Precision Syringe Drive/4 Smooth Flow Technical Manual

Warranty Information

Hamilton Company warrants this equipment[1] to be free of defects in material and workmanship for 12 months from the date of receipt. The warranty does not cover normal wear and tear of the valves or equipment. This warranty is extended to the buyer of record on the original purchase order to Hamilton Company. Hamilton Company or an authorized Hamilton representative agrees to repair or replace, at its option and free of charge to the buyer at a normal place of business or at a Hamilton repair facility, any part or parts that under proper and normal use prove to be defective during the warranty period.[2] Abuse, unauthorized replacement of parts, modifications or adjustments made by other than Hamilton Company or its assigned representatives voids this warranty.

This warranty gives you specific rights. No other warranties, expressed or implied, including implications of warranties of merchantability and fitness for a particular product, are made. Hamilton Company's liability on the sale of all products shall be limited to repair, replacement or refund of price of any defective product.[2]

Hamilton Company endeavors to provide prompt and satisfactory service.

[1] *All Hamilton Company valves are warranted to be free of defects in material and workmanship at the time of delivery.*

[2] *Hamilton Company reserves the right to refuse to accept the return of any instrument or valve that has been used with radioactive, microbiological substances or any other material that may be deemed hazardous to employees of Hamilton Company.*

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Conventions Used in this Manual

Throughout this manual symbols are used to call your attention to various kinds of information.

Biohazard: Information that is related to interactions with biohazards.

Important! Information that is essential for avoiding damage to equipment.

Note: Interesting information that can help improve system performance.

CHAPTER 1: Getting Started

1.1 Introduction

The Precision Syringe Drive/4 Smooth Flow (PSD/4 SF) is a compact syringe pump designed to perform all liquid handling operations including dispensing, serial dispensing, and diluting, as well as applications that require smooth and consistent flow.

The precision manufactured body provides a rigid platform for system components resulting in a reduction of overall system hysteresis. This combined with a self-lubricating, wear compensating lead nut provide unsurpassed syringe plunger positioning. Each PSD/4 SF is provided with a National Institute of Standards and Technology (N.I.S.T.) traceable performance test report performed on that module, assuring outstanding accuracy, precision, and flow rate characteristics.

The module can be fitted with a choice of syringes and valves to meet even the most demanding applications.

Operating on 24VDC, the PSD/4 SF can be used either as a single syringe pump or connected in series to form a bank of up to sixteen modules. Control is available in an RS-232, RS-485 or Control Area Network (CAN) format.

The fluid contact surfaces of the PSD/4 SF are chemically inert materials, such as, PTFE, FEP, CTFE, ceramic and glass.

1.2 Safety Precautions

For proper handling and care of the PSD/4 SF it is essential that operating personnel follow the general safety procedures and safety instructions described in this manual.

1.2.1 Operating the PSD/4 Smooth Flow

When using the PSD/4 SF, Good Laboratory Practices (GLP) should be observed. Users should wear protective clothing, safety glasses and protective gloves, especially if working with radioactive, biohazardous or harsh chemicals.

During the operation of a PSD/4 SF instrument, stand clear of moving parts. Never try to remove valves, syringes or tubing when the PSD/4 SF syringe drive is moving. Never move the PSD/4 SF while it is in operation.

1.2.2 Electrical

The PSD/4 SF must be disconnected from the power source when removing any mechanical or electrical components.

Do not connect the unit to a power source of any other voltage or frequency beyond the range stated on the power rating.

Avoid damaging the power cord while operating the instrument. Do not bend excessively, step on or place heavy objects on the power cord. Any damaged power cord may easily become a shock or fire hazard. Never use a damaged power cord.

1.2.3 Radioactive, Biohazardous, or Harsh Chemicals

Biohazard: The PSD/4 SF does not provide any user protection against radioactivity, biohazardous or harsh chemicals.

When operating the PSD/4 SF wear the appropriate laboratory clothing. Operators must be trained to handle hazardous materials before working with the PSD/4 SF. If the PSD/4 SF becomes contaminated with radioactive, biohazardous or harsh chemicals, it should be cleaned immediately. Failure to observe and carry out the procedures may impair or damage the PSD/4 SF. Materials consumed or produced during use of this device should be disposed of in accordance with local, state and federal laws.

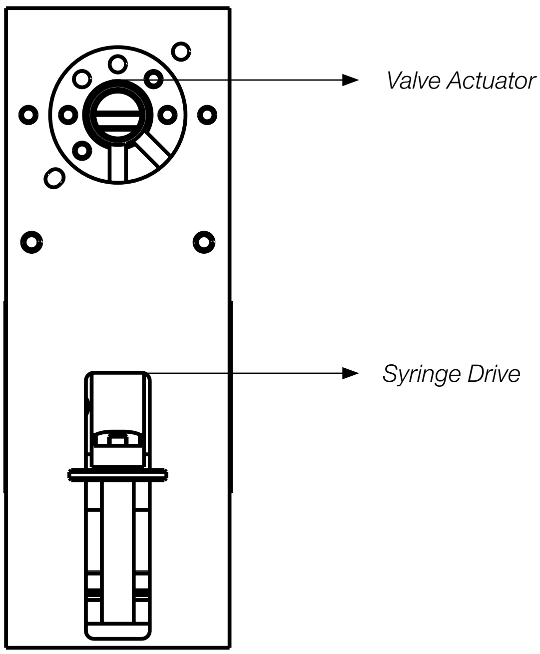
CHAPTER 2:
Hardware

2.1 Description of PSD/4 Smooth Flow Drive Unit Components

The drive unit contains a precision drive motor, a valve and syringe. This section will show a detailed diagram of the front and back of the PSD/4 SF and provide a description of the components required to operate the instrument.

2.1.1 Description of the Front View of the PSD/4 Smooth Flow

Figure 2-1 Front View of the PSD/4 Smooth Flow



Valve Actuator

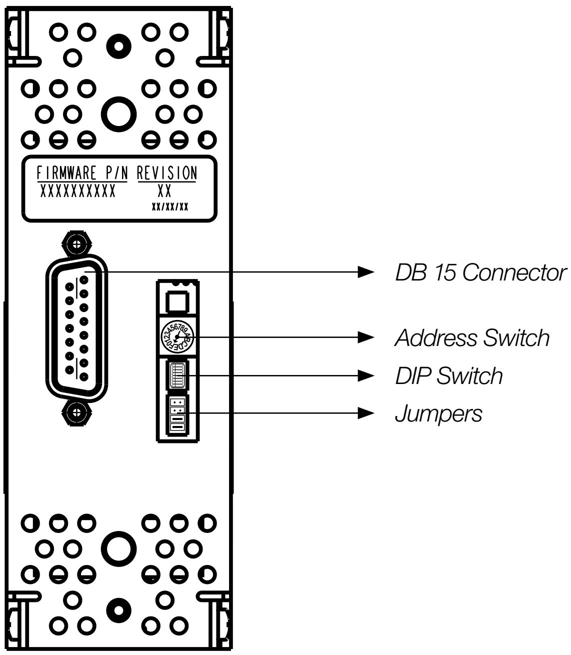
The valve actuator turns the valve at the appropriate time to fill and dispense solutions. A variety of valves can be mounted to the valve actuator. See Section 2.2 page 7.

Syringe Drive

The syringe drive mechanism positions Hamilton syringes with high-resolution stepper motors. The syringes are threaded into the valve and the plunger is attached to the syringe drive with a thumbscrew, see Section 2.3 page 9.

2.1.2 Description of the Rear View of the PSD/4 Smooth Flow

Figure 2-2 Rear View of the PSD/4 Smooth Flow



Note: For mounting hole locations and dimensions of the pump, see Appendix C page 69 for more details.

DB-15 Connector

The DB-15 connector is used for communication and power.

Address Switch

This is used when controlling multiple pumps so that each pump has a unique address.

DIP Switches

These switches are used to set the valve configuration and communication settings. For more details, see Appendix D page 71.

Jumpers

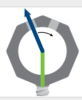
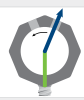
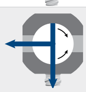
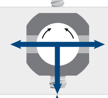
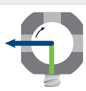
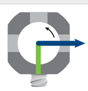
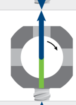
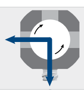
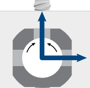
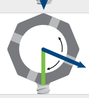
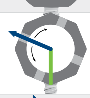
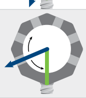
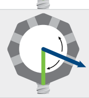
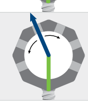
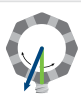
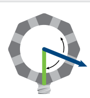
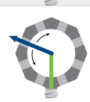
Jumpers are factory installed in the default position. The alternate position is used when updating the firmware; see Table 3-4 page 20 for more details.

2.2 Valve Selection and Installation

This section will describe the different valve configurations and material fluid paths available Instructions for mounting the valves onto the PSD/4 SF are also discussed in this section.

2.2.1 Selecting the Appropriate Valve

Table 2-1 PSD/4 Smooth Flow Valves

Valve Diagrams					
Input	**Output**	**Bypass/Extra**	**Valve Configuration**	**PTFE/CTFE**	**Ceramic**
			Y-block	9537-01	
			Y-valve	57252-01*	8778-01*
			3-3 “T” flow path, two ports plus syringe port	58889-01*	8063-01
			3-5 Distribution flow path, three ports plus syringe port		7991-01
			4-2, 90° flow path, three ports plus syringe port		9234-01
			4-5 Distribution flow path with four ports plus syringe port		7992-01**
			6-5 Distribution flow path with six ports plus syringe port		9998-01
			8-5 Distribution flow path with eight ports plus syringe port		7993-01** 59943-01

**This valve is not compatible with 12.5 mL syringe volume.*
***This valve is not compatible with syringe volumes of 2.5 to 12.5 mL..*

Note: The syringe port is on the bottom vertical port on the diagrams above.

Note: The valve ports have ¼-28 UNF threaded connections.

2.2.2 Installation of the Valve onto the PSD/4 Smooth Flow Pump

To install the valve:

Step 1. Insert valve shaft into the valve actuator and rotate the valve until the valve stem engages with the valve drive on the PSD/4 SF. See Figure 2-3A.

Step 2. Continue to rotate valve until the alignment pins slip into the front of the instrument. The syringe port should point down toward the syringe drive mechanism. When the alignment pins engage, press the valve firmly against the PSD/4 SF. See Figure 2-3B.

Step 3. Tighten the mounting screws on the valves no greater than 40 in-oz. See Figure 2-3C.

Figure 2-3 Valve Installation

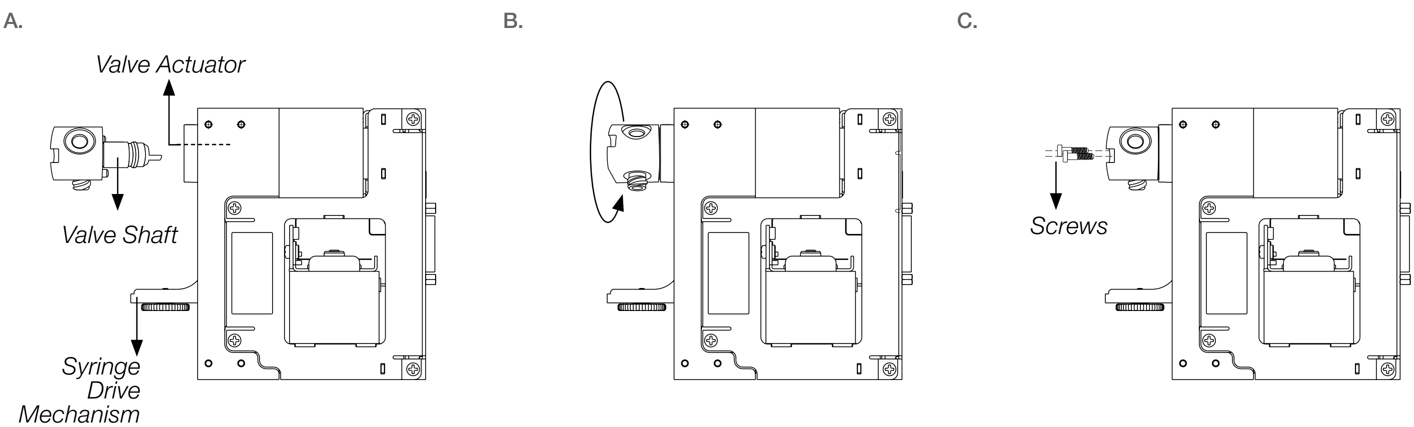


Table 2-2 Valve DIP Switch Settings

	Switch Circuits		
Switch Position Description	**4**	**5**	**6**
3-Port Y Valve	OFF	OFF	OFF
T-Port Valve	ON	OFF	OFF
3-Port Distribution Valve	OFF	ON	OFF
4-Port Distribution Valve 4-Port Wash Valve	OFF	OFF	ON
6-Port Distribution Valve	OFF	ON	ON
8-Port Distribution Valve	ON	ON	OFF

Note: Additional details on the DIP Switches can be found in Appendix D page 71.

2.3 Syringe Selection and Installation

In this section the user will learn how to properly prepare and install the syringes onto the PSD/4 SF. Before the syringes are installed on the PSD/4 SF a syringe must be selected. Use Table 2-3 to select the best syringe for the application.

2.3.1 Selecting the Appropriate Syringe

Table 2-3 Syringe Part Numbers for use with the PSD/4 Smooth Flow

Volume	PTFE-tipped Syringes	UHMWPE-tipped Syringes
12.5 µL	5495-10	
25 µL	5495-15	8250-15
50 µL	5495-20	8250-20
100 µL	5495-22	8250-22
125 µL	5495-25	8250-25
250 µL	5495-30	8250-30
500 µL	5495-35	8250-35
1.0 mL	5495-38	8250-37
1.25 mL	5495-40	8250-40
2.5 mL	5495-45**	8250-45**
5.0 mL	5495-50**	8250-50**
12.5 mL	5495-55*	

**Not compatible with 57252-01, 58889-01, 8778-01, 7992-01 and 7993-01.*
***Not compatible with 7992-01 and 7993-01. Use valve 59943-01 as a substitute for 7993-01.*

Table 2-4 PSD/4 Smooth Flow Accuracy and Precision

	Accuracy and Precision Specifications		
Syringe Size (µL)	Percent Stroke	Accurary (±%)	Precision (%)
12.5	5% ≤ Stroke < 30%	3.00	2.00
	Stroke ≥ 30%	2.00	0.20
25	5% ≤ Stroke < 30%	3.00	2.00
	Stroke = 30%	1.50	0.20
	Stroke = 100%	1.00	0.20
50	5% ≤ Stroke < 30%	2.00	1.00
	Stroke = 30%	1.00	0.20
	Stroke = 100%	1.00	0.10
100/125	5% ≤ Stroke < 30%	2.00	1.00
	Stroke = 30%	1.00	0.20
	Stroke = 100%	1.00	0.10
250	5% ≤ Stroke < 30%	1.50	0.50
	Stroke = 30%	1.00	0.20
	Stroke = 100%	1.00	0.05
500	1% ≤ Stroke < 5%	3.00	1.50
	5% ≤ Stroke < 30%	1.50	0.50
	Stroke = 30%	1.00	0.20
	Stroke = 100%	1.00	0.05
1,000 and larger	1% ≤ Stroke < 5%	3.00	1.50
	5% ≤ Stroke < 30%	1.20	0.50
	Stroke = 30%	1.00	0.10
	Stroke = 100%	1.00	0.05

Note: This accuracy and precision table was developed using deionized water at 22 °C.

Table 2-5 PSD/4 Smooth Flow Flow Accurary and Precision

Flow Rate Range	Flow Accurary (±%)	Flow Precision (%)
26 nL/minute to 53 mL/minute	5%	≤ 5%

Note: Verified with deionized water at a flow rate range of 2.1 to 50 µL/minute. 12.5 mL syringe was tested with 35 psi back pressure. The rest of syringes were tested with 45 psi back pressure. Sensirion SLI-0430 flow meter was used at a sampling rate of 3 ms. All sampling times were 4 minutes minimum once flow stabilized.

