XP 3000 Modular Digital Pump
OPERATOR'S MANUAL
725730C

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1 - Getting Started

Congratulations on your purchase of the Model XP 3000 Modular Digital Pump from Cavro Scientific Instruments, Inc.

The XP 3000 is a compact OEM pump module designed to handle precision liquid handling applications in the 5 μL to 5 mL range. It is controlled by an external computer or microprocessor and automates pipetting, diluting, and dispensing functions.

This chapter includes these topics:

- Regulatory Considerations
- XP 3000 Features at-a-Glance
- Unpacking the XP 3000
- Functional Description of the XP 3000
- Tips for Setting Up the XP 3000
- Mating Connector Suppliers
- Power and Electrical Considerations
- Choosing a Power Supply

Regulatory Considerations

The XP 3000 is a general laboratory module. Since it is not a medical device, it is not subject to FDA regulatory approval. The XP 3000 uses UL-approved components wherever possible.

CE

Wherever possible, UL-approved components have been used in the design and manufacturing of the XP 3000. As a module designed for incorporation into larger systems which require independent testing and certification, the XP 3000 does not carry its own CE mark. Compliance with EMC Directive 89/336 EEC may be inferred from testing of the Cavro MSP 9000 Mini Sample Processor, including the XP 3000, which meets all requirements of the EMC Directive.

Radio Interference

The XP 3000 generates, uses, and can radiate radio frequency energy which may cause interference to radio and television communications. Follow standard good engineering practices relating to radio frequency interference when integrating the XP 3000 into electronic laboratory systems.

XP 3000 Features at-a-Glance

The XP 3000 is a compact syringe pump that is designed for OEM precision liquid handling applications. It has the following standard features and functions:

- Small and lightweight
- Syringe sizes from 50 µL to 5 mL
- Accuracy < 1.0% at full stroke
- Precision ≤ 0.05% at full stroke
- Standard dispense/aspirate resolution of 3,000 steps
- Microstep dispense/aspirate resolution of 24,000 steps
- 3-port-, 3-port distribution-, and T- valves, or Y-block
- Borosilicate glass, Kel-F® and Teflon® fluid contact
- Optional RS-232/RS-485 or CAN/RS-485 interface
- Programmable plunger speeds from 1.2 sec/stroke to 20 min/stroke, with ramps and on-the-fly speed changes
- Valve leak detection
- Rack and pinion drive with lost-step detection
- Manually movable syringe drive (power off)
- Pump diagnostics, self-test, and error reporting
- 5K programmable EEPROM
- Auxiliary inputs and outputs
- Operates using a single 24VDC power supply

Unpacking the XP 3000

To unpack the module, follow these steps:

1. Remove the pump module(s) and accessories from the shipping cartons.
2. Check the contents against the packing slip to make sure that all the components are present.

ESD Considerations

The XP 3000 is an electronic device that is sensitive to electrostatic discharge (ESD). Static discharge from clothing or other fixtures can damage these components. To prevent premature failure of pump components, the XP 3000 should be handled using good ESD practices. These include, but are not limited to:

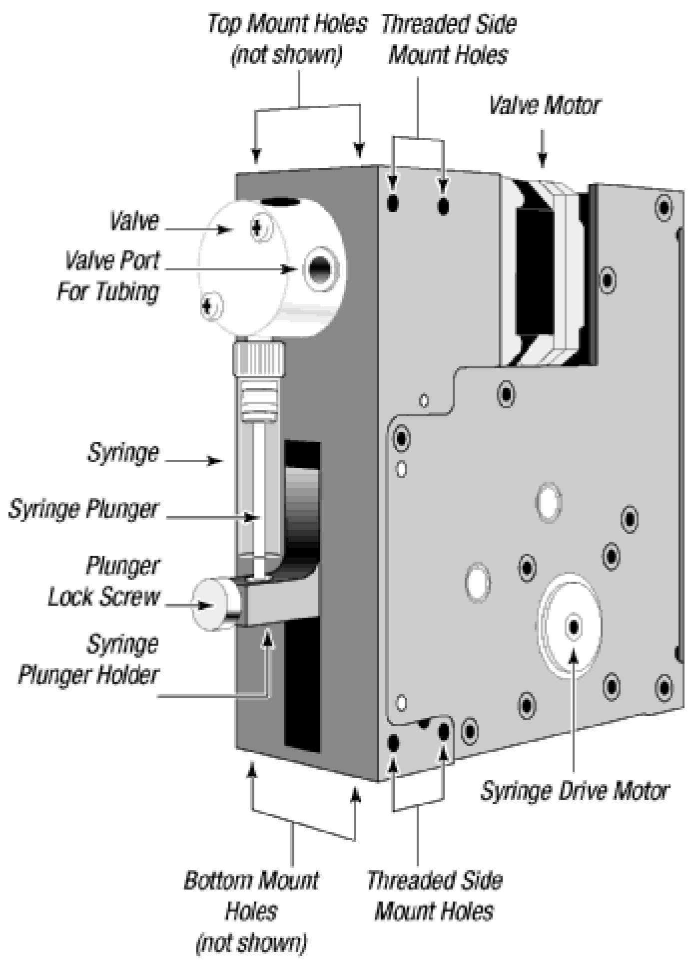
- Using wrist or ankle straps
- ESD mats or worktables
- ESD wax on the floor

