
a Insert the plunger holder into the mounting hole of the plunger.
b Pull up the syringe barrel to the valve and screw the syringe into the valve port.
c Tighten the plunger lock screw to ensure the syringe plunger into place.
6 Reinitialize the pump.

Note: Make sure the plunger lock screw is securely tightened.

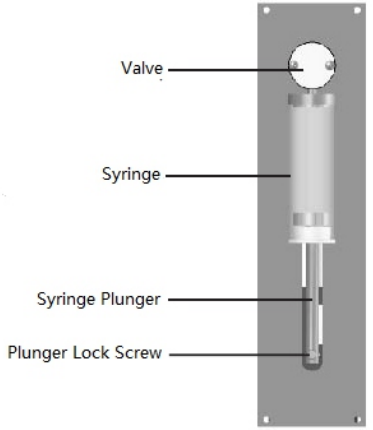


Figure 5-1 Syringe Replacement

5.3.4 Replacing the Valve

To replace the valve, follow these steps:

1 Remove as much fluid as possible from the system by cycling the pump and using air as the system fluid.
2 Initialize the pump using the [ZR] command so that the valve motor shaft is in the correct position.
3 Send an [A6000R] command to move the plunger to the bottom of travel. Remove the syringe and tubing.
4 Remove the head screws on the front of the valve, then remove the valve from the pump.
5 Install the new valve by placing it on the front panel so the screw holes line up. The valve coupler fitting mates to the valve motor shaft. Replace the valve screw.

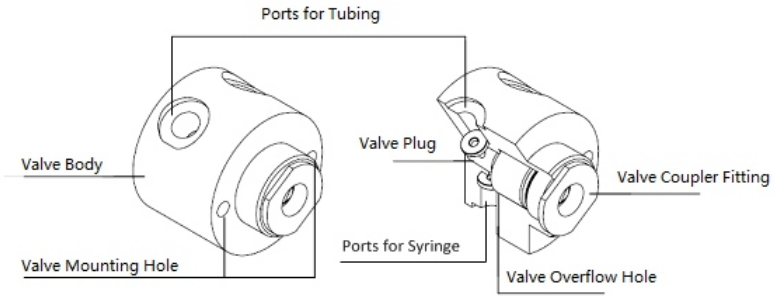


Figure 5-2 SP1-CX Valve Replacement (3-Port Valve)

5.4 On-Site Replacements

5.4.1 Details see service manual

6 Technical Service

For more information or questions about ordering or operating, please contact company through the methods listed below:

Phone: 86-0312-3110087
Fax: 86-0312-3168553
URL: Http://www.longerpump.com
Mailing address:
Baoding Longer Precision Pump Co., Ltd.
Address: 3rd/4th Floor, Building 6B, University Science Park Baoding National, High - Tech Industrial Development Zone Baoding, Hebei, China 071051

When you call company for technical service, please provide below material:

- Serial Number
- Operating Environment
- Description of the problem

Appendix A Plunger Information

Plunger Force

Plunger force setting and parameter as below:
Full force≥10kgf Half force≥5kgf Quarter force ≥2kgf
(Parameter <n>: 0，3~40=full; 1=half; 2=quarter)

Plunger Time Calculation

Following are calculations for determining SP1-CX plunger speeds. 3 different cases are presented below:

Case 1 When the top speed V is smaller than 1000Hz, the start speed and cutoff speed are equal to top speed.
Case 2 If the ramp up steps, or ramp down steps, or ramp up steps + ramp down steps, is greater than the total set steps, the start speed, top speed and cutoff speed are equal to 1000Hz.
Case 3 Typical move with ramp up, top speed and ramp down.

Symbol Definitions

Table 7-1

Symbol	Name	Range (n)	Unit
v	Start speed	50-1000	Hz or Pulses/sec
V	Top Speed	5-5000	Hz or Pulses/sec
c	Cutoff Speed	50-2700	Hz or Pulses/sec
L	Slope	1-20	n*2500 pulses/sec2 or Hz/s
A	Move Distance	0-6000	Steps
t1	Ramp Up Time		Seconds
t2	Top Speed Time		Seconds
t3	Ramp Down Time		Seconds
t	Total Move Time	t1+t2+t3	Seconds
A1	Ramp Up Steps		Steps
A2	Top Speed Steps		Steps
A3	Ramp Down Steps		Steps

Move Calculations

Example 1: Including the Case 1 and Case 2.