2.3.2 Preparing the Syringe for Installation

Before inserting the plunger into the syringe barrel the plunger tip will need to be conditioned. To condition the plunger tip, first wet the tip and insert into the glass barrel, stroke the syringe ten times while applying steady and even pressure; avoid twisting movements.

☆ **Important!** To condition the tip and barrel, wet the plunger tip with deionized water or a solvent. Do NOT use viscous oils to lubricate plunger tips.

2.3.3 Installation of the Syringe onto the PSD/4 Smooth Flow Pump

Step 1. Position syringe plunger to the center of the stroke (see Figure 2-4).

Step 2. Insert the luer end of the syringe into the valve and rotate until finger-tight.

Step 3. Pull the plunger down until it reaches the syringe drive stem.

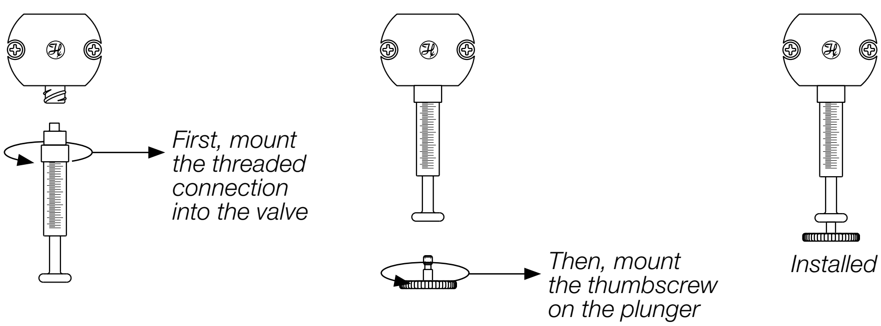
Step 4. Position the plunger so that the plunger button sets into the channel of the drive stem.

Step 5. Hold the plunger and tighten the thumbscrew into the plunger.

Step 6. Initialize the PSD/4 SF.

Step 7. Re-tighten the syringe into the valve.

Figure 2-4 Syringe Installation



There may be a need to relocate the thumbscrew on the syringe depending on the syringe/valve combination being used.

To Remove:

1. Pry the E-clip away from the thumbscrew shaft.
2. Remove E-clip and thumbscrew.

To Install:

1. Drop E-clip into drive stem position.
2. Insert thumbscrew into position.
3. Apply a lateral pressure on the thumbscrew against the open face of the E-clip until the E-clip engages.

Note: The syringe is required to be installed parallel to the face of the PSD/4 SF or damage will result to the syringe and/or valve.

Figure 2-5 Syringe Drive Thumbscrew Location

2.4 Tubing Selection and Installation

In this section the user will learn how to properly install the tubing onto the PSD/4 SF Pump. Hamilton Valves are designed to use ¼-28 flat bottom fittings. The valves are compatible with flanged and flange free fittings. Fittings should be installed finger tight (approximately 8 – 10 in-oz torque). Over tightening of fittings will cause damage to the valve. Table 2-6 contains general guidelines, but contact your Hamilton representative for more detailed guidance.

2.4.1 Selecting the Appropriate Tubing Size

Hamilton's general recommendation is use 12 gauge PTFE tubing for syringes with nominal volumes that exceed 2.5 mL and 18 gauge PTFE tubing for volumes of 2.5 mL or less, see Table 2-6. The tubing is generally sized for relatively quick fills and dispenses. Since the typical smooth flow application will be at slow speeds it is possible to use smaller tubing gauges with large syringes. For the dispense tubing it may also be desirable to consider PEEK tubing with a small internal diameter. The smoothest flow is achieved when the system is under some backpressure. Contact you Hamilton representative to discuss your application prior to finalizing tubing selection.

Fill Tubing

Provides the liquid path from a reservoir of reagent or diluent to the left side of the valve. Tubing is blunt cut.

Dispense Tubing

Provides a liquid path to pick-up samples and reagents from reservoirs and tubes. It also serves as the dispense path for all reagents and samples. Tubing is tapered at the tip to improve transfer efficiency.

Table 2-6 Tubing Selection Guide

Syringe Size	Tubing Size	Part Number	Description
12.5 µL 25 µL 50 µL 100 µL 125 µL 250 µL 500 µL 1.0 mL 1.25 mL 2.5 mL	18 gauge	Fill Tubing 88939 Dispense Tubing 88938	18 gauge, 762 mm length, ¼"-28 fitting fill tubing 18 gauge, 762 mm length, ¼"-28 fitting dispense tubing
5.0 mL 12.5 mL	12 gauge	Fill Tubing 88942 Dispense Tubing 88941	12 gauge, 762 mm length, ¼"-28 fitting fill tubing 12 gauge, 762 mm length, ¼"-28 fitting dispense tubing

2.4.2 Installation of the Tubing onto the PSD/4 Smooth Flow Pump

Figure 2-6 Installation of Tubing

Step 1. Thread the hub of the fill tubing into the left side of the valve and finger-tighten.

Step 2. Thread the hub of the dispense tubing into the right side of the valve and finger-tighten.

> **Note:** Do not use tools to tighten a tube fitting on a valve, as this will result in distortion of the valve seat, which could result in premature valve leakage; finger-tighten only.

> **Note:** Do not use molded fittings or machined fittings of different dimensions, as this could cause an improper sealing of the fitting to the valve and distortion of the valve seat, resulting in premature valve leakage. Metal fittings will also damage seals.

2.5 Powering the PSD/4 Smooth Flow

The PSD/4 SF requires a 24 VDC power supply with a current rating of at least 1.5 amp, which is provided through the DB-15 connector. It is not recommended to daisy chain power to more than two PSD/4 SF pumps.

CHAPTER 3:
Cabling and Switches

3.1 Overview

This chapter will discuss the RS-232, RS-485 and CAN communication interfaces including discussions on the cabling, DIP Switch settings and address settings.

3.2 RS-232/485 Communication

The following describes how the pump is connected for operation using and RS-232 or RS-485 communication, such as a PC serial port. Figure 3-1 shows the cabling for RS-232 and Figure 3-2 (page 18) shows cabling for RS-485 communication.

The first pump is connected to an RS-232 port, see Table 3-1.

Table 3-1 RS-232 Computer to Pump #1 Cable

PC Serial Port Connector		Pump #1 Connector	
Function	**DB-9**	**Function**	**DB-15**
RXD	2	TXD	2
TXD	3	RXD	3
CTS[1]	8	RTS[1]	4
GND	5	GND	10

[1] *This connection is only required if the host system makes use of the CTS line.*

3.2.1 Communication Cabling

- Successive PSD/4 SF pumps are connected through pins 11 (RS-485 A) and 12 (RS-485 B) of the DB-15 connectors.
- Power is supplied to pins 1 (24 VDC) and 9 (GND) of the DB-15 connectors.
  No more than two devices should be connected in parallel to the same power line.
- The Address Switch is set such that the first PSD/4 SF is set to “0,” second to “1,” and so forth.
- Up to sixteen devices can be addressed from one controller port.
- The communication termination switches must be set on both the first and last units. The middle units are left open. External resistors can be used instead of the communication switches on the last device in an RS-485 chain. If the resistors are used, the termination switches are not required.

Figure 3-1 RS-232 Communication Cabling

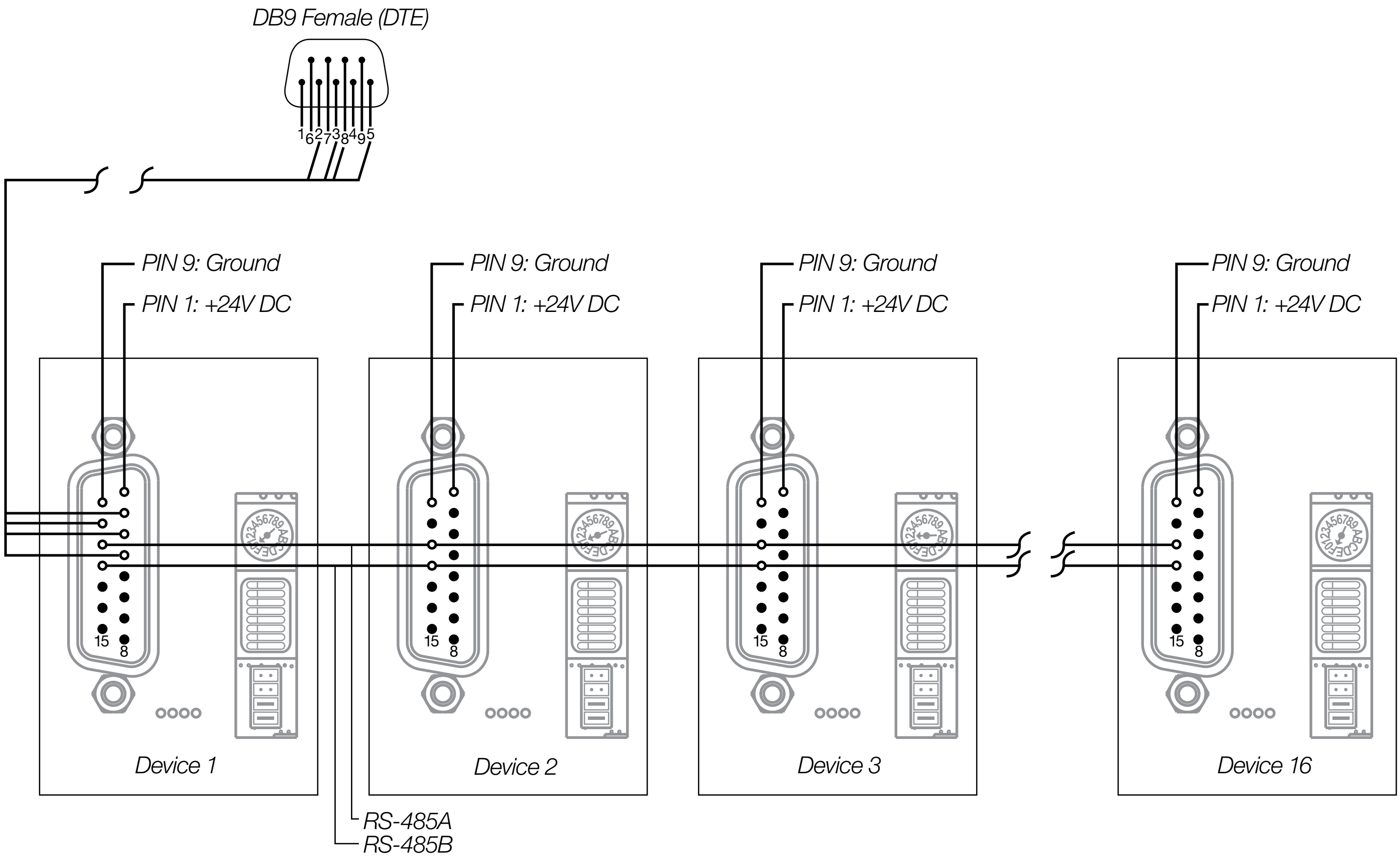


Figure 3-2 RS-485 Communication Cabling

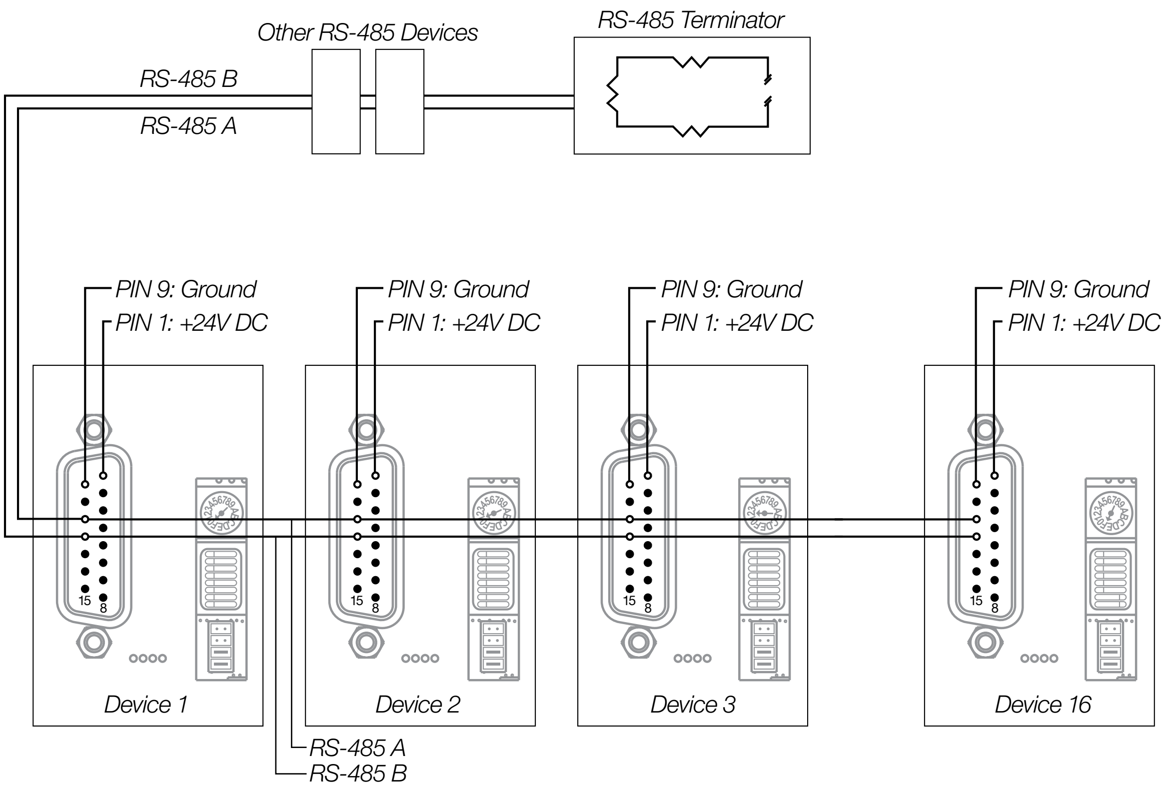


Table 3-2 DIP Switch Settings for RS-485 Communications

Switch Position Description	Details	Default	Switch Cuircuit 1	2	3	4	5	6	7	8
RS-485 Communication Termination	Single unit, first or last in chain	X	–	–	–	–	–	–	ON[2]	ON[3]
	Non-end unit in chain		–	–	–	–	–	–	OFF	OFF

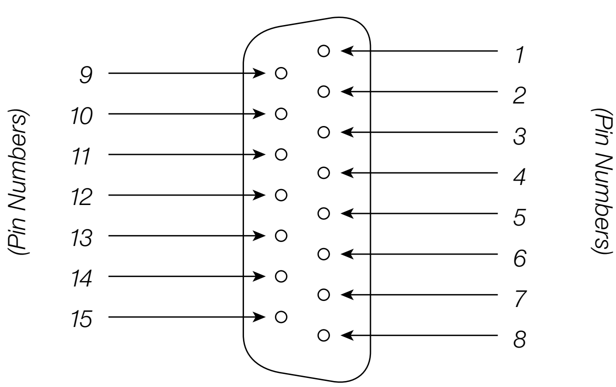
[1] A dash "-," represents a switch circuit that has no effect on the associated configuration.
[2] RS-485 A
[3] RS-485 B

3.2.2 DB-15 Connector Pins

Table 3-3 DB-15 Connector Pin Assignments

Pin	Function	Remark
1	24 VDC	
2	RS-232 TxD line	Output data
3	RS-232 RxD line	Input data
4	RS-232 RTS line	Line is high with power on
5	CAN high signal line	
6	CAN low signal line	
7	Auxiliary Input #1	Digital level
8	Auxiliary Input #2	Digital level
9	Ground	Power and logic
10	Ground	Power and logic
11	RS-485 A line	
12	RS-485 B line	
13	Auxiliary Output #1	Digital level
14	Auxiliary Output #2	Digital level
15	Auxiliary Output #3	Digital level

Figure 3-3 DB-15 Connector Pins



3.2.3 Setting Jumpers

Table 3-4 Jumper Configuration

Description	Settings
Normal Operation	5-6, 7-8
Updating Firmware	1-2, 3-4

Contact Hamilton to update the firmware.