Prepare an ESD-free work area before the chassis is grounded.

Functional Description of the XP 3000

The XP 3000 uses a stepper-motor driven syringe and valve design to aspirate and dispense measured quantities of liquid. Both the syringe and the valve are replaceable. Functional descriptions and illustrations of each major XP 3000 component are provided in the sections that follow.

Figure 1-1. XP 3000 Modular Digital Pump



Syringe and Syringe Drive

The syringe plunger is moved within the syringe barrel by a rack and pinion drive that incorporates a 1.8° stepper motor and quadrature encoder to detect lost steps.

The syringe drive has a 30 mm travel length and resolution of 3000 steps (3000 or 24000 steps for microstep-enabled firmware). When power is not applied to the pump, the syringe drive can be moved by pushing up or down firmly on the plunger holder assembly. This facilitates syringe removal.

The base of the syringe plunger is held to the drive by a knurled screw. The top of the syringe barrel attaches to the pump valve by a 1/4-28" fitting.

Figure 1-2 shows the components of a typical syringe.

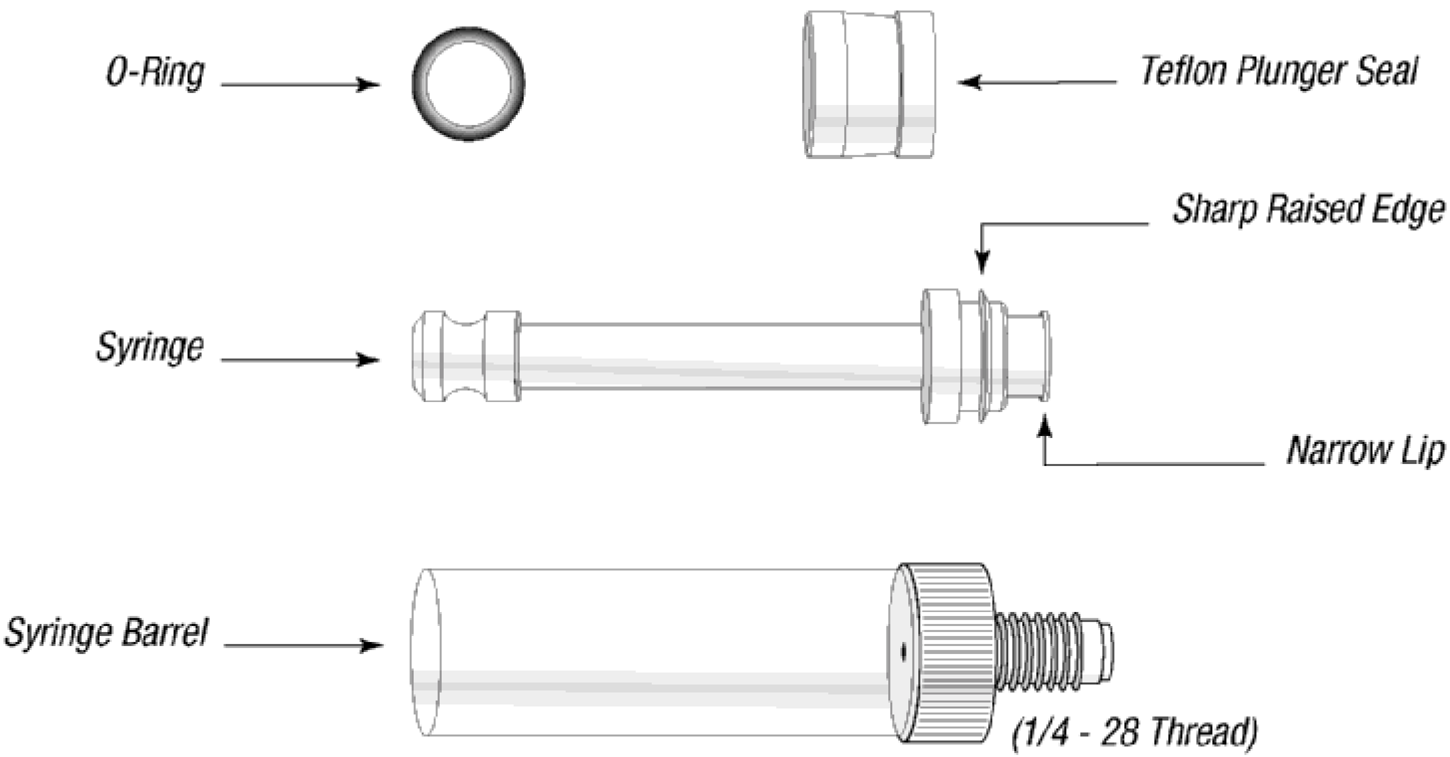


Figure 1-2. Syringe Components

Syringes are available in these sizes: 50 µL, 100 µL, 250 µL, 500 mL, 1.0 mL, 2.5 mL, and 5.0 mL. For ordering information, see Appendix A, “Ordering Information.”

Valve and Valve Drive