Start speed, Top speed and Cutoff speed are equal
Diagram of move:

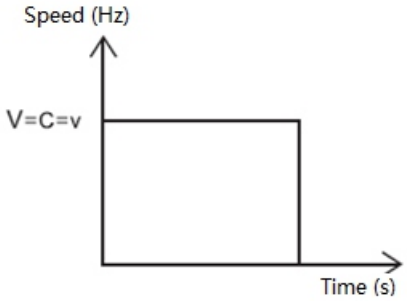


Figure 7-1

Parameters:

v=900Hz L=14
V=900Hz A=6000 steps
c=900Hz

Calculate the total move time: t=A/V=6000/900=6.67 s
Note: unit of the speed is Hz or pulses/sec, 1 step needs 1 pulse.

Example 2: Case 3 Typical move with ramp up, top speed and ramp down.

Case 2 is used when A1+A3<A
Diagram of Move:

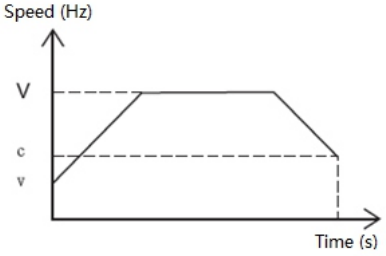


Figure 7-2

Parameters:

v=50Hz L=14

V=5000Hz A=6000 steps

c=500Hz

Calculate the total move time:
Ramp up steps: $A1=(V^2-v^2)/(2*L)=(5000^2-50^2)/(2*14*2500)=357$steps

Ramp down steps: $A3=(V^2-c^2)/(2*L)=(5000^2-500^2)/(2*14*2500)=354$steps

If A1+A3<A (357+354)<6000，then:

Ramp up time: t1=(V-v)/L=(5000-50)/(14*2500)=0.14 s

Ramp down time: t3=(V-c)/L=(5000-500)/(14*2500)=0.13s

Top speed steps: A2=A-A1-A3=6000-357-354=5289 steps

Top speed time: t2=A2/V=5289/5000=1.06 s

Total move time: t=t1+t2+t3=0.14+1.06+0.13=1.33 s

Appendix B ASCII Chart

Table 7-2

Decimal	Hexadecimal	Character or Function
0	00	none
1	01	SOH
2	02	STX
3	03	ETX
4	04	EOT
5	05	ENQ
6	06	ACK
7	07	BEL
8	08	BS
9	09	HT
10	0A	LF
11	0B	VT
12	0C	FF
13	0D	CR
14	0E	SO
15	0F	SI
16	10	DLE
17	11	DC1
18	12	DC2
19	13	DC3
20	14	DC4
21	15	NAK
22	16	SYN
23	17	ETB
24	18	CAN
25	19	EM
26	1A	SUB
27	1B	ESC
28	1C	FS
29	1D	GS
30	1E	RS
31	1F	US
32	20	SP
33	21	!
34	22	"
35	23	#
36	24	$
37	25	%
38	26	&
39	27	'(apostrophe)
40	28	(
41	29	)
42	2A	*
43	2B	+
44	2C	,(comma)
45	2D	-(en dash)
46	2E	.(Period)
47	2F	/
48	30	0
49	31	1
50	32	2
51	33	3
52	34	4
53	35	5
54	36	6
55	37	7
56	38	8
57	39	9
58	3A	:
59	3B	;
60	3C	<
61	3D	=
62	3E	>
63	3F	?

Decimal	Hexadecimal	Character or Function
64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O
80	50	P
81	51	Q
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\(backslash)
93	5D	]
94	5E	^ (control)
95	5F	- (emdash)
96	60	` (tick)
97	61	a
98	62	b
99	63	c
100	64	d
101	65	e
102	66	f
103	67	g
104	68	h
105	69	i
106	6A	j
107	6B	k
108	6C	l
109	6D	m
110	6E	n
111	6F	o
112	70	p
113	71	q
114	72	r
115	73	s
116	74	t
117	75	u
118	76	v
119	77	w
120	78	x
121	79	y
122	7A	Z
123	7B	{ (Left brace)
124	7C	| (Vertical bar)
125	7D	} (Right brace)
126	7E	~ (Tilde)
127	7F	DEL

Appendix C Chemical Resistance Chart

Table 7-3, which starts on the following page, provides a summary of chemical compatibility information provided by the manufacturers of components in the SP1-CX fluid path. LongerPump recommends that you use this information as a guideline only, and that you test each application fluid for chemical compatibility.