3.2.4 Address Switch

A sixteen position rotary switch is provided for setting the address position of each module for RS-232, RS-485, or CAN communication.

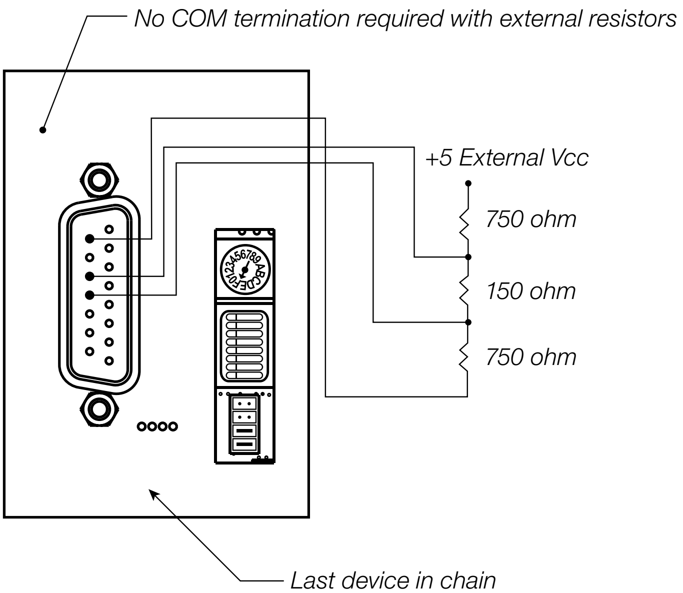
Table 3-5 Address Switch Settings for RS-232 or RS-485 Communication

	Address	
Default	Hex	ASCII
0	31	1
1	32	2
2	33	3
3	34	4
4	35	5
5	36	6
6	37	7
7	38	8
8	39	9
9	3A	:
A	3B	;
B	3C	<
C	3D	=
D	3E	>
E	3F	?
F	40	@

3.2.5 RS-485 Communication Termination with External Resistors

External resistors can be used, see Figure 3-4, instead of the communication switches on the last device in an RS-485 chain. If the resistors are used, the termination switches are not required.

Figure 3-4 RS-485 Termination with External Resistors



Note: Ground of external 5 V must be connected with 24 VDC ground.

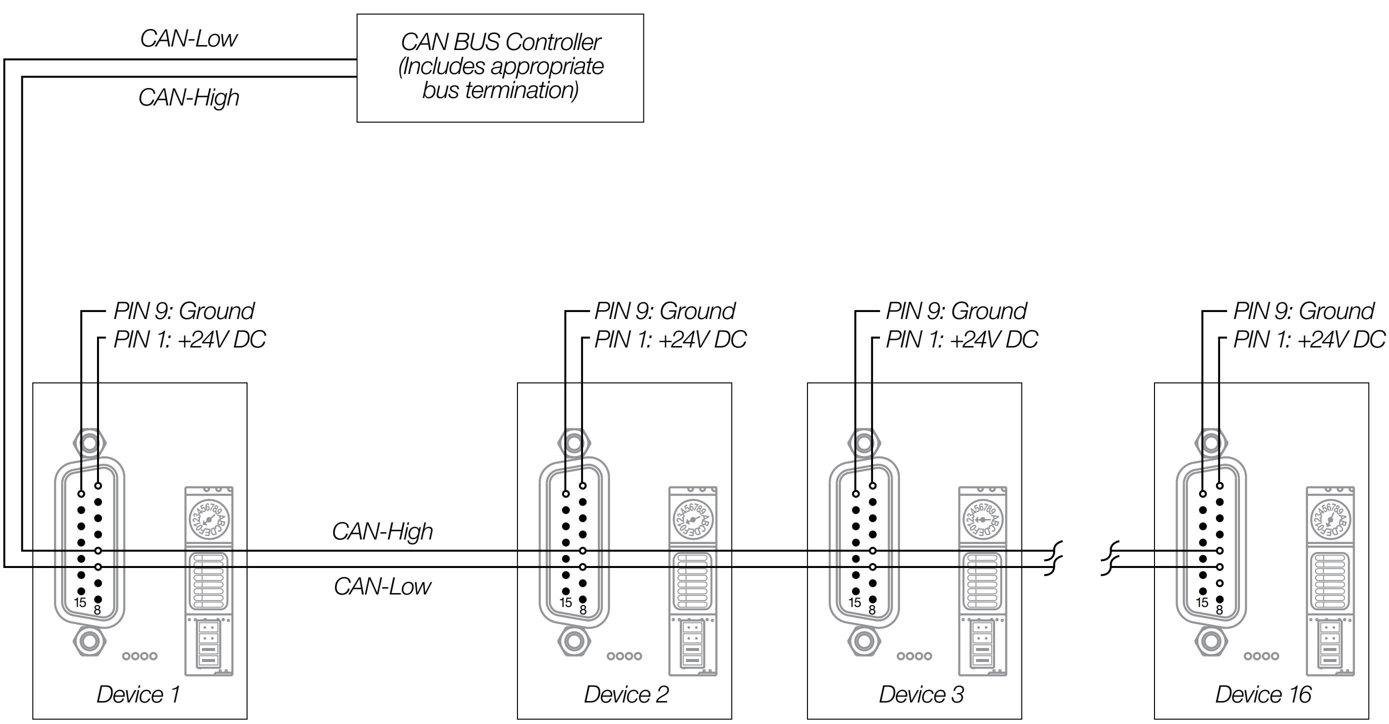
3.3 CAN Communication

The following describes how the pump is connected when operating from a Controller Area Network (CAN) controller, see Figure 3-5.

3.3.1 Communication Cabling

- PSD/4 SF pumps are connected through pins 5 (CAN high) and 6 (CAN low) of the DB-15 connectors to the CAN controller and/or other devices in the chain.
- Power is supplied to pins 1 (24 VDC) and 9 (GND) of the DB-15 connectors. No more than two devices should be connected in series to the same power line.
- The Address Switch is set such that the first PSD/4 SF is set to “0,” second to “1”, and so forth.
- Up to sixteen devices can be addressed from one controller port.
- The communication termination switches are not needed for CAN hook-up.
- CAN termination is not provided by the PSD/4 SF.

Figure 3-5 CAN Connections



3.3.2 Address Switch

Table 3-6 Address Switch Settings for RS-232 or RS-485 Communication

	PSD/4 Smooth Flow CAN Address		
PSD/4 Smooth Flow Address Switch Settings	**Binary**	**Hex**	**ASCII**
0	0000	31	1
1	0001	32	2
2	0010	33	3
3	0011	34	4
4	0100	35	5
5	0101	36	6
6	0110	37	7
7	0111	38	8
8	1000	39	9
9	1001	3A	:
A	1010	3B	;
B	1011	3C	<
C	1100	3D	=
D	1101	3E	>
E	1110	3F	?
F	1111	40	@

Note: CAN communication does not support broadcast command strings.

CHAPTER 4:

Communication Protocols

4.1 Overview

The PSD/4 SF supports three different protocols for communicating between the syringe pump and a controlling device. Terminal Protocol and Standard Protocol can both be used with an RS-232 or RS-485 physical layer. The third protocol is used for controlling the pump on a Control Area Network or CAN bus.

Terminal Protocol – is ideal for prototyping and qualification testing as it is easy to send commands from a simple Serial Terminal Emulator program. While Terminal Protocol is ideal for simple benchtop testing, it lacks mechanisms for ensuring that data integrity is not lost between the pump and the controller. For most applications this protocol is not robust enough for integration into production units.

Standard Protocol – uses checksums and sequence numbers to ensure that no data is lost and provides mechanisms for retransmitting lost or corrupt data. Standard Protocol is the preferred method for communicating with the PSD/4 SF via RS-232/485.

CAN Protocol – offers the same data integrity features as the Standard Protocol with the added benefit that polling sequences are eliminated. The pumps will asynchronously report back to the control device upon completion of the current task. This protocol communicates via a CAN bus.

4.2 Terminal Protocol (RS-232/485)

Terminal Protocol commands sent from a controlling device to a PSD/4 SF must begin with a '/' followed by the instrument's address and end with a carriage return <CR>. Instruments will only respond to commands that contain their unique address. If it is desirable to send a single command to multiple instruments there are a series of broadcast addresses listed in Table 4-2. These broadcast addresses will be acted upon by the appropriate instruments in the chain, but no response string will be sent from the pump back to the controlling device. Terminal Protocol is most easily expressed in ASCII characters, which are displayed below. For conversion to Hex, Decimal, or Binary, check Appendix F page 75.

Table 4-1 Parameter Settings for RS-232/485 Communication with Terminal Protocol

Description	Settings
Baud rate	9,600 (DIP Switch 3 OFF) 38,400 (DIP Switch 3 ON)
Data bits	8
Parity	None
Stop bit	1
Handshaking	None

Commands Sent from the Controlling Device to the PSD/4 Smooth Flow:

/<Address><Data><CR>

- Beginning of Command
- Address of the pump(s) (See Section 4.2.1 page 27)
- Command String (See Section 4.3 page 30)
- End of Command

Responses from the PSD/4 Smooth Flow to the Controlling Device:

/0<Status Byte><Data><ETX><CR><LF>

- Beginning of Command
- Address of the control device
- Status Byte (See Table 4-3 page 28)
- Response String (This will be blank unless the command asked the pump for a response. See Section 4.3 page 30)
- Three characters at the End of the Response

4.2.1 Addressing the Pumps

Instruments will only respond to commands that start with their unique address. If it is desirable to send a single command to multiple instruments there are a series of broadcast addresses listed in Table 4-2. These broadcast addresses will be acted upon by the appropriate instruments in the chain but no response string will be sent from the pump back to the controlling device.

Table 4-2 Address Switch Settings

<table>
<tr><th rowspan="2">Address Switch</th><th colspan="2">1 PSD/4 Smooth Flow Address</th><th colspan="2">2 PSD/4 Smooth Flow Address</th><th colspan="2">4 PSD/4 Smooth Flow Address</th><th colspan="2">16 PSD/4 Smooth Flow Address</th></tr>
<tr><th>ASCII</th><th>Hex</th><th>ASCII</th><th>Hex</th><th>ASCII</th><th>Hex</th><th>ASCII</th><th>Hex</th></tr>
<tr><td>0</td><td>1</td><td>31</td><td rowspan="2">A</td><td rowspan="2">41</td><td rowspan="4">Q</td><td rowspan="4">51</td><td rowspan="16">_</td><td rowspan="16">5F</td></tr>
<tr><td>1</td><td>2</td><td>32</td></tr>
<tr><td>2</td><td>3</td><td>33</td><td rowspan="2">C</td><td rowspan="2">43</td></tr>
<tr><td>3</td><td>4</td><td>34</td></tr>
<tr><td>4</td><td>5</td><td>35</td><td rowspan="2">E</td><td rowspan="2">45</td><td rowspan="4">U</td><td rowspan="4">55</td></tr>
<tr><td>5</td><td>6</td><td>36</td></tr>
<tr><td>6</td><td>7</td><td>37</td><td rowspan="2">G</td><td rowspan="2">47</td></tr>
<tr><td>7</td><td>8</td><td>38</td></tr>
<tr><td>8</td><td>9</td><td>39</td><td rowspan="2">I</td><td rowspan="2">49</td><td rowspan="4">Y</td><td rowspan="4">59</td></tr>
<tr><td>9</td><td>:</td><td>3A</td></tr>
<tr><td>A</td><td>;</td><td>3B</td><td rowspan="2">K</td><td rowspan="2">4B</td></tr>
<tr><td>B</td><td><</td><td>3C</td></tr>
<tr><td>C</td><td>=</td><td>3D</td><td rowspan="2">M</td><td rowspan="2">4D</td><td rowspan="4">]</td><td rowspan="4">5D</td></tr>
<tr><td>D</td><td>></td><td>3E</td></tr>
<tr><td>E</td><td>?</td><td>3F</td><td rowspan="2">O</td><td rowspan="2">4F</td></tr>
<tr><td>F</td><td>@</td><td>40</td></tr>
</table>

4.2.2 Status Byte

The status byte is used in PSD/4 SF responses from the pump to tell the control device if the pump was ready to receive a new command and if an error has occurred in the execution of that command. The table below shows all the possible status bytes which are constructed from the bits as follows:

Bit 7	**Always 0**
Bit 6	**Always 1**
Bit 5	**1 if ready, 0 if busy**
Bit 4	**Always 0**
Bits 3-0	**Error Status**

Table 4-3 Definition of Status Bytes

Status Bytes	ASCII		Decimal	
76543210	Bit 5 = 0*	Bit 5 = 1**	Error Code	Error Description
01X00000	@	‘	0	No error
01X00001	A	a	1	Initialization error – occurs when the pump fails to initialize.
01X00010	B	b	2	Invalid command – occurs when an unrecognized command is used.
01X00011	C	c	3	Invalid operand – occurs when and invalid parameter is given with a command.
01X00100	D	d	4	Invalid command sequence – occurs when the command communication protocol is incorrect.
01X00110	F	f	6	EEPROM failure – occurs when the EEPROM is faulty.
01X00111	G	g	7	Syringe not initialized – occurs when the syringe fails to initialize.
01X01001	I	i	9	Syringe overload – occurs when the syringe encounters excessive back pressure.
01X01010	J	j	10	Valve overload – occurs when the valve drive encounters excessive back pressure.
01X01011	K	k	11	Syringe move not allowed – when the valve is in the bypass or throughput position, syringe move commands are not allowed.
01X01111	O	o	15	Pump is busy – occurs when the command buffer is full.

** Indicates that the pump is busy and will only accept Query and Asynchronous commands.*
*** Indicates the pump is ready to receive new command.*

4.2.3 General Program Flow

When creating a program to control the PSD/4 SF Hamilton recommends the commands are sent according to the following flow:

1. **Initialize the pump(s) to be controlled (once at the beginning when the pumps are first turned on).**
2. **Send the first command to each pump or to multiple pumps via the broadcast addresses.**
3. **Process response from the pump. If a broadcast address is used there will be no response.**
4. **Poll each pump individually with a 100 ms delay using the ‘Q’ command to make sure each pump completes the task with no errors before the next command is sent. While the pump is busy with the current task it will only respond to Query and Asynchronous commands.**
5. **Send the second command and monitor with the Q command.**
6. **Repeat the process of sending and polling for all remaining commands.**

Examples:

Example 1: The control device sends a command to the first pump on the bus and it is successfully received by the pump and executed.

Command Sent:	/1ZR<CR>
Response Received:	/0‘<ETX><CR><LF>

Example 2: The controlling device sends the Q command to the first pump to see if it has completed the previous command and is now ready for the next command.

Command Sent:	/1Q<CR>
Response Received if Busy:	/0@<ETX><CR><LF>
Response Received if Ready:	/0‘<ETX><CR><LF>

Example 3: The controlling device broadcasts an absolute move command to all pumps on the bus.

Command Sent:	/_A3000R<CR>
Response Received:	No response is sent to broadcasted commands

4.3 Standard Protocol (RS-232/485)

Standard Protocol commands sent from a controlling device to PSD/4 SF Instruments will only respond to commands that start with their unique address. If it is desirable to send a single command to multiple instruments there are a series of broadcast addresses listed in Section 4.2.1. These broadcast addresses will be acted upon by the appropriate instruments in the chain but no response string will be sent from the pump back to the controlling device. Standard Protocol is most easily expressed in ASCII characters which are displayed below. For conversion to Hex, Decimal, or Binary check Appendix F page 75.