The valve is made of a Kel-F body and Teflon plug. The plug rotates inside the valve body to connect the syringe port to the various input and output ports. The valve is turned by a 1.8° stepper motor that has an encoder coupled to it for positioning feedback. A small circuit board is located under the valve drive. This board contains the optical sensor for the valve encoder and a home sensor for the syringe drive.

Figure 1-3 shows the components of a 3-port valve.

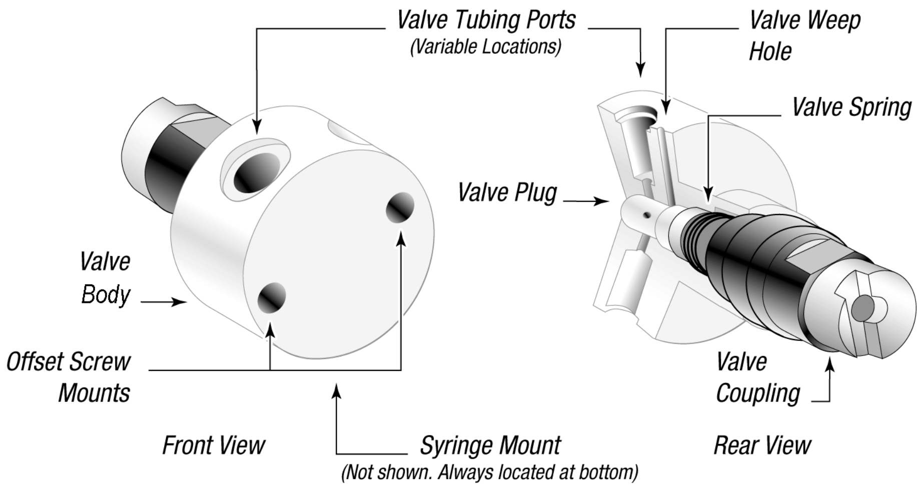


Figure 1-3. 3-Port Valve Components

The XP 3000 is available with the following valves:

- Three-port valve. This valve has an input port, output port, and syringe port. The syringe port is a “common” port, which means it is always connected to one of the other two ports. In the standard configuration, the ports are placed at 120° intervals around the circular valve body.
- T-valve. This valve has an input port, output port, and syringe port. The syringe port is a “common” port, which means it is always connected to one of the other two ports. The input and output ports are designed to be easily flushed. The ports are placed at 90° intervals from the syringe port.
- Three-port distribution valve. This valve has four ports. The common syringe port can distribute fluid to an input port, an output port, and an extra port. The ports are placed at 90° intervals around the circular valve body.
- Y-block. In place of the switchable valve, there is a Kel-F manifold with two ports at 120° intervals from the syringe port for input and output. No valve motor is included.