Caution: Failure to test chemicals used in individual applications with the SP1-CX may result in damage to the pump and/or test results.

The materials listed in Table 7-3 are used in the following areas of the SP1-CX:

PTFE Tubing, Valve Plug, Seal
PCTFE Valve Body
PEEK Fitting for Tubing

The codes and symbols in Table 7-3 are as follows:
- \- No Data
- 0 No effect – excellent
- 1 Minor effect – good
- 2 Moderate effect – fair
- 3 Severe effect – not recommended

Table 7-3 Chemical Resistance Chart

Solvent	Tefion	Kel - F	PEEK
Acetaldehyde	0	0	0
Acetates	–	0	–
Acetic Acid	0	0	0
Acetic Anhydride	–	0	–
Acetone	0	0	0
Acetyl Bromide	0	–	–
Ammonia	0	–	–
Ammonium Acetate	0	–	–
Ammonium Hydroxide	0	0	0
Ammonium Phosphate	–	0	–
Ammonium Sulfate	–	0	0
Amyl Acetate	0	–	0
Aniline	0	0	–
Benzene	0	3	0
Benzyl Alcohol	0	0	–
Boric Acid	0	0	–
Bromine	0	0	3
Butyl Alcohol	0	0	0
Butyl Acetate	0	–	–
Carbon Sulfide	0	–	–
Carbon Tetrachloride	0	1	0
Chloracetic Acid	0	0	–
Chlorine	0	1	–
Chlorobenzene	–	–	0
Chloroform	0	–	0
Chromic Acid	0	0	0
Cresol	0	–	–
Cyclohexane	0	–	0
Ethers	0	–	–
Ethyl Acetate	0	–	0
Ethyl Alcohol	0	–	0
Ethyl Chromide	0	1	–
Formaldehyde	0	0	0

Solvent	Teflon	Kel - F	PEEK
Formic Acid	0	0	0
Freon	0	2	–
Gasoline	0	0	0
Glycerin	0	0	0
Hydrochloric Acid	0	0	0
Hydrochloric Acid (conc)	0	0	0
Hydrofluoric Acid	0	0	3
Hydrogen Peroxide	0	0	0
Hydrogen Peroxide (conc)	0	0	0
Hydrogen Sulfide	0	0	0
Kerosene	0	0	–
Methyl Ethyl Ketone (MEK)	0	–	–
Methyl Alcohol	0	–	0
Methylene Chloride	0	0	–
Naptha	0	1	–
Nitric Acid	0	0	0
Nitric Acid	0	0	0
Nitrobenzene	0	–	0
Phenol	0	–	–
Pyridine	0	–	–
Silver Nitrate	0	–	–
Soap Solutions	0	–	0
Stearic Acid	0	–	–
Sulfuric Acid	0	0	–
Sulfuric Acid (conc)	0	0	–
Sulfurous Acid	0	0	–
Tannic Acid	–	0	–
Tanning Extracts	0	–	–
Tartaric Acid	0	–	–
Toluene	0	1	0
Trichloroethylene	0	3	0
Turpentine	0	0	–
Water	0	0	0
Xylene	0	0	0