Table 4-4 Settings for RS-232/485 Communication with Standard Protocol.

Parameter	Settings
Baud rate	9,600 or 38,400
Data bits	8
Parity	None
Stop bit	1
Handshaking	None

Note: The Baud rate is set by the DIP Switches. See Appendix D page 71 for more details.

Example 1

Commands sent from the controlling device to the PSD/4 SF:

<STX><Address><Sequence><Data><ETX><Checksum>

- Beginning of Command
- Address of the pump(s) (See Section 4.2.1 page 27)
- Sequence Data (See Table 4-5)
- Command String (See Section 4.2.1 page 27)
- End of Command
- Checksum (See Table 4-6 page 32)

Responses from the PSD/4 SF to the controlling device:

<STX>0<Status Byte><Data><ETX><Checksum>

- Beginning of Command
- Address of the control device
- Status Byte (See Table 4-3 page 28)
- Response String (This will be blank unless the command asked the pump for a response. See Section 4.2.1 page 27)
- End of Response
- Checksum (See Table 4-6 page 32)

4.3.1 Sequence Data

The Sequence Data is used to ensure that a command is not skipped or the same command is not executed twice due to a communication error. During normal operation the repeat bit is set to 0 and the sequence number noted by the pump. When the repeat bit is set to 1 this indicates that this command had been sent previously. When the pump sees the command is a repeat, it checks the current sequence number with the last command that was received. If the command was already received the pump acknowledges the command but does not execute it. If the sequence number does not match the pump will acknowledge the command and execute it.

The current command is compared to the last executed command so it is not necessary for the control device to increment through all 7 sequence numbers. It is just critical that two consecutive commands do not have the same sequence number.

Bit 7	**Always set to 0**
Bit 6	**Always set to 0**
Bit 5	**Always set to 1**
Bit 4	**Always set to 1**
Bit 3	**Repeat Bit**
Bits 2 - 0	**Sequence Number**

Table 4-5 ASCII Commands for all Possible Combinations of Sequence Number and Repeat Bit

	Sequence Bits	ASCII	
Sequence Number	**76543210**	**Bit 3 = 0**	**Bit 3 = 1**
1	0011X001	1	9
2	0011X010	2	:
3	0011X011	3	;
4	0011X100	4	<
5	0011X101	5	=
6	0011X110	6	>
7	0011X111	7	?

4.3.2 Checksum Calculation

The Checksum for a Data Block consists of the bitwise exclusive OR (XOR) of the bytes in the Data Block from the STX to the ETX, inclusive. A Data Block received with a Checksum that matches the computed Checksum is considered to be received successfully. A Data Block received with an invalid Checksum is ignored.

Table 4-6 Example of a Checksum Calculation for the Command

			Binary							
	ASCII	**Hex**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	<STX>	02	0	0	0	0	0	0	1	0
Address	1	31	0	0	1	1	0	0	0	1
Sequence	1	31	0	0	1	1	0	0	0	1
Example Data Block	Z	5A	0	1	0	1	1	0	1	0
	R	52	0	1	0	1	0	0	1	0
	<ETX>	03	0	0	0	0	0	0	1	1
Checksum	**<HT>**	**09**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**

Note: To calculate a Checksum add up all the values in the Bit 0 column. If the total is odd then the value for that bit is 1 if the total is even then the value is 0. Repeat this process for the seven remaining bits.

4.3.3 General Program Flow

When creating a program to control the PSD/4 SF Hamilton recommends the commands are sent according to the following flow:

1. **Initialize the pump(s) to be controlled (once at the beginning when the pumps are first turned on).**
2. **Send the first command to each pump or to multiple pumps via the broadcast addresses.**
3. **Process response from the pump. If a broadcast address is used there will be no response.**
4. **Poll each pump individually with a 100 ms delay using the Q command to make sure each pump completes the task with no errors before the next command is sent. While the pump is busy with the current task it will only respond to Query and asynchronous commands.**
5. **Send the second command and monitor with the Q command.**
6. **Repeat the process of sending and polling for all remaining commands.**

Examples

Example 1: The control device sends a command to the first pump on the bus and it is successfully received by the pump and executed.

Command Sent:	<STX>11ZR<ETX><HT>
Response Received:	<STX>0 @ <ETX>q

Example 2: The controlling device sends an absolute move command but the pump does not receive it because the Checksum indicated the data was corrupt. The control device reissues the command with the repeat bit set to 1 after timing out on the transaction. The pump receives this command and checks it against the previous command that was received. The pump sees the command is unique and responds and executes accordingly.

Command Sent:	<STX>11A300R<ETX>!
Repeat of Command Sent:	<STX>19A300R<ETX>)
Response Received:	<STX>0 @ <ETX>q

4.4 CAN Protocol

Controller Area Network or CAN bus was developed by Bosch for the automotive industry. Since then it has become a popular standard for industrial automation and medical equipment. CAN protocol eliminates the need for polling to verify when a task is completed. With CAN the pumps are able to asynchronously respond to the control device once the task has been completed.

With CAN the data is sent via a standard length frame like the one below. This manual will only discuss the highlighted PSD/4 SF specific aspects of communication using the CAN 2.0 standard.

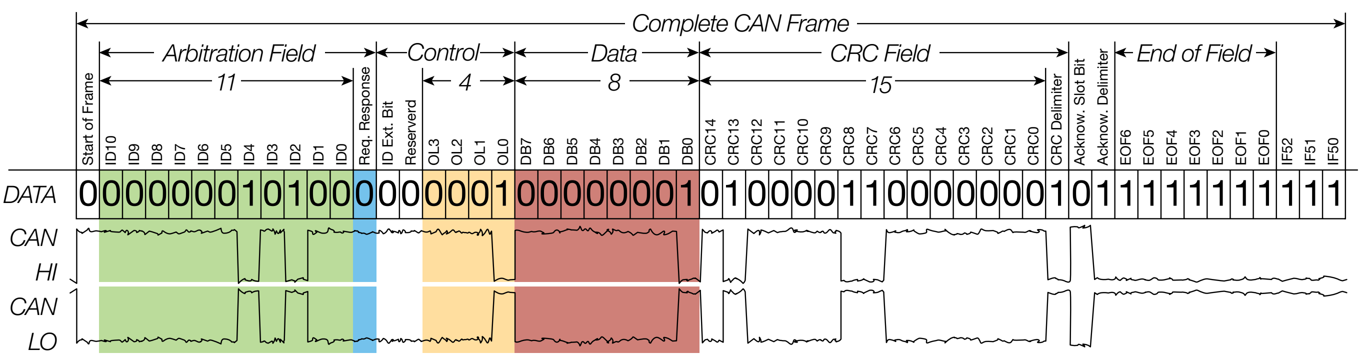


Table 4-7 CAN Parameter Settings

Parameter	Setting
Baud rate	100,000 (DIP Switch 3 OFF)
	125,000 (DIP Switch 3 ON)

Frame ID

The Frame ID is 11 bits of information that communicate the direction of the frame the address of the device and the type of frame being sent. The Frame ID field is broken up according to the figure below.

Table 4-8 Frame ID Bits

	Frame ID Bits										
	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Description	**Direction**		**Group**			**Address**				**Type**	
Frames from master to slave	0										
Frames from slave to master	1										
Boot requests use group 1		0	0	1							
All communication uses group 2		0	1	0							
Address Switch 0					0	0	0	0			
Address Switch 1					0	0	0	1			
Address Switch 2					0	0	1	0			
Address Switch 3					0	0	1	1			
Address Switch 4					0	1	0	0			
Address Switch 5					0	1	0	1			
Address Switch 6					0	1	1	0			
Address Switch 7					0	1	1	1			
Address Switch 8					1	0	0	0			
Address Switch 9					1	0	0	1			
Address Switch A					1	0	1	0			
Address Switch B					1	0	1	1			
Address Switch C					1	1	0	0			
Address Switch D					1	1	0	1			
Address Switch E					1	1	1	0			
Address Switch F					1	1	1	1			
On-the-fly commands (Type 0)									0	0	0
Action Commands (Type 1)									0	0	1
Common commands (Type 2)									0	1	0
Multi-frame start (Type 3)									0	1	1
Multi-frame data (Type 4)									1	0	0
Report answer commands (Type 6)									1	1	0

Note: Broadcasting of commands is not supported by this implementation of CAN protocol.

Frame Types

The frame type indicates what kind of command is being sent to enable faster processing of the command. The PSD/4 SF supports the following types:

Table 4-9 Frame Types

<table>
<tr><th>Type</th><th>Commands</th><th>Details</th></tr>
<tr><td>0</td><td>On-the-fly commands</td><td>This type is used for asynchronous Action Commands that can be executed while the pump is currently busy executing another action command. This includes speed change and termination commands.</td></tr>
<tr><td>1</td><td>Action or end of multi-frame commands</td><td>This type is used with commands that ask the pump to perform a task like initialization, syringe or valve move, or parameter changes. This type also indicates the last data in a multi-frame message indicates that the CAN Frame is the end of a PSD/4 SF CAN Data Block that contains Action Commands.</td></tr>
<tr><td>2</td><td>Common commands</td><td>This type is used for boot requests from the pump to the control device and for the following commands one byte commands from the control device to the pump:
<table>
<tr><th>ASCII</th><th>Description</th></tr>
<tr><td>0</td><td>Reset PSD/4 SF.</td></tr>
<tr><td>1</td><td>Execute command buffer.</td></tr>
<tr><td>2</td><td>Clear command buffer.</td></tr>
<tr><td>3</td><td>Execute command buffer from beginning, same as “X” command.</td></tr>
<tr><td>4</td><td>Terminate execution, same as “T” command.</td></tr>
</table></td></tr>
<tr><td>3</td><td>Multi-frame start data</td><td>In CAN protocol if a block of data exceeds 8 bytes it must be sent in multiple frames. This frame type tells the receiving device to expect additional frames in this message.</td></tr>
<tr><td>4</td><td>Multi-frame middle data</td><td>When sending a command that exceeds 16 bytes this type is used for all data between the first frame (type 3) and the last frame (type 1).</td></tr>
<tr><td>6</td><td>Report/answer commands</td><td>This type is used with Query Commands. See Section 5.8 page 56 for details on the available commands.</td></tr>
</table>

Remote Transmission Request Bit (RTR)

This is a standard CAN bit and is always set to 0 when communicating with the PSD/4 SF.

Data Length

In CAN communication the Data Block can be between 0 and 8 bytes in length. If the command is longer than 8 bytes, it must be sent in more than one CAN frame. Within a single CAN frame the Data Length field indicates how many bytes to expect in the data field.

Table 4-10 Data Length

Number of Bytes	Data Length (Binary)			
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0

Data Field

The data field contains the command string to the pump or the response string from the pump. The possible commands and responses are detailed in Chapters 5 and 6 of this manual.

When the pump responds the first byte in the data field will be the Status Byte as defined in Section 4.3. The second byte is the <NUL> character. Then the remaining 6 bytes are for any response data. If the response data exceeds 6 bytes the information is sent in a multi-frame message.

4.4.1 General Program Flow

When creating a program to control the PSD/4 SF Hamilton recommends the commands are sent according to the following flow:

1. When a pump is first turned on it will send a boot request every 100 ms to let the control device know it exists.
2. The control device must respond to this boot request before attempting to communicate with the pump.
3. After responding to the boot request the pump(s) can be initialized (must be initialized once before any movement commands will be accepted by the pump).
4. Send the first CAN frame to the pump and follow with additional frames if this is a multi-frame message.
5. Once the end of the message is received by the pump it will respond with a frame containing no data to acknowledge the command has been received.
6. The pump will execute the command and upon completion will send another response to the pump that contains the Status Byte, see Table 4-3 page 28, a <NUL> character, and then any additional information if relevant.
7. The control device must wait for the pumps completion response before sending the next command. The pump will only process one command of a given type at the same time. Alternatively, commands of different frame types like query and Action Commands will be processed at the same time.

Examples:

Example 1: A pump at address 1 has just been powered up and is now sending the Boot Request every 100 ms. The Control device sees this request and sends the appropriate response which is the pumps group and address repeated twice, see below. Next a pump at address 2 is powered up and begins sending Boot Requests. The control device sees this and responds accordingly.

CAN Frame Data

	Frame ID											RTR	Length				Data
Description	**Direction**	**Group**			**Address**				**Type**								**Hex**
Boot Request Address 0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	
Host Response	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	20 20*
Boot Request Address 2	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	
Host Response	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	22 22*

*The boot response from the pump is the instruments group and the address constructed as follows:

Bit 7	**Always set to 0**
Bit 6-4	**Instrument Group**
Bit 3-0	**Instrument Address**

Example 2: The control device sends a command (ZR) to the first pump on the bus. The pump receives the command and acknowledges and executes the command. When execution is complete the pump notifies the control device by sending the Status Byte followed by the <NUL> character.

CAN Frame Data

	Frame ID											RTR	Length				Data
Description	**Direction**	**Group**			**Address**				**Type**								**Hex**
Address = 0 Action command type = 1 Message length = 2 Data = ZR	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	5A 52
Pump acknowledges	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	
Execution is complete Data = [1]<NUL>	1	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	60 00

Example 3: The control device needs to send the command “IP3000OD3000G100R” that is 17 bytes. Since this exceeds the maximum of 8 bytes per frame the multi-frame frame type is used. When the pump receives the complete command it acknowledges and executes the command. When execution is complete the pump notifies the control device by sending the Status Byte followed by the <NUL> character.

	CAN Frame Data																
	Frame ID											RTR	Length				Data
Description	**Direction**	**Group**			**Address**				**Type**								**Hex**
Address = 2 Multi-message start type = 3 Message length = 8 Data = IP3000OD	0	0	1	0	0	0	1	0	0	1	1	0	1	0	0	0	49 50 33 30 30 30 4F 44
Multi-message start type = 4 Message length = 8 Data = 3000G100	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	33 30 30 30 47 31 30 30
Multi-message start type = 1 Message length = 1 Data = R	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	52
Pump acknowledges	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	
Execution is complete	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	60 00

Example 4: The control device wants to query the pump for its current status using query command 29.

	CAN Frame Data																
	Frame ID											RTR	Length				Data
Description	**Direction**	**Group**			**Address**				**Type**								**Hex**
Address = 0 Action command type = 6 Message length = 2 Data = 29	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	32 39
Report/answer type = 6 Message length = 2 Data = [1]<NUL>	1	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	60 00

Note: For Query Commands they do not elicit an acknowledgement response.

CHAPTER 5:

Basic Command Set

5.1 Execute Commands

R - Execute Command Buffer

- *R* executes the commands in the command buffer starting with the first unexecuted command in the command buffer.
- When a Command String that consists of only an *R* is sent to the PSD/4 SF, the PSD/4 SF will execute the command buffer starting with the first unexecuted command in the command buffer.
- *R* is not required to execute Query Commands.

Table 5-1 Execute Command Buffer – Example

Command Example	Description
IA12000A0G8**R**	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.
R	Send *R* again, no action takes place.

X - Execute Command Buffer from Beginning

- *X* executes the commands in the command buffer starting with the first command in the command buffer.
- When a Command String that consists of only an *X* is sent to the PSD/4 SF, the PSD/4 SF will execute the command buffer from the beginning.

Table 5-2 Execute Command Buffer from Beginning – Example

Command Example	Description
IA12000A0G8**X**	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.
X	Send *X* again, the Command String repeats from the beginning

5.2 Initialize Commands

Note: See PSD/4 SF CAN Examples on page 38, for additional CAN initialization command information.

Zx - Initialize PSD/4 Smooth Flow, Assign Valve Output to Right

- *Z* initializes the syringe to the home position and sets valve output position to the right side of the PSD/4 SF (as viewed from the front of the PSD/4 SF).
- Parameter - $x = 0$ initializes at full plunger force; $x = 1$ initializes at half plunger force, or speed where $10 \leq x \leq 40$.
- All of the valves used on the PSD/4 SF have a designated input and output port for PSD/4 SF initialization. See Table 2-1 input/output port location page 7.