Printed Circuit Board

The printed circuit board (PCB) holds the microprocessor and circuitry to control the syringe and valve drives. The accessible external face of the PCB provides connectors for electrical inputs and outputs, jumpers for configuring different modes of operation, and a communications address switch. Jumpers can be added or removed to select the desired communication mode. For more information on the modes of operations, see Chapter 3, “Software Communication.”

Figure 1-4 shows the accessible components of the printed circuit board.

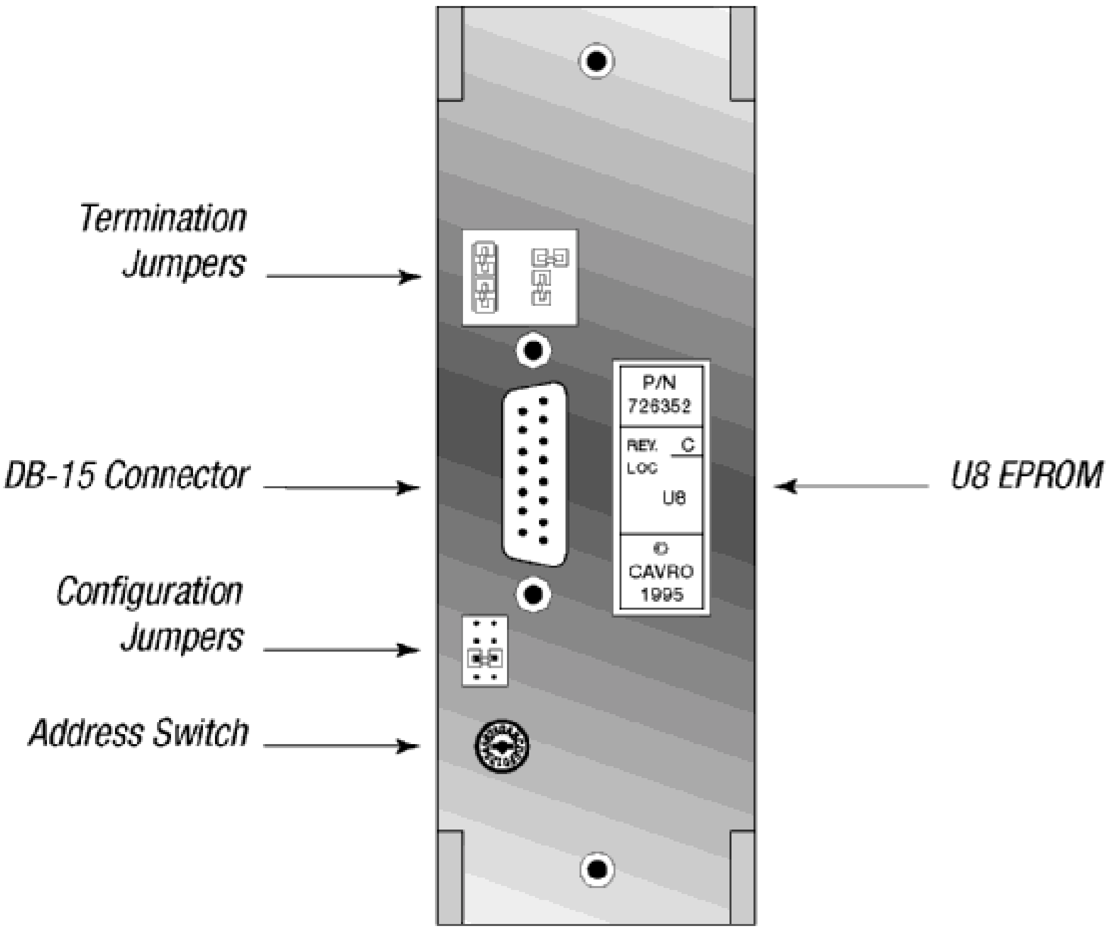


Figure 1-4. XP 3000 Printed Circuit Board External Connectors

For more information on the printed circuit board inputs/outputs, jumpers, the address switch, and EPROM, see Chapter 2, “Hardware Setup.”