Appendix D Technical Specification

Plunger	
Principle	Step motor, Ball screw drive, block detection by encoder
Full Stroke	60mm (6000steps)
Time for One Stroke	1.26s-20min (includes time for ramp up/ramp down)
Control Resolution	1 step of 0.01mm
Travel Control Accuracy	error≤±5‰ at ≥30% of full stroke
Plunger Force	Full；Half；1/4
Syringe	50ul 100ul 250ul 500ul 1ml 2.5ml 5ml 10ml 25ml
Valve	
Valve Type	3-Port Valve, 4-Port Valve, T-Valve, 3-Port Distribution Valve, Y-block.
Turn Time	≤250ms between adjacent ports
Valve Drive	Step motor with optical encoder for positioning feedback
Valve Material	Plug：PTFE Body：PCTFE
Valve Fitting	Tubing fitting：1/4-28；Syringe fitting：1/4-28
External Interface	
Communication Interface	Rs485 interface, 9600bps or 38400bps
	Rs232 interface, 9600bps or 38400bps
	CAN bus：100KB，125KB，250KB，500KB，1MB
Inputs	2 TTL level inputs；Used to resume the execution after [H] command
Outputs	3 OC gate outputs
Device Address Switch	Set the pump address through the Address Switch
DIP Dial Switch	Set the valve type, baud rate, RS232 or RS485, turn on or turn off the auto mode.
Commands	
Initialization Commands	Initialize the valve and plunger
Set Commands	Set the speed, slope, dead volume, backlash steps.
Valve Command	Move valve to desired position
Plunger Movement Command	Move plunger to desired position
Control Commands	Execute, repeat, delay, halt or terminate the single command, command string, and/or program in EEPROM
Report Commands	Monitor valve position, plunger position, plunger force, plunger speed and other status.

Outline Dimension	Height	254mm
	Width	65mm
	Depth	150mm
Power Supply	Power Voltage	24V DC
	Max Current	⩾1.5 A
Operating Environment	Temperature	15℃-40℃
	Humidity	20-95% @ 40℃

Appendix E SP1-CX Command Quick Reference

Control commands dimensions(for operating and execution)

Table 7-4

Command	Parameter<n>	Parameter Description	Command Description
R	-	-	Executes the command immediately
X	-	-	Executes the last executed command
G<n>	0~30000	0=endless loop; 1~30000=repeat number	Repeats command sequence
g	-	-	Marks the start of a repeat sequence
M<n>	5~30000	Delay time 5~30000ms	Delays the execution of a command
H<n>	0~2	0= Waits for [R] or rising edge of either input 1 or 2 to resume the execution, 1= Waits for [R] or rising edge of input 1 to resume the execution,2= Waits for [R] or rising edge of input 2 to resume the execution	Halts command execution
h		Pause the current pump motion	Pause command execution
r		Resume the current pump motion	Resume command execution
T	-	Terminates the command (string)	Terminates command execution
J<n>	0~7	0=Three outputs are low level; 7=Three outputs are high level;	Output control command
s<n>	0~14	The program number to be loaded	Load the program string into EEPROM
e<n>	0~14	The program number to be executed	Execute the program string in the EEPROM

Initialization Commands

Table 7-5

Command	Parameter<n>	Parameter Description	Command Description
Z<n>	0~40	0,3~9：Initializes at full plunger force and at default initialization speed (500Hz) 1：Initializes at half plunger force and at default initialization speed (500Hz) 2：Initializes at 1/4 plunger force 10~40：Initialization at full plunger force and at speed code <n>. Refer to command [S] for a list of speed codes (S10~S40)	Initialize the plunger and valve drive and moves the valve to set the output port on the right side (look from the front of pump).
Y<n>	0~40	Same as <n> of Z<n>	Initialize the plunger and valve drive and moves the valve to set the output port on the left side (look from the front of pump).
W<n>	0~40	Same as <n> of Z<n>	Initialize the plunger drive for pump without valve.

Plunger Movement Commands

Table 7-6

Command	Parameter<n>	Parameter Description	Command Description
A<n>	0~6000	The number of absolute position	Moves plunger to the absolute position
P<n>	0~6000	The number of steps	Moves the plunger down the number of steps
D<n>	0~6000	The number of steps	Moves the plunger up the number of steps

Valve Commands

Table 7-7

Command	Description
I	Move the valve to the input position
O	Move the valve to the output position
B	Move the valve to the bypass position
E	Move the valve to the extra position

Set Commands

Table 7-8

Command	Parameter<n>	Parameter Description	Command Description
K<n>	0~31	Number of backlash steps	Sets number of backlash steps
k<n>	0~80	The offset in steps from zero position	Set the dead volume steps.
L<n>	1~20	The slope code	Set the slope of plunger speed ramp up/ ramp down.
v<n>	50~1000	Start speed	Set start speed
V<n>	5~5000	Top speed	Set top speed
S<n>	0~40	Top speed code	Set top speed
c<n>	50~2700	Cutoff speed	Set cutoff speed