Table 5-3 Initialize PSD/4 Smooth Flow, Assign Valve Output to Right – Example

Command Example	Description
ZR	Initialize the syringe drive to the home position and set valve output position to the right side of the PSD/4 SF.

Yx - Initialize PSD/4 Smooth Flow, Assign Valve Output to Left

- *Y* initializes the syringe drive to the home position and sets valve output to the left side of the PSD/4 SF (as viewed from the front of the PSD/4 SF).
- Parameter - $x = 0$ initializes at full plunger force; $x = 1$ initializes at half plunger force, or speed where $10 \leq x \leq 40$.
- All of the valves used on the PSD/4 SF have a designated input and output port for PSD/4 SF initialization. See Table 2-1 input/output port location page 7.

Table 5-4 Initialize PSD/4 Smooth Flow, Assign Valve Output to Left – Example

Command Example	Description
YR	Initialize the syringe drive to the home position and set valve output position to the left side of the PSD/4 SF.

Wx - Initialize PSD/4 Smooth Flow, Configure for No Valve

- *W* initializes the syringe for a PSD/4 SF without a valve drive.
- Parameter - $x = 0$ initializes at full plunger force; $x = 1$ initializes at half plunger force, or speed where $10 \leq x \leq 40$.
- Once the *W* command is issued to a PSD/4 SF, valve commands will be ignored until the power is cycled to the PSD/4 SF or the valve drive is re-enabled.

Table 5-5 Initialize PSD/4 Smooth Flow, Configure for No Valve – Example

Command Example	Description
WR	Initialize and configure unit for no valve.

5.3 Syringe Commands

z - Set Counter Position

- *z* sets the PSD/4' SFs position counter to the value contained in the current encoder position.
- Use *z* after a syringe overload error to resynchronize the PSD/4 SF's actual position with its internally recorded position without having to go through the entire initialization sequence.

> **Note:** Re-initialization is recommended over the ***z*** command in order to ensure proper accuracy and precision.

Table 5-6 Set Counter Position – Example

Command Example	Description
zR	Set the PSD/4 SF's position counter to the value contained in the current encoder position.

Ax - Absolute Position

- *A* moves the syringe to absolute position x.
- Parameter - absolute position *x* where 0 ≤ *x* ≤ 192,000.

Table 5-7 Absolute Position – Examples

Command Example	Description
A2400	Moves syringe plunger to position 2,400.
A0	Moves syringe plunger to position 0.
A24000	Moves syringe plunger to position 24,000.
Q	*Answer block* to *Query* shows pump busy (i.e., bit 5 is 0).

Table 5-8 Absolute Position with Busy Status – Example

Command Example	Description
I**A12000**O**A0**G8R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

Px - Relative Pickup

- *P* moves the syringe down *x* steps.
- Parameter - number of steps *x* where 0 ≤ *x* ≤ 192,000.

Table 5-9 Relative Pickup – Example

Command Example	Description
I**P12000**OD12000G8R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

Dx - Relative Dispense

- *D* moves the syringe up *x* steps.
- Parameter - number of steps *x* where 0 ≤ *x* ≤ 192,000.
- For example, the syringe is at position 3,000. *D300* will move the syringe up 300 steps to an absolute position of 2,700.

Table 5-10 Relative Dispense – Example

Command Example	Description
IP12000**D12000**G8R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

Kx - Return Steps

- *K* sets Return Steps to *x* steps.
- Parameter - Return Steps *x* where 0 ≤ *x* ≤ 6,400.

Table 5-11 Execute Command Buffer From Beginning – Example

Command Example	Description
K160R	Set Return Steps to 160.

Note: When the pump is initialized the Return Steps will reset to the default settings.

kx - Back-off Steps

- *kx* sets Back-off Steps to *x* steps.
- Parameter - Back-off Steps *x* where 0 ≤ *x* ≤ 12,800.

Table 5-12 Back-off Steps – Example

Command Example	Description
k50ZR	Initialize the syringe to the home position and set valve Output position to the right side, move the syringe 50 Back-off Steps.

Note: The Back-off Steps will not reset when the pump is initialized.

5.4 Valve Commands

Ix - Move Valve to Input Position

- *I* without *x* parameter moves the valve to the input position set by the *Y* and *Z* Initialize Commands.
- Parameter - Input position where *x* = valve position 1 – 8 on multi-port valves.
  See Table 2-1 input/output port location page 7.

Table 5-13 Move Valve to Output Position – Example

Command Example	Description
IA12000OA0G8R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

Ox - Move Valve to Output Position

- *O* without *x* parameter moves the valve to the output position set by the *Y* and *Z* commands.
- Parameter - Output position where *x* = valve position 1 – 8 on multi-port valves.
  See Table 2-1 input/output port location page 7.

Table 5-14 Move Valve to Output Position – Example

Command Example	Description
IA12000**O**A0G8R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

B - Move Valve to Bypass (Throughput Position)

- *B* connects the input and output positions, bypassing the syringe.
  See Table 2-1 input/output port location page 7.

Table 5-15 Move Valve to Bypass – Example

Command Example	Description
IA12000**B**R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to bypass.

E - Move Valve to Extra Position

- *E* moves the valve to the extra position (port) relative to the *Y* and *Z* commands.

Table 5-16 Move Valve to Extra Position – Example

Command Example	Description
IA12000**E**R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to the extra position.

5.5 Action Commands

> **Note:** See PSD/4 SF CAN examples on page 38, for additional CAN Action Command information.

g - Define a Position in a Command String

- *g* marks a position in a Command String that can be matched with *G* commands.
- The *G* command is used with the *g* command to repeat commands within a Command String. *g* marks the start of the commands and is paired with *Gx* to mark the end of the commands and repeats them *x* number of times. Up to ten pairs of *g* / *Gx* can be nested in a string.

Table 5-17 Repeat-sequence Example for the Command A0gIP500OD500gP150D150G10G5R

Command Segment	Description
A0	Move syringe to position 0.
g	Outer loop start.
IP4000	Move valve to input, move syringe down 4,000 steps.
OD4000	Move valve to output, move syringe up 4,000 steps.
g	Inner loop start.
P1200	Move syringe down 1,200 steps.
D1200	Move syringe up 1,200 steps.
G10	Inner loop end, repeat ten times.
G5	Outer loop end, repeat five times.
R	Execute command.

Gx - Repeat Commands

- *G* repeats a command in the command buffer *x* number of times.
- Parameter - *x* where 1 ≤ *x* ≤ 65,535. For *x* = 0 and if *x* is omitted, the sequence is repeated until a terminate command is received at the PSD/4 SF.
- The *G* command allows the user to define the number of times a command in the Command String will be repeated. A *G* command without a matching *g* command repeats from the beginning of the command buffer.

Table 5-18 Repeat Commands – Example

Command Example	Description
IA12000OA0**G8**R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated 8 times.

This is an example of using *g* and *G* to perform nested loops. This example is a method to dispense a volume of liquid into a vessel ten times, then go back and mix ten times and repeat the method 5 times:

A0gIP4000OD4000G10gP1200D1200G10G5R

Mx - Delay

- *M* performs a delay of *x* milliseconds.
- Parameter - *x* where 5 ≤ *x* ≤ 30,000 milliseconds.
- Use the *M* command to pause the execution of the Command Buffer for a given amount of time.

Table 5-19 Table Delay – Example

Command Example	Description
M10000A3000R	PSD/4 SF waits 10 seconds after the command string is sent, then moves syringes to absolute position 3,000.

Hx - Halt Command Execution

- *H* halts execution of the commands in the command buffer. Execution of the command buffer can be resumed with an appropriate digital signal or with the execute command buffer command.
- Parameter - *x* where
- *x* = 0 - Waits for control command or either input 1 or input 2 to go from high to low.
- *x* = 1 - Waits for control command or input 1 to go from high to low.
- *x* = 2 - Waits for control command or input 2 to go from high to low.
- Unlike the *M* command, the *H* command is used to put an indefinite pause in a Command String or sequence. The operator can use an external device to trigger the Command String to resume.

Note: The status of the digital input lines can be read using ?13 and ?14 commands as described in the Query Commands section of this manual.

Jx - Auxiliary Outputs

- *J* sets the digital output lines.
- Parameter - *x* where 0 ≤ *x* ≤ 7 and is defined in Table 5-20.
- Use the *J* command to control the three digital outputs in the DB15 connector located on the back of the PSD/4 SF.

Table 5-20 Digital Output Control

PSD/4 Smooth Flow 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

Table 5-21 Auxiliary Output – Example

Command Example	Description
J7R	Set digital outputs 1, 2, and 3 high.

sx - Store Command String

- *s* stores the commands following the *s* command in the Command String in the specified EEPROM location.
- Parameter - *x* where 0 ≤ *x* ≤ 14 and *x* identifies the EEPROM location.
- Use the *s* command to store the remaining commands in the Command String into the EEPROM. The Command String can then be executed by the controlling device, or upon power-up. (See Chapter 4, Communication Protocols page 24.)
- Up to 15 Command Strings, numbered 0 through 14 can be loaded into the EEPROM. Each Command String contains up to 42 commands.
- This is an example of how to store a Command String to execute a syringe movement of 12,000 steps from an external controlling device.

> **Note:** Use *h* commands in the Command Strings to digitally control execution of the Command Strings stored in the EEPROM.

Table 5-22 Load Command s2ZS4gIP1500OD1500H2GR into EEPROM – Example

Command Example	Description
s2ZS4gIP12000O D12000H2GR	Store the following Command String in EEPROM location #2: Initialize the PSD/4 SF and set the syringe speed to 4. Start a loop. Move the valve to the Input position and move the syringe down 12,000 steps. Move the valve to the Output position and move the syringe up 12,000 steps. Halt the command execution and waits for resume signal. Repeat from the start of the loop endlessly.

ex - Execute Command String in EEPROM Location

- *e* executes the Command String stored in an EEPROM location.
- Parameter - *x* where 0 ≤ *x* ≤ 14, *x* identifies the EEPROM location.

> **Note:** Link Command Strings stored in the EEPROM by ending one Command String with an *ex* where *x* refers to the second Command String.

Table 5-23 Execute Command String From EEPROM Location – Example

Command Example	Description
e2R	Moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated eight times.

5.6 Motor Control Commands

Lx - Set Acceleration

- *L* sets the velocity ramp used by syringe moves to acceleration *x*.

Table 5-24 Acceleration Values *x* and the Corresponding Step Rates

Acceleration Code	Motor Steps per second/second
1	2,500
2	5,000
3	7,500
4	10,000
5	12,500
6	15,000
7	17,500
8	20,000
9	22,500
10	25,000
11	27,500
12	30,000
13	32,500
14	35,000
15	37,500
16	40,000
17	42,500
18	45,000
19	47,500
20	50,000

Table 5-25 Set Acceleration – Example

Command Example	Description
L2R	Set Acceleration to 5,000 motor steps per second per second.

vx - Set Start Velocity

- *v* sets the start velocity in motor steps/second the syringe begins its movement.
- Parameter - motor steps/second *x* where $50 \le x \le 800$.

Table 5-26 Set Start Velocity – Example

Command Example	Description
v50R	Set start velocity to 50 motor steps per second.

Vx - Set Maximum Velocity

- *V* sets the maximum velocity in motor steps/second.
- Parameter - motor steps/second *x* where $2 \le x \le 3{,}400$.
- *V* is also an Async command. See “Async Commands” on page 54.

Table 5-27 Set Maximum Velocity – Example

Command Example	Description
V1000R	Set Maximum velocity to 1,000 motor steps per second.

ux - Set Maximum µstep Velocity

- *u* sets the maximum velocity in µsteps/minute.
- Parameter - µsteps/minute x where $400 \le x \le 816{,}000$.
- *u* is also an Async command. See “Async Commands” on page 54.

Note: The u command’s resolution changes with µstep velocity. See Table 5-28 for resolution ranges. Input values that fall between velocity boundaries will be rounded to the nearest µstep velocity.

Table 5-28 Maximum Microstep Velocity Resolution

Selected Speed (µstep/min)	Stroke Time	Step Rate Increment (µstep/min)
400 – 12,000	8 hr – 16 min	1
12,001 – 48,000	16 min – 4 min	15
48,001 – 204,000	4 min – 1 min	250
204,001 – 816,000	1 min – 14 sec	1500

Table 5-29 Set Maximum µstep Velocity – Example

Command Example	Description
u100000R	Set Maximum Velocity to 100,000 µsteps per minute.

Sx - Set Speed

- *S* sets a predefined syringe maximum velocity.
- Parameter - pre-set syringe speed *x* where 1 ≤ *x* ≤ 40.

Table 5-30 Speed Codes with Corresponding Motor Step Rate and Slew Time

Speed Code	Motor Steps per Second	Approximate Velocity in seconds per stroke	Speed Code	Motor Steps per Second	Approximate Velocity in seconds per stroke
1	3400	14.4	21	150	402.5
2	3200	15.4	22	140	439.1
3	2800	17.6	23	130	371.5
4	2600	18.9	24	120	402.5
5	2400	20.5	25	110	439.1
6	2200	22.4	26	100	483
7	2000	24.6	27	90	536.7
8	1800	27.3	28	80	603.8
9	1600	30.7	29	70	690
10	1400	35.1	30	60	805
11	1200	41	31	50	960
12	1000	49.2	32	40	1200
13	800	61.5	33	30	1600
14	600	80.5	34	20	2400
15	400	120.8	35	18	2666.7
16	200	241.5	36	16	3000
17	190	301.9	37	14	3428.6
18	180	322	38	12	4000
19	170	345	39	10	4800
20	160	371.5	40	8	6000

Table 5-31 Set Speed – Example

Command Example	Description
S11IA12000OA0G8R	Set syringe speed to 41 seconds per stroke, moves the valve to Input position, syringe to position 12,000 then moves the valve to Output position and syringe plunger to position 0. The sequence is repeated eight times.

cx - Stop Velocity

- *c* sets the stop velocity in motor steps per second.
- Parameter - motor steps/second *x* where 50 ≤ *x* ≤ 1,700.
- Setting a stop velocity resets the cutoff steps to zero.

Table 5-32 Stop Velocity – Example

Command Example	Description
c500R	Set stop velocity to 500 motor steps per second.

Cx - Increase Stop Velocity by Steps

> **Note:** It is recommended that *cx* be used for Stop Velocity control.

- *Cx* increases the stop velocity by reducing the number of deceleration steps by the number of steps given.
- Parameter - number of steps *x* where 0 ≤ *x* ≤ 25.

Table 5-33 Increase Stop Velocity by Steps – Example

Command Example	Description
C10R	Increases stop velocity steps to 10.

5.7 Async Commands

Note: See PSD/4 SF CAN Examples on page 38, for additional CAN Async Command Information

T - Terminate Command Buffer

- *T* stops execution of the command buffer. It also aborts the command being executed, except for valve commands.
- The *R* command may be used to resume the execution of the command buffer from the next unexecuted command.
- *T* is used to terminate a command or Command Strings. *T* will not terminate a valve movement however it will terminate the Command String at the end of the valve move. Use *R* to resume the Command String or sequence.
- *T* is an Async command.

Note: If *T* was used to terminate a syringe move in mid stroke it may cause the motor to lose steps. The PSD/4 SF should be re-initialized after a syringe move is terminated or if an error occurs.

Table 5-34 Terminate Command Buffer – Example

Command Example	Description
T	Stop execution of the Command Buffer.

t - Stop Command Buffer

- Functions identically to the "T" command with the exception of non-initialization plunger moves
- *T* stops a non-initialization plunger move in a way that allows the pump to remain in a usable state (without initialization)
- *T is an Async command*

Table 5-35 Terminate Command Buffer – Example

Command Example	Description
t	Stops execution of the Command Buffer in a way that leaves the plunger in a usable state.