Communication Interfaces

Depending on the pump configuration, the XP 3000 can communicate singly or in a multi-pump configuration through an RS-232, RS-485, or CAN (Controller Area Network) interface. For RS-232 and RS-485, baud rates of 9600 and 38400 are supported. For CAN, baud rates of 100K and 125K are supported.

For details on the communications interfaces, see Chapter 2, “Hardware Setup.”

Multi-Pump Configurations

Up to fifteen XP 3000s can be connected together in a *multi-pump configuration* (also called “daisy-chaining”). Within a multi-pump configuration, the RS-485 communications bus is required, although the first pump in the chain may receive either RS-232 or RS-485 communications. For CAN communication, neither RS-232 or RS-485 is required. Each pump can be addressed separately from a single terminal via its unique address, which is set using the address switch on the back panel of the pump. For more information on setting addresses, see Chapter 2, “Hardware Setup.” For XPs with microstep-enabled firmware, up to 16 XP 3000s can be connected together in a multi-pump configuration.

Valve Sensor

The XP 3000 sensor board includes a circuit that detects fluid leakage out the back of the valve. The valve is made of a Kel-F body and a Teflon plug which rotates inside the body. Over time, the plug wears, causing the valve to leak. The length of time before leakage occurs depends on the type of fluids used, duty cycle of the pump, and maintenance procedures. The circuit will detect conductive fluid (i.e., ionic solution). On power-up, the valve leak detector is set to 0, which means it is disabled. The user sets the sensitivity of the leak detector. If fluid is detected, the pump returns an error code.

Tips for Setting Up the XP 3000

For complete information on setting up the XP 3000, see Chapter 2, “Hardware Setup” and Chapter 3, “Software Communication.”

To ensure proper operation, follow these tips:

- ❑ Always set up and mount the pump in an upright position. Failure to do so can cause problems priming the system.
- ❑ Always run liquid through the syringe and valve when they are moving. Failure to do so can damage the sealing surfaces.
- ❑ Before running any organic solvents through the pump, see Appendix D, “Chemical Resistance Chart” for more information on solvents.
- ❑ Keep fingers out of the syringe slot while the pump is running. Failure to do so can cause injury.
- ❑ Always power down the instrument when connecting or disconnecting pumps.

Mating Connector Suppliers

Cavro does not sell mating connectors beyond those found on its evaluation power supply. For customer convenience, a list of DB-15 mating connectors is provided below (Table 1-1).

Table 1-1. DB-15 Mating Connectors

Manufacturer	Description	Manufacturing Part Number
	Cable Connector, Receptacle	
AMP	15 pin female - solder cup, receptacle	747909-2
Cinch	15 pin female - solder cup, receptacle	DA-15S
	Cable Connector, Housing	
AMP	Plastic housing with locks	207908-4
Cinch	Plastic housing with locks	SDH-15GL-CS
Fujitsu	Metal Housing	FCN-770C015-C/E
Fujitsu	Locking post screw	FCN-770A15
	Circuit Board Connectors	
Fujitsu	15 pin female - straight for .62 to .93 mm thick PCB	FCN-774J015-G/C
AMP	15 pin female - straight for .62 to .93 mm thick PCB	745184-1
	Flat Ribbon	
3M	15 pin female - 15 pin flat ribbon receptacle	89815-8000
3M	15 pin female - strain relief	3448-8D15A

Power and Electrical Considerations

Choosing a Power Supply

The XP 3000 is powered by a 24VDC line via the DB-15 connector. The 24VDC supply for a single XP 3000 should meet the following basic requirements:

- Output voltage: 24V nominal
- Output voltage tolerance: ±10% minimum, ±5% preferred
- Output voltage regulation: ±1% with varying line (input voltage) and load
- Output current (not including loads other than a single pump):
  - ≥ 1.5A for power supplies with minimal capacitance
  - ≥ 850mA for power supplies with internal filter capacitance of at least 1000 μF per amp of output current
  - ≥ 850mA for power supplies with external capacitance of at least 1000 μF per amp of output current (aluminum electrolytic capacitor preferred)
- Output voltage ripple: 50mV rms maximum at full load
- Conformance to required safety and EMI/RFI specifications
- Voltage turn-on and turn-off overshoot: < 2 volts
- Minimum current load (for switchers): see "Switching Power Supplies" in this chapter.