Report Commands

Table 7-9

Command	Return Parameter	Parameter Description	Command Description
Q	Status Byte	Refer to table 7-11	Reports pump status and error codes
?	0~3000	Absolute plunger position	Reports absolute target position of the plunger
?1	50~1000 Hz	Start speed	Report start speed of plunger
?2	5~5000 Hz	Top speed	Report top speed of plunger
?3	50~2700 Hz	Cutoff speed	Report cutoff speed of plunger
?4	0~3000	Actual absolute position of plunger	Report actual absolute position of plunger
?5	1~20	Slope	Report slope
?6	0~12	Valve position	Report valve position
?8	0，1，2	Plunger force: 0:full; 1:half; 2:quarter	Report plunger force
?10	36h 34h, Or 39h 36h	Command buffer status: 39h 36h= empty; 36h 34h= commands in buffer;	Report command buffer status
?12	0~31	Backlash steps	Report number of backlash steps
?13	0 or 1	Status of input 1: 0：low；1：high	Report status of input 1
?14	0 or 1	Status of input 2: 0：low；1：high	Report status of input 2
?15	1~15	Pump address	Report pump address
?23	N/A	N/A	Report software version
?24	0~80	Dead volume in steps	Report the syringe dead volume

Error Codes

Table 7-10

Error Code	Description
0(00h)	Error Free Condition.
1(01h)	Initialization error. This error occurs when the pump fails to initialize.
2(02h)	Invalid Command. This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally
3(03h)	Invalid Parameter. This error occurs when an invalid parameter <n> is given with a command. Correct the parameter and pump operation will continue normally.
4(04h)	Reserved.
5(05h)	Reserved.
6(06h)	Reserved.
7(07h)	Device Not Initialized. This error occurs when the pump is not initialized. To clear the error, initialize the pump.
9(09h)	Plunger Overload. This error occurs when movement of the syringe plunger is blocked by excessive backpressure. The pump must be reinitialized before normal operation can resume. This error can only be cleared by reinitializing the pump.
10(0Ah)	Valve Overload. This error occurs when the valve drive loses steps by blockage or excess backpressure. The pump must be reinitialized before normal operation can resume. Sending another Valve command reinitializes the valve and sets it to the correct location. Continual valve overload errors are an indication the valve should be replaced.
11(0Bh)	Plunger Move Not Allowed. When the valve is in the bypass or throughput position, Plunger Movement commands are not allowed.
15(0Fh)	Command buffer overflow. This error occurs when the command buffer contains too many characters, or Plunger Movement command, Set command, Valve command is sent while the plunger is moving, or new command is sent while 'M'/'H' is executing.

Error Code and Pump Status

Table 7-11

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
76543210	0	or 1	0	or 1	Number	Error
01X00000	40h	60h	64	96	0	No Error
01X00001	41h	61h	65	97	1	Initialization Error
01X00010	42h	62h	66	98	2	Invalid Command
01X00011	43h	63h	67	99	3	Invalid Parameter
01X00100	44h	64h	68	100	4	Reserved
01X00101	45h	65h	69	101	5	Reserved
01X00110	46h	66h	70	102	6	Reserved
01X00111	47h	67h	71	103	7	Device Not Initialized
01X01001	49h	69h	73	105	9	Plunger Overload
01X01010	4Ah	6Ah	74	106	10	Valve Overload
01X01011	4Bh	6Bh	75	107	11	Plunger Move Not Allowed
01X01111	4Fh	6Fh	79	111	15	Command Overflow

DB-15 Pin Definition

Table 7-12

Pin	Function	Remarks
1	DC_24V	Power Supply+
2	TXD	Rs232 Output data
3	RXD	Rs232 Input data
4	COM	Logic ground for input and output
5	CAN-H	CAN high signal
6	CAN-L	CAN low signal
7	In1	Input 1
8	In2	Input 2
9	GND	Power and logic
10	GND	Power and logic
11	RS-485 A	RS-485 A
12	RS-485 B	RS-485 B
13	OUT1	Output 1
14	OUT2	Output 2
15	OUT3	Output 3