Vx - Set Maximum Velocity (on-the-fly speed change)

- **_Vx_ is used to change the Maximum Velocity while the syringe is in motion.**
- **Parameter - (on-the-fly speed change) motor steps/second _x_ where 2 ≤ _x_ ≤ 850.**

Note: *V* is an Async command when used for on-the-fly speed changes.

Note: There are no ramps when changing the Maximum µstep Velocity on-the-fly. Large, on-the-fly changes to velocity can cause the pump to stall. If stalling occurs, the desired velocity change may need to be implemented in more than one incremental step.

Note: Stop velocity will be lost if an on-the-fly speed change is issued using the Vx command. Back-off moves (if any) will still be executed.

Table 5-36 Set Maximum Velocity (on-the-fly speed change) – Example

Command Example	Description
S11A3000R	Set syringe speed to 1,200 motor steps per second, move syringe to position 3,000.
V1000R	Change syringe speed to 1,000 motor steps per second.

ux - Set Maximum µstep Velocity (on-the-fly speed change)

- **_ux_ is used to change the Maximum µstep Velocity while the syringe is in motion.**
- **Parameter - (on-the-fly speed change) µsteps/minute _x_ where 400 ≤ _x_ ≤ 204,000.**

Note: *u* is an Async command when used for on-the-fly speed changes.

Note: There are no ramps when changing the Maximum µstep Velocity on-the-fly. Large, on-the-fly changes to velocity can cause the pump to stall. If stalling occurs, the desired velocity change may need to be implemented in more than one incremental step.

Note: Stop velocity will be lost if an on-the-fly speed change is issued using the ux command. Back-off moves (if any) will still be executed.

Table 5-37 Set Maximum µstep Velocity (on-the-fly speed change) – Example

Command Example	Description
S15A3000R	Set syringe speed to 400 motor steps per second, move syringe to position 3,000.
u100000R	Change syringe speed to 100,000 µsteps/minute.

5.8 Query Commands

Note: See PSD/4 SF CAN Query Commands on page 38, for CAN Query information.

Note: A Control Command is not required to execute a Query Command.

F - Command Buffer Status

- *F* reports the command buffer status

Table 5-38 Report Buffer Status

Command Buffer Status	Return Status Code
Empty	0
Not Empty	1

& - Firmware Version

- & reports the firmware revision in ASCII.

- Firmware Checksum

- # reports the firmware checksum.
- Returned as 4 digit hexadecimal value.

Q - Pump Status

- *Q* reports the pump status.
- See 'Pump Status' definition in Glossary.

? - Absolute Syringe Position

- *?* reports the given position of the syringe.
- Position is reported back where $0 \leq x \leq 192{,}000$.

?1 - Start Velocity

- ?1 reports the start velocity in motor steps/second.
- Start velocity is reported back in motor steps/second, $50 \leq x \leq 800$.

?2 - Maximum Velocity

- *?2* reports the maximum velocity in motor steps/second or µsteps/minute, depending on which command was used to enter the maximum velocity.
- Maximum Velocity is reported back in motor steps/second, $2 \le x \le 3{,}400$, or in µsteps/minute, $400 \le x \le 816{,}000$.

?3 - Stop Velocity

- *?3* reports the stop velocity in motor steps/second.
- Stop velocity is reported back in motor steps/second, $50 \le x \le 1{,}700$.

?4 - Actual Position of Syringe

- *?4* reports the actual position of the syringe in steps based on encoder information.
- Position is reported back where $0 \le x \le 192{,}000$.

?12 - Number of Return Steps

- *?12* reports the number of Return Steps.
- Position is reported back where $0 \le x \le 6{,}400$.

?13 - Status of Auxiliary Input #1

- *?13* reports the Status of the Auxiliary Input #1.
- 0 - Auxiliary Input Low; 1 - Auxiliary Input High.

?14 - Status of Auxiliary Input #2

- *?14* reports the Status of the Auxiliary Input #2.
- 0 - Auxiliary Input Low; 1 - Auxiliary Input High.

?22 - Returns 255

- *?22* Returns 255.

?24 - Number of Back-off Steps

- *?24* reports the number of Back-off Steps where $0 \le x \le 12{,}800$.

CHAPTER 6:

Extended Command Set

6.1 h Factor Command Details

The PSD/4 SF has a set of commands known as h Factor commands. These augment the capabilities of the PSD/4 SF by enabling the user to access expanded features such as multi-port valving and digital input/output controls.

> **Note:** In order to access the h Factor commands, they must first be enabled by sending h30001R to the PSD/4 SF.

6.1.1 Enable/Disable h Factor Commands

h30001 - Enable h Factor Commands and Queries

- *Enable h Factor Commands and Queries* turns on the Hamilton Company extension commands.

h30000 - Disable h Factor Commands and Queries

- *Disable h Factor Commands and Queries* turns off the Hamilton Company extension commands.

6.1.2 Syringe Commands

h100xx - Initialize Syringe Only

- *Initialize Syringe* initializes the syringe.
- 10,000 + speed code.
- This command does not disable the valve like the *W* command.

h110xx - Set Syringe Mode

- *Set Syringe Mode* configures the syringe.

  xx is the sum of 11,000 AND:

  1 - Standard resolution

  0 - Do not ignore overload
  2 - Ignore overload

  0 - Enable initialization sensor
  4 - Disable initialization sensor

  0 - Enable initialize
  8 - Disable initialize

6.1.3 Valve Commands

h20000 - Initialize Valve

- *Initialize Valve initializes* the valve.

h20001 - Enable Valve Movement

- *Enable Valve Movement* enables the valve to be moved after valve movement was disabled.

h20002 - Disable Valve Movement

- *Disable Valve Movement* makes the PSD/4 SF ignore all subsequent valve movement commands.

h2100x - Set Valve Type

- Configure PSD/4 SF for specific valve type.
- *x* is the sum of 21,000 AND:

  0 - 3-way 120 degree Y valve
  1 - 4-way 90 degree T valve
  2 - 3-way 90 degree distribution valve
  3 - 8-way 45 degree valve
  4 - 4-way 90 degree valve
  5 - Not used
  6 - 6-way 45 degree valve

h23001 - Move Valve to Input Position in Shortest Direction

- *Move Valve to Input Position in Shortest Direction* moves the valve to the input position taking the shortest route in terms of degrees traveled.

h23002 - Move Valve to Output Position in Shortest Direction

- *Move Valve to Output Position in Shortest Direction* moves the valve to the output position taking the shortest route in terms of degrees traveled.

h23003 - Move Valve to Wash Position in Shortest Direction

- *Move Valve to Wash Position in Shortest Direction* moves the valve to the wash position taking the shortest route in terms of degrees traveled.

h23004 - Move Valve to Return Position in Shortest Direction

- *Move Valve to Return Position in Shortest Direction* moves the valve to the return position taking the shortest route in terms of degrees traveled.

h23005 - Move Valve to Bypass Position in Shortest Direction

- *Move Valve to Bypass Position in Shortest Direction* moves the valve to the bypass position taking the shortest route in terms of degrees traveled.

h23006 - Move Valve to Extra Position in Shortest Direction

- *Move Valve to Extra Position in Shortest Direction* moves the valve to the extra position taking the shortest route in terms of degrees traveled.

h2400x - Move Valve in Clockwise Direction

- *Move Valve in Clockwise Direction* moves the valve in a clockwise direction to one of eight positions.
- $1 \leq x \leq 8$

h2500x - Move Valve in Counterclockwise Direction

- *Move Valve in Counterclockwise Direction* moves the valve in a counterclockwise direction to one of eight positions.
- $1 \leq x \leq 8$

h2600x - Move Valve in Shortest Direction

- *Move Valve in Shortest Direction* moves the valve to position *x* in shortest direction in terms of degrees traveled.
- $1 \leq x \leq 8$

h27xxx - Clockwise Angular Valve Move

- *Clockwise Angular Valve Move* moves the valve to angle *x* in clockwise direction in 15° increments.
- Sum of 27,000 and $0 \leq x \leq 345$

h28xxx - Counterclockwise Angular Valve Move

- *Counterclockwise Angular Valve Move* moves the valve to angle *x* in counterclockwise direction in 15° increments.
- Sum of 28,000 and $0 \leq x \leq 345$

h29xxx - Shortest Direct Angular Valve Move

- *Shortest Direct Angular Valve Move* moves the valve to angle *x* in shortest direction in terms of degrees traveled.
- Sum of 29,000 and $0 \leq x \leq 345$

6.2 Query Commands

6.2.1 Syringe Query Commands

?10000 - Syringe Status

- *Syringe Status* queries the syringe. Response to query is decoded to determine the syringe status.
- PSD/4 SF Response: *xx* where *xx* is decoded as the sum of:

0 - Syringe initialized
1 - Syringe not initialized

0 - No syringe stall or overload
6 - Syringe stall

0 - No initialization error
8 - Syringe initialization error

?11000 - Syringe Mode

- *Syringe Mode* queries the syringe. Response to query is decoded to determine the syringe mode.
- PSD/4 SF Response: *xx* where *xx* is decoded as the sum of:

1 - Standard mode set

0 - Syringe overload not ignored
2 - Syringe overload ignored

0 - Enable initialization sensor
4 - Disable initialization sensor

0 - Enable initialize
8 - Disable initialize

6.2.2 Valve Query Commands

?20000 - Valve Status

- *Valve Status* queries the valve. Response to query is decoded to determine the valve status.
- PSD/4 SF Response: *xx* where *xx* is decoded as the sum of:

0 - Valve initialized
1 - Valve not initialized

0 - No valve initialization error
2 - Valve initialization error

0 - No valve stall
4 - Valve stall

0 - Valve enabled
16 - Valve not enabled

0 - Valve is not busy
32 - Valve is busy

?21000 - Valve Type

- Response to *Valve Type* is the valve type.
- PSD/4 SF Response: *x* where 0 ≤ *x* ≤ 4 and corresponds to:

0 - 3-way 120 degree Y valve
1 - 4-way 90 degree T valve
2 - 3-way 90 degree distribution valve
3 - 8-way 45 degree valve
4 - 4-way 90 degree valve
5 - Not used
6 - 6-way 45 degree valve

?23000 - Valve Logical Position

- Response to *Valve Logical Position* is defined below in PSD/4 SF Response.
- PSD/4 SF Response: *x* where *x* is defined as:

0 - Not at logical position
1 - Input
2 - Output
3 - Wash
4 - Return
5 - Bypass
6 - Extra

?24000 - Valve Numerical Position

- Response to *Valve Numerical Position* is defined below in PSD/4 SF Response.
- PSD/4 SF Response: *x* where 0 ≤ *x* ≤ 8 (0 corresponds to not a numerical position).

?25000 - Valve Angle

- Response to *Valve Angle* is defined below in PSD/4 SF Response.
- Parameters: none.
- PSD/4 SF Response: *xxx* where 0 ≤ *xxx* ≤ 345.

6.2.3 System Query Commands

?37000 - Last Digital Out Value

- Reports the last digital output value.
- PSD/4 SF Response: *x* where 0 ≤ *x* ≤ 7 corresponding to the last digital out values.

?38000 - Syringe Diagnostic Timer Value

- Reports the current timer start value used to manage syringe motor position.
- PSD/4 SF Response: *x* where 0 ≤ *x* ≤ 65,535 corresponding to the current timer ticks.

6.2.4 Action Reset

h30003 - Reset PSD/4 Smooth Flow

- *Reset PSD/4 SF* resets the PSD/4 SF and sets power-up default values.

Appendices

Appendix A

Contacting Hamilton Company

Hamilton Americas & Pacific Rim:

Hamilton Company, Inc.
4970 Energy Way
Reno, Nevada 89502

Customer Service
1 (888) 525-2123

Technical Support/Service
1 (800) 648-5950

Outside the U.S.
+1 (775) 858-3000

Hamilton Europe, Asia & Africa:

Hamilton Bonaduz A.G.
Via Crusch 8
CH-7402 Bonaduz, Switzerland

Customer Service
Tel: +41-58-610-10-10
Fax: +41-58-610-00-10

Appendix B

Specifications

Table B-1 PSD/4 Smooth Flow Specifications

General Specifications		
Flow Rate	Accuracy: ± 5%*	Precision: ≤ 5%*
Flow Rate Range	26 nL/minute to 53 mL/minute	
Dispense Volume	Accuracy: ± 1% at 100% stroke	Precision: ≤ 0.05% at 100% stroke
Fluid Path	Borosilicate glass, PTFE, PFA, CTFE, ETFE, UHMW-PE, or ceramic	
Weight	2.7 lbs (1.2 kg)	
Dimensions	Height: 5.00 inches (127.0 mm) Width: 1.75 inches (44.5 mm) Depth: 4.20 inches (106.7 mm)	
RoHS Compliant	Yes	
Linear Force Capability	23 lbf (10.43 kgf) Refer to Appendix J page 84	
Power Requirements		
Supply Voltage	24 VDC	
Average Current	850 mA maximum	
Syringe and Syringe Drive		
Syringe Volumes	12.5 µL – 12.5 mL	
Syringe Materials	Glass barrel, PTFE or PFA insert, stainless steel or aluminum plunger with PTFE coating, PTFE or UHMWPE plunger tip	
Resolution	192,000 steps	
Syringe Drive Mechanism	Stepper motor driven lead screw and optical encoder	
Stroke Length	30 mm	
Syringe Speeds	14 seconds to 8 hours per full stroke	
Valve and Valve Drive		
Valve Drive Speed	250 ms per 120° rotation	
Valve Drive Mechanism	Stepper motor with optical encoder feedback	
Valve Fittings	¼” – 28	
Valve Materials	CTFE, PTFE, ETFE, or ceramic	
Nominal Fluid Path Diameter	All valves: 0.060” (1.524 mm) unless otherwise noted	

** Verified with deionized water at a flow rate range of 2.1 to 50 µL/minute. 12.5 mL syringe was tested with 35 psi back pressure. The rest of syringes were tested with 45 psi back pressure. Sensirion SLI-0430 flow meter was used at a sampling rate of 3 ms. All sampling times were 4 minutes minimum once flow stabilized.*

Table B-1 PSD/4 Smooth Flow Specifications (Continued)

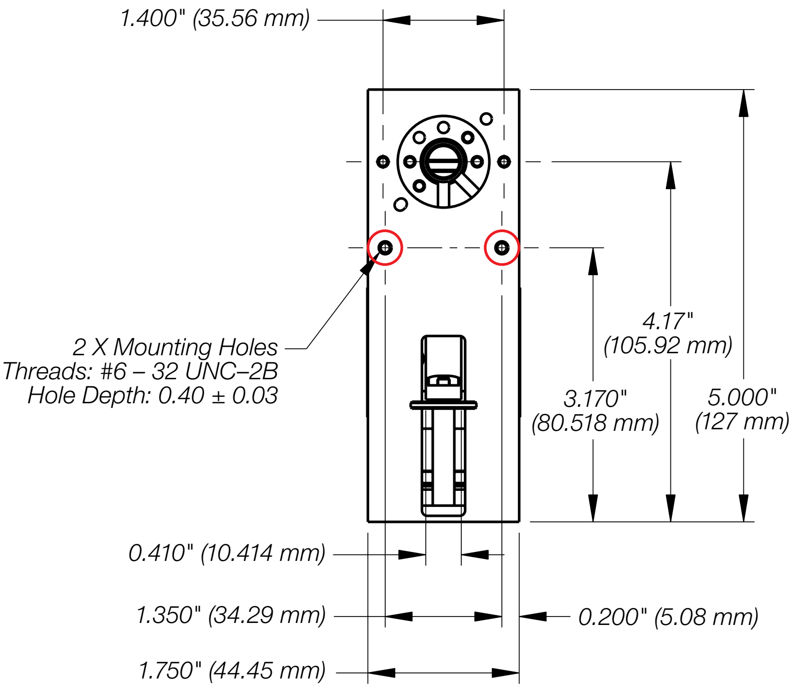
Communication	
Type	RS-232, RS-485, or CAN
Protocols	Terminal or Standard
Baud Rate	9,600 or 38,400 (RS-232, RS-485) 100,000 or 125,000 (CAN)
Data Bits	8
Parity	None
Stop Bit	1, Half duplex
Daisy Chain Length	Up to 16 individual pumps
Programmable Capabilities	Ramps, cutoff velocity, backlash compensation, syringe speeds, loops, on-the-fly speed changes, terminate moves and delays, error detection, valve rotation selection, enhanced “h” Factor capabilities including valve rotation clockwise and counter-clockwise, 15 location method storage
Environmental Operating and Storage Range	
Operating Temperature	59 °F (15 °C) to 104 °F (40 °C)
Operating Humidity	20 – 95% relative humidity, non-condensing
Storage Temperature	-4 °F (-20 °C) to 149 °F (65 °C)
Storage Humidity	20 – 95% relative humidity, non-condensing
Additional Regulator Compliance Information	
Pollution Degree	2
Installation Category	II
Altitude	6,562 ft (2000 m)

Indoor operation and use only.

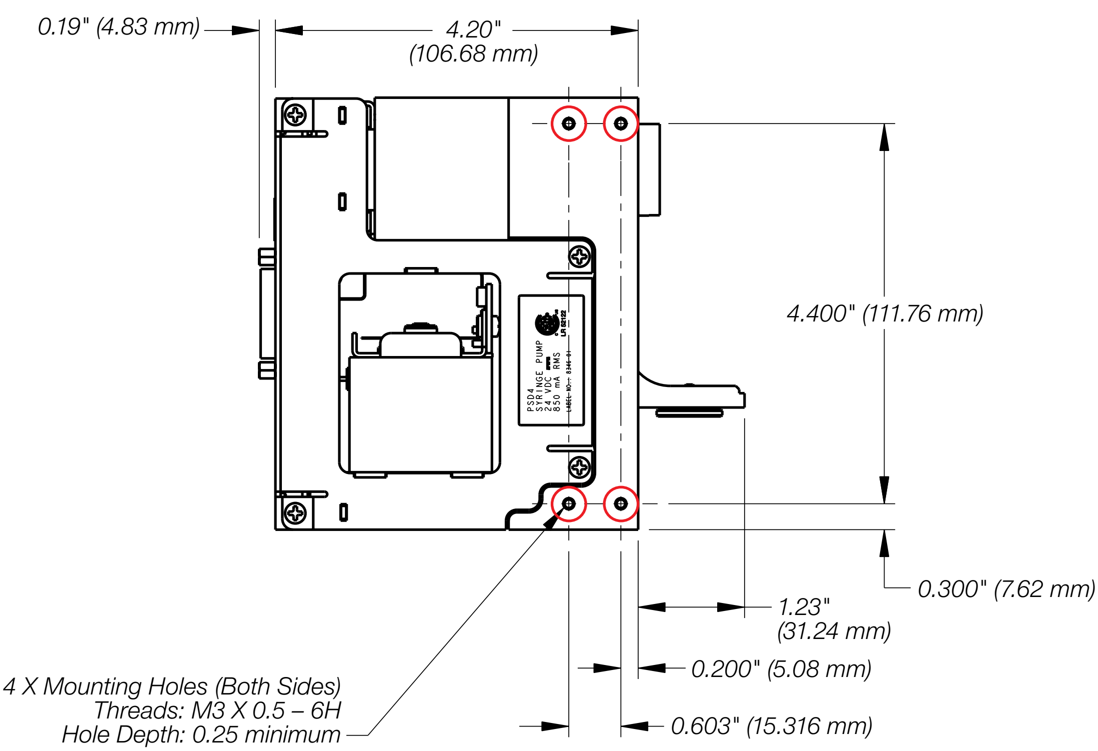
Appendix C

Mounting Hole Locations and Product Dimensions

Front



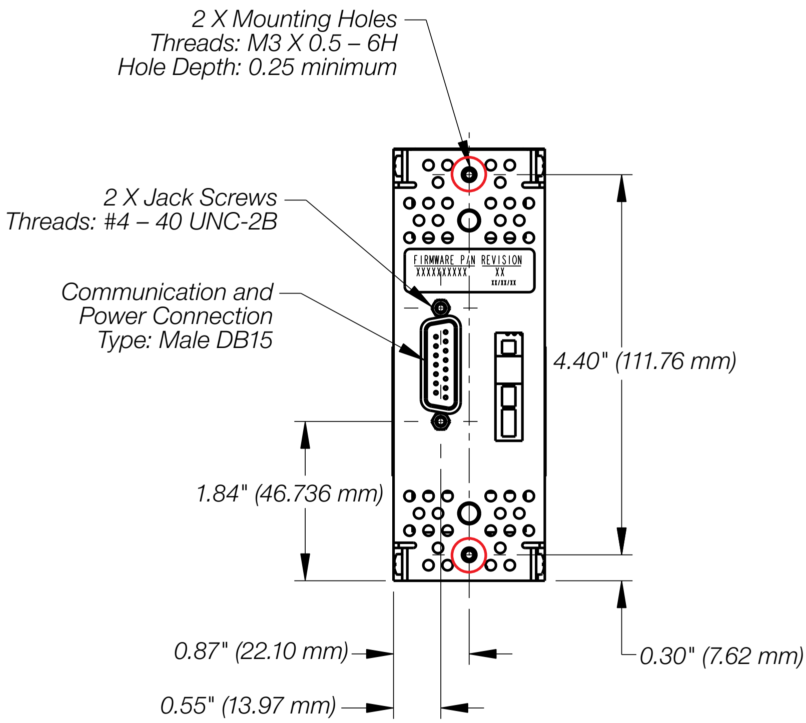
Side



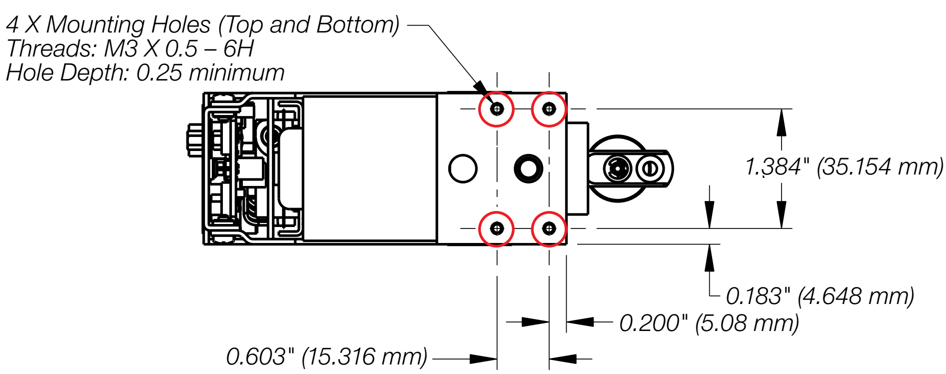
Appendix C (Continued)

Mounting Hole Locations and Product Dimensions

Back



Bottom



Appendix D

DIP Switch Settings

Table D-1 DIP Switch Settings

Switch Position Descriptions	Details	Default	Switch Circuit 1	2	3	4	5	6	7	8
Syringe Overload Detection	Enabled	X	OFF	–	–	–	–	–	–	–
	Disabled		ON	–	–	–	–	–	–	–
EEPROM AutoStart/Self-Test	Disabled	X	–	OFF	–	–	–	–	–	–
	Enabled		–	ON[1]	–	–	–	–	–	–
Baud Rate	9,600 baud 100,000 baud for CAN	X	–	–	OFF	–	–	–	–	–
	38,400 baud for CAN		–	–	ON	–	–	–	–	–
Force Boot	Enabled		–	–	–	ON	ON	ON	–	–
3-Port Y Valve		X	–	–	–	OFF	OFF	OFF	–	–
T-Port Valve			–	–	–	ON	OFF	OFF	–	–
3-Port Distribution Valve			–	–	–	OFF	ON	OFF	–	–
4-Port Distribution Valve 4-Port Wash Valve			–	–	–	OFF	OFF	ON	–	–
6-Port Distribution Valve			–	–	–	OFF	ON	ON	–	–
8-Port Distribution Valve			–	–	–	ON	ON	OFF	–	–
RS-485 Communication Termination	Single unit, first or last in chain	X	–	–	–	–	–	–	ON[2]	ON[3]
	Non-end unit in chain		–	–	–	–	–	–	OFF	OFF

[1] *Self-Test actuated with Address Switch set to "F," Address Switch set to "0-E" executes. Command Strings stored in EEPROM locations 0 – 14*
[2] *RS-485-A*
[3] *RS-485-B*
[4] *A dash "-," represents a switch circuit that has not effect on the associated configuration.*

Appendix E

Basic Command Quick Reference

Table E-1 Command Summary

ASCII Command RS-232/485	Parameters	Description	ASCII Command CAN
Control Commands			
R		Execute Command Buffer	R
X		Execute Command Buffer From Beginning	X
Initialization Commands			
Zx	x = 0 or blank initializes at full plunger force; x =1 initializes at half plunger force. x = 10 – 40, speed	Initialize PSD/4 SF, assign output position to right side.	Zx
Yx	x = 0 or blank initializes at full plunger force; x =1 initializes at half plunger force. x = 10 – 40, speed	Initialize PSD/4 SF, assign output position to left side.	Yx
Wx	x = 0 or blank initializes at full plunger force; x =1 initializes at half plunger force. x = 10 – 40, speed	Initialize PSD/4 SF, configure for no value.	Wx
Syringe Commands			
z		Reset syringe counter position	z
Ax	x where $0 \leq x \leq 192{,}000$	Absolute movement to step position x	Ax
Px	x where $0 \leq x \leq 192{,}000$	Pickup x steps	Px
Dx	x where $0 \leq x \leq 192{,}000$	Dispense x steps	Dx
Kx	x where $0 \leq x \leq 6{,}400$	Set Return Steps to x steps	Kx
kx	x where $0 \leq x \leq 12{,}800$	Set syringe back-off steps to x steps	kx

Table E-1 Command Summary (Continued)

ASCII Command RS-232/485	Parameters	Description	ASCII Command CAN
Valve Commands			
Ix	x where 1 ≤ x ≤ 8 valve position	Move valve input position	Ix
Ox	x where 1 ≤ x ≤ 8 valve position	Move valve output position	Ox
B		Move valve to bypass position	B
E		Move valve to extra position	E
Action Commands			
g		Marks a position in a Command String that can be matched with G commands.	g
Gx	x where 1 ≤ x ≤ 65535	Repeats the Command String x number of times. If x = 0 or x is omitted, the sequence is repeated until a terminate command is received.	Gx
Mx	x where 5 ≤ x ≤ 30,000	Executes a delay of x milliseconds	Mx
Hx	x = 0 - Waits for R or either input 1 or input 2 to go from high to low x = 1 - Waits for R or input 1 to go from high to low x = 2 - Waits for R or input 2 to go from high to low	Halts execution of the commands in the command buffer, x defines resume parameter.	Hx
Jx	0 ≤ x ≤ 7	Sets digital output lines. See Table 5-20 page 48, Digital output control	Jx
sx	x where 0≤ x ≤ 14	Stores all commands listed after the s command in the EEPROM location x.	sx
ex	x where 0≤ x ≤ 14	Executes the Command String stored in an EEPROM location x.	ex
^x	x - is set to 255	(command ignored)	^x
Motor Control Commands			
Lx	Slope x where 0 ≤ x ≤ 20	Set acceleration slope to x	Lx
vx	x where 50 ≤ x ≤ 800	Set start velocity to x motor steps/second	vx
Vx	x where 2 ≤ x ≤ 3,400	Set maximum velocity to x motor steps/second	Vx
ux	x where 400 ≤ x ≤ 816,000	Set maximum velocity to x µsteps/minute	ux
Sx	x where 1 ≤ x ≤ 40	Set syringe speed to preset speed x	Sx
cx	x where 50 ≤ x ≤ 1,700	Set stop velocity to x motor steps/second	cx
Cx	x where 0 ≤ x ≤ 25	Increase stop velocity by x steps	Cx

Table E-1 Command Summary (Continued)

ASCII Command RS-232/485	Parameters	Description	ASCII Command CAN
Async Commands			
T		Terminate Command Buffer	T
t		Stops plunger arm moves in progress leaving plunger in a usable state	t
Vx	x where 2 ≤ x ≤ 850	Set maximum velocity for on-the-fly speed changes to x motor steps/second	Vx
ux	x where 400 ≤ x ≤ 204,000	Set maximum velocity for on-the-fly speed changes to x µsteps/minute	ux

Table E-2 Query Commands

RS-232/485 Query	Response	Description	CAN Query
F	0 - Empty 1 - Not Empty	Report command buffer status	10
&	(string response)	Report firmware version	23
#	*xxxx*	Report firmware Checksum in hexadecimal	
Q		Pump status	29
?	0 ≤ ***x*** ≤ 192,000	Report absolute syringe position in steps	0 (zero)
?1	50 ≤ ***x*** ≤ 800	Report start velocity in motor steps/second	6
?2	2 ≤ ***x*** ≤ 3,400 motor steps/second 400 ≤ ***x*** ≤ 816,000 µsteps/minute	Report maximum velocity in motor steps/second or µsteps/minute	4
?3	50 ≤ ***x*** ≤ 1,700	Report cutoff velocity in motor steps/second	7
?4	0 ≤ ***x*** ≤ 192,000	Report Actual syringe position in steps	1
?12	0 ≤ ***x*** ≤ 6,400	Report number of Return Steps in steps	12
?13	0 - Auxiliary Input Low; 1 - Auxiliary Input High	Report status of auxiliary input 1	13
?14	0 - Auxiliary Input Low; 1 - Auxiliary Input High	Report status of auxiliary input 2	14
?22	Returns 255	Report 255	22

Appendix F

h Factor Command Quick Reference

Table F-1 Command Summary

Command	Parameters	Description
Enable/Disable h Factor Commands		
h30001		Enable h Factor Commands and Queries
h30000		Disable h Factor Commands and Queries
Syringe Commands		
h100xx	pre-set syringe speed *x* where 0 ≤ *x* 40 10000 + (0 ≤ *x* ≤ 40)	Initialize Syringe at speed code *x* (Refer to Table 5-30 page 52, Speed codes with corresponding motor step rate and slew time)
h1100x	*x* where *x* is the sum of 11000 AND: 1 - Standard resolution 0 - Do not ignore overload 2 - Ignore overload 0 - Enable initialization sensor 4 - Disable initialization sensor 0 - Enable initialize 8 - Disable initialize	Set Syringe Mode to *x*
Valve Commands		
h20000		Initialize Valve
h20001		Enable Valve Movement
h20002		Disable Valve Movement
h2100x	*x* = 0: 3-way 20 degree Y valve 1: 4-way 90 degree T valve 2: 3-way 90 degree valve 3: 8-way 45 degree valve 4: 4-way 90 degree valve	Set Valve Type to type *x*
h23001		Move Valve to Input Position in Shortest Direction
h28xxx	22000 + 0 ≤ *xxx* ≤ 345	Counterclockwise Angular Valve Move to angle *x*
h29xxx	27000 + 0 ≤ *xxx* ≤ 345	Shortest Direct Angular Valve Move to angle *x*
Firmware Commands		
h30003		Reset PSD/4 SF

Table F-2 Query Commands

Query	Response	Description
?10000	*xx* where *xx* is decoded as the sum of: 0 - Syringe initialized 1 - Syringe not initialized 0 - No syringe stall 6 - Syringe stall 0 - No initialization error 8 - Syringe initialization error	Syringe Status
?11000	*xx* where *xx* is decoded as the sum of: 1 - Standard resolution mode 0 - Syringe overload not ignored 2 - Syringe overload ignored 0 - Enable initialization sensor 4 - Disable initialization sensor 0 - Enable initialize 8 - Disable initialize	Syringe Mode
?20000	Response: *xx* where *xx* is decoded as the sum of: 0 - Valve initialized 1 - Valve not initialized 0 - No initialization error 2 - Syringe intialization error 0 - No valve stall 4 - Valve stall 0 - No valve positioning error 8 - Valve positioning error 0 - Valve enabled 16 - Valve not enabled 0 - Valve is not busy 32 - Valve is busy	Valve Status

Table F-2 Query Commands (Continued)

Query	Response	Description
?21000	*x* where 0 ≤ *x* ≤ 4 and corresponds to: 0-3-way 120 degree Y valve 1-4-way 90 degree T valve 2-3-way 90 degree distribution valve 3-8-way 45 degree valve 4-4-way 90 degree valve	Valve Type
?23000	*x* where *x* is defined as: 0 - Not at a logical position 1 - Input 2 - Output 3 - Wash 4 - Return 5 - Bypass 6 - Extra	Valve Logical Position
?24000	*x* where 0 ≤ *x* ≤ 8 (0 corresponds to not at a numerical position)	Valve Numerical Position
?25000	*xxx* where 0 ≤ *xxx* ≤ 345	Vave Angle
?36000	*x* where 0 ≤ *x* ≤ 65,535 corresponding to the current timer ticks	Current Timer Start Value
?37000	*x* where 0 ≤ *x* ≤ 7 corresponding to the last digital out values	Last Digital Out Value

Appendix G

Table G-1 ASCII Chart

Binary	Decimal	Hex	ASCII
00000000	0	00	<NUL>
00000001	1	01	<SOH>
00000010	2	02	<STX>
00000011	3	03	<ETX>
00000100	4	04	<EOT>
00000101	5	05	<ENQ>
00000110	6	06	<ACK>
00000111	7	07	<BEL>
00001000	8	08	<BS>
00001001	9	09	<HT>
00001010	10	0A	<LF>
00001011	11	0B	<VT>
00001100	12	0C	<FF>
00001101	13	0D	<CR>
00001110	14	0E	<SO>
00001111	15	0F	<SI>
00010000	16	10	<DLE>
00010001	17	11	<DC1>
00010010	18	12	<DC2>
00010011	19	13	<DC3>
00010100	20	14	<DC4>
00010101	21	15	<NAK>
00010110	22	16	<SYN>
00010111	23	17	<ETB>
00011000	24	18	<CAN>
00011001	25	19	<EM>
00011010	26	1A	<SUB>
00011011	27	1B	<ESC>
00011100	28	1C	<FS>
00011101	29	1D	<GS>
00011110	30	1E	<RS>
00011111	31	1F	<US>

Binary	Decimal	Hex	ASCII
00100000	32	20	
00100001	33	21	!
00100010	34	22	“
00100011	35	23	#
00100100	36	24	$
00100101	37	25	%
00100110	38	26	&
00100111	39	27	‘
00101000	40	28	(
00101001	41	29	)
00101010	42	2A	*
00101011	43	2B	+
00101100	44	2C	,
00101101	45	2D	-
00101110	46	2E	.
00101111	47	2F	/
00110000	48	30	0
00110001	49	31	1
00110010	50	32	2
00110011	51	33	3
00110100	52	34	4
00110101	53	35	5
00110110	54	36	6
00110111	55	37	7
00111000	56	38	8
00111001	57	39	9
00111010	58	3A	:
00111011	59	3B	;
00111100	60	3C	<
00111101	61	3D	=
00111110	62	3E	>
00111111	63	3F	?

Table G-1 ASCII Chart (Continued)

Binary	Decimal	Hex	ASCII
01000000	64	40	@
01000001	65	41	A
01000010	66	42	B
01000011	67	43	C
01000100	68	44	D
01000101	69	45	E
01000110	70	46	F
01000111	71	47	G
01001000	72	48	H
01001001	73	49	I
01001010	74	4A	J
01001011	75	4B	K
01001100	76	4C	L
01001101	77	4D	M
01001110	78	4E	N
01001111	79	4F	O
01010000	80	50	P
01010001	81	51	Q
01010010	82	52	R
01010011	83	53	S
01010100	84	54	T
01010101	85	55	U
01010110	86	56	V
01010111	87	57	W
01011000	88	58	X
01011001	89	59	Y
01011010	90	5A	Z
01011011	91	5B	[
01011100	92	5C	\
01011101	93	5D	]
01011110	94	5E	^
01011111	95	5F	_
01100000	96	60	`
01100001	97	61	A
01100010	98	62	b
01100011	99	63	c
01100100	100	64	d
01100101	101	65	e
01100110	102	66	f
01100111	103	67	g
01101000	104	68	h
01101001	105	69	i
01101010	106	6A	j
01101011	107	6B	k
01101100	108	6C	l
01101101	109	6D	m
01101110	110	6E	n
01101111	111	6F	o
01110000	112	70	p
01110001	113	71	q
01110010	114	72	r
01110011	115	73	s
01110100	116	74	t
01110101	117	75	u
01110110	118	76	v
01110111	119	77	w
01111000	120	78	x
01111001	121	79	y
01111010	122	7A	z
01111011	123	7B	{
01111100	124	7C	|
01111101	125	7D	}
01111110	126	7E	~
01111111	127	7F	

Appendix H

Calculation of Parameter "*V*" and Stroke Length

Range of parameter "*V*" (Speed Code)

- $V_{min} = 2$
- $V_{max} = 3{,}420$
- Syringe stroke = 192,000 steps

Calculation of flow rate for parameter "*V*"

$$\text{Parameter } V \text{ (steps/second)} = \frac{\text{desired flow rate (µL/s) x 192,000 steps}}{\text{4 x syringe volume (µL)}}$$

Calculation of real flow rate

$$\text{Actual Flow Rate (µL/s)} = \frac{\text{parameter V (steps/second) x syringe volume (µL) x 4}}{\text{192,000 steps}}$$

Calculation of stroke length (steps)

$$\text{Stroke (steps)} = \frac{\text{desired dispense or aspirate volume (µL) x 192,000 steps}}{\text{syringe volume (µL)}}$$

Calculation of Parameter "u" and Stroke Length

Range of parameter "*u*"

- $u_{min} = 400$
- $u_{max} = 820{,}000$
- Syringe stroke = 192,000 steps

Calculation of flow rate for parameter "*u*"

$$\text{Parameter u} \left(\frac{\text{steps}}{\text{minute}}\right) = \frac{\text{desired flow rate} \left(\frac{\text{µL}}{\text{min}}\right) \text{ x 192,000 steps}}{\text{syringe volume (µL)}}$$

Calculation of real flow rate

$$\text{Actual Flow Rate} \left(\frac{\text{µL}}{\text{minute}}\right) = \frac{\text{parameter u} \left(\frac{\text{steps}}{\text{minute}}\right) \text{ x syringe volume (µL)}}{\text{192,000 steps}}$$

Calculation of stroke length (µsteps)

$$\text{Stroke (steps)} = \frac{\text{desired dispense or aspirate volume (µL) x 192,000 steps}}{\text{syringe volume (µL)}}$$

Appendix I

Chemical Compatibility

This section contains information about chemical compatibility with the PSD/4 SF instrument at room temperature. The fluid path consists of the inside syringe barrel which is made of borosilicate glass, the tip of the syringe plunger which is made of PTFE and the internal valve components which are made of PTFE and CTFE.

Legend

0 = No data available
A = No effect, excellent
B = Minor effect, good
C = Moderate effect, fair
D = Severe effect, not recommended

Table I-1 Chemical Compatibility of the PSD/4 Smooth Flow units

Solvent	Borosilicate Glass	PTFE	CTFE
Acetaldehyde	A	A	A
Acetates	B	A	A
Acetic acid	A	A	A
Acetic anhydride	0	A	A
Acetone	A	A	A
Acetonitrile	A	A	A
Acetyl bromide	0	A	0
Ammonia	A	A	A
Ammonium acetate	A	A	0
Ammonium hydroxide	0	A	A
Ammonium phosphate	0	A	A
Ammonium sulfate	0	A	A
Amyl acetate	A	A	A
Aniline	A	A	A
Benzene	A	A	B-C
Benzyl alcohol	A	A	A
Boric acid	A	A	A
Bromine	A-B	A	A
Butyl acetate	A	A	A
Butyl alcohol	A	A	B
Carbon sulfide	A	A	A

Table I-1 Chemical Compatibility of the PSD/4 Smooth Flow units (Continued)

Solvent	Borosilicate Glass	PTFE	CTFE
Carbon tetrachloride	A	A	B-C
Chloracetic acid	A	A	A
Chlorine, liquid	A	A	B
Chlorobenzene	0	A	B
Chloroform	A	A	B
Chromic acid	A	A	A
Cresol	A	A	A
Cyclohexane	A	A	B
Ethers	A	A	B
Ethyl acetate	A	A	B-C
Ethyl alcohol	A	A	0
Ethyl chromide	0	A	B
Ethyl ether	0	A	A-B
Formaldehyde	A	A	A
Formic acid	A	A	A
Freon 11, 12, 22	A	A	B-C
Gasoline	A	A	A
Glycerin	A	A	A
Hydrochloric acid	A	A	A
Hydrochloric acid (conc)	A	A	A
Hydrofluoric acid	D	A	B
Hydrogen peroxide	A	A	B
Hydrogen peroxide (conc)	A	A	B
Hydrogen sulfide	0	A	A-B
Kerosene	A	A	A
Methyl alcohol	A	A	A
Methyl ethyl ketone (MEK)	A	A	A-B
Methylene chloride	A	A	B
Naptha	0	B	A
Nitric acid	A	A	A
Nitric acid (conc)	A-B	A	A-B
Nitrobenzene	A	A	A-B
Phenol	A	A	B
Pyridine	0	A	A

Table I-1 Chemical Compatibility of the PSD/4 Smooth Flow Units (Continued)

Solvent	Borosilicate Glass	PTFE	CTFE
Silver nitrate	A	A	B
Soap solutions	A	A	A
Stearic acid	A	A	0
Sulfuric acid	A	A	A
Sulfuric acid (conc)	A	A	A
Sulturous acid	0	A	A-B
Tannic acid	0	A	A-B
Tanning extracts	0	0	0
Tartartic acid	0	A	B
Toluene	A	A	B
Trichlorethane	A	A	B
Trichloroethylene	A	A	B-C
Turpentine	A	A	A
Water	A	A	A
Xylene	A	A	B-C

Appendix J

Linear Force Capability

Table J-1 Linear Force Capability

Syringe Size (mL)	Max Back Pressure (psi)
2.5 and smaller	100
5	88
12.5	35

Note: Linear force capability is 23 lbf (10.43 kgf).

Note: PSD/4 valves are rated up to 100 psi and limit the system's capabilities for small syringe sizes. Contact Hamilton if higher pressure valves are required.

Glossary

Action Commands
Action Commands consist of the set of commands that may be stored in the Command Buffer.

ASCII
American Standard Code for Information Interchange; a standard 8-bit information code that allows computers made by different manufacturers to interpret code in the same way.

Async Commands
Async Commands consist of those commands that affect the PSD/4 SF while the Command Buffer is being executed.

Back Pressure
Pressure opposed to the desired flow of fluids in confined places, such as a tube, due mostly to friction between the fluid and the tube wall. Back pressure can improve fluid flow precision. Flow restrictors can be implemented to increase the back pressure in the system.

Back-off Steps
Back-off Steps refers to the number of Steps the syringe motor moves down after the initial motor stall during an initialization command. The syringe Back-off prevents syringe tip compression from adversely effecting accuracy and precision.

Baud
A measurement of the speed at which information can be transmitted between computer devices. If the baud rate is 9600, then 9600 bits can be transmitted per second.

Cavitation
An occurrence caused by applying a high vacuum to a liquid (gas dissolved in liquid can be pulled out of solution). It generally occurs when large syringes (5 and 12.5 mL) are driven at high speeds.

Checksum
A digit representing the correct sum of digits which is stored as digital data and is used to compare with data strings later to detect errors.

Command Buffer
The Command Buffer is a list of zero or more Action Commands to be executed by the PSD/4 SF.

Command String
A valid Command String consists of one of the following:

a. Nothing
b. An Async Command
c. A Query Command
d. A Control Command
e. One or more Action Commands
f. One or more Action Commands followed by a Control Command

In cases a, e, and f:

1. The Command Buffer is cleared before the Command String is processed.
2. The Action Commands (if any) in the Command String are placed into Command Buffer.
3. A Control Command that starts execution of the Command Buffer starts execution from the beginning of the Command Buffer.

In cases b, c, and d:

1. The command is processed immediately.

Commands
Commands are the primary communications syntax used by the PSD/4 SF. All commands are a single character followed by a numeric parameter. If the parameter is omitted, it is assumed to be zero. Some commands do not require a parameter, and therefore ignore the parameter.

Control Commands
Control Commands consist of those commands that are used to start or resume execution of the Command Buffer.

Controlling Device
The system used to communicate with the PSD/4 SF.

Daisy Chain
A string of instruments connected in a serial configuration.

Data Block
The basic unit of communication between the Controlling Device and the PSD/4 SF when using Standard or Terminal Protocols.

Default
A predetermined value in a program or in computer circuitry that an operator may or may not alter.

Diluent
A fluid that is added to a sample to lessen the sample's concentration.

Dispense Tubing
This provides a liquid path to pick up reagents and samples from reservoirs and tubes. It also serves as the dispense path for all reagents and samples.

Execute
To run a computer program or a method; to interpret machine instructions to perform programmed operations.

Fill Tubing
This provides the liquid path from a reservoir of reagent or diluent to the left side of the active valve.

Initialize
To establish the basic or "home" conditions for starting a process.

Maximum Velocity
The maximum velocity in Motor Steps per second the syringe motor may attempt to reach.

Prime
Fluid running through the tubing lines of an instrument ensure that neither bubbles nor air gaps exist in the tubing. The system must be primed before using it for the first time such as at the start of a work day or between fluid changes.

Pump Status
The first byte of all Response Strings.

Query Commands
Query Commands consist of those commands that are used to return information about the PSD/4 SF to the Controlling Device.

Response String
A Response String consists of data being returned from the PSD/4 SF to the Controlling Device. The first byte of all Response Strings is the Pump Status. The term Response String does not refer to any of the protocol information that accompanies the response data.

Return Steps
Return Steps refers to the number of steps the syringe motor uses to compensate for mechanical backlash, which increases syringe accuracy and precision. Each downward movement of the syringe drive travels an extra Return Step, and is immediately followed by an upward movement of Return Steps.

Sequence Data
Ensures that a command is not skipped or the same command is not executed twice due to a communication error.

Standard Resolution
Standard Resolution is the default resolution for the PSD/4 SF. In Standard Resolution, the PSD/4 SF has 192,000 steps per full stroke.

Start Velocity
The velocity in Motor Steps per second at which a syringe move starts. The Start Velocity used for a given move is never greater than the Maximum Velocity for that move.

Steps
Steps are the number of stopping positions available for use with the PSD/4 SF.

Stop Velocity
The velocity in Motor Steps per second at which a syringe move ends. The Stop Velocity used for a move in the down direction is equal to the Start Velocity for that move. The Stop Velocity used for a given move is never less than the Start Velocity and never greater than the Maximum Velocity for that move.

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HAMILTON®

Web: www.hamiltoncompany.com
USA: 800-648-5950
Europe: +41-58-610-10-10

Hamilton Americas & Pacific Rim
Hamilton Company Inc.
4970 Energy Way
Reno, Nevada 89502 USA
Tel: +1-775-858-3000
Fax: +1-775-856-7259
sales@hamiltoncompany.com

Hamilton Europe, Asia & Africa
Hamilton Bonaduz A.G.
Via Crusch 8
CH-7402 Bonaduz, Switzerland
Tel: +41-58-610-10-10
Fax: +41-58-610-00-10
contact.lab.ro@hamilton.ch

To find a representative in your area, please visit hamiltoncompany.com/contacts.