To meet the above basic requirements, the supply must incorporate either linear or switching regulation; it must have adequate output filter capacitance.

A current-limiting power supply is recommended. Current limiting above 1.0A is acceptable, assuming that no additional equipment is operated from the supply.

If the power supply uses current feedback, the time-current foldback point must be sufficient to allow charging of a 470 μF capacitor without folding back. If an external capacitor is used, exercise care to ensure that the supply always starts after foldback, particularly at low AC line voltage.

Integrating a Power Supply

When a power supply is used to operate more than one XP 3000 or other device, it must provide the total average current for all devices. The power supply and filter capacitance together must satisfy the total peak input current for all devices.

For example, if a system incorporates six XP 3000s with other equipment that together require 4 amps, a 10A power supply is satisfactory, provided the output filter capacitance in the supply is at least 10,000 μF:

6 x 0.85 = 5.1A; +4A = 9.1A (choose a 10A power supply)

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

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

In this example, it is assumed that all the pumps and other equipment will sometimes operate simultaneously.

External equipment with inadequate bypass capacitance or that is inadequately sourced for current can cause overvoltage transients and sags, and can create unnecessary ripple current in the XP 3000. This can result in decreased component life. Additionally, it is possible for a regulated power supply to become unstable with certain loads and oscillate if adequate filter capacitance is not present. Some forms of oscillation can cause failures in the XP 3000. These issues can be avoided by using a properly designed commercial power supply.

Consideration should also be given to the wiring of the XP 3000 and any additional devices. Wiring should be of sufficient gauge for the current, and as short as possible. Unless otherwise required by safety requirements, the power supply lines to the XP 3000 should be 20AWG or heavier. Multiple XP 3000s can be daisy-chained, provided that the wire size and the power supply are adequate for the total current. In the example of the six XP 3000s above, use 18AWG wire if the units are daisy-chained. It is best if each pair is twisted or dressed together from the device to the supply. For more information on multi-pump cabling, see Chapter 2, “Hardware Setup.”

To control power to the XP 3000, switch power to the power supply. Do not use a relay or switch contacts between the 24V supply and the XP 3000 (i.e., do not switch DC input to the pump).

Switching Power Supplies

Be sure to check carefully the minimum load requirement of the power supply. Typically, switching supplies have a minimum load requirement of up to 10% of the rated output current.

NOTE The XP 3000 idle current is less than 10% of the full running current.

For example, in a system with multiple XP 3000s, a 24V 5-amp switcher with a minimum load less that 500mA may not provide sufficient current when the XP 3000 motors are idle and all other devices are in a low current state. If the XP 3000 is the only load on the 24V supply, a switcher should have a minimum load specification of 50mA or less. An appropriate external power resistor can be used to ensure that the minimum load is met.

2 - Hardware Setup

This chapter includes these sections describing the various parts of hardware setup:

Power

The XP 3000 requires a 24VDC power supply with a current rating of at least 1.5A, provided through a DB-15 connector. Cavro recommends using one power cable for every two pumps to provide noise immunity; i.e., power should not be daisy-chained to more than two pumps.

For complete information on choosing a power supply, see Chapter 1, “Getting Started.”

Cabling

A single cable supplies both power and communications to each XP 3000. (Power is described in the “Power” section in this chapter.)

Set a unique address to identify each pump module. For more information, see “Address Switch Settings” in this chapter; see also Chapter 3, “Software Communication.”

Table 2-1. DB-15 Connector Pin Assignments

Pin	Function	Remarks
1	24VDC	
2	RS-232 TxD line	Output data
3	RS-232 RxD line	Input data
4	Unused	
5	CAN high signal line	
6	CAN low signal line	
7	Auxiliary input #1	TTL level
8	Auxiliary input #2	TTL 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	TTL level
14	Auxiliary output #2	TTL level
15	Auxiliary output #3	TTL level

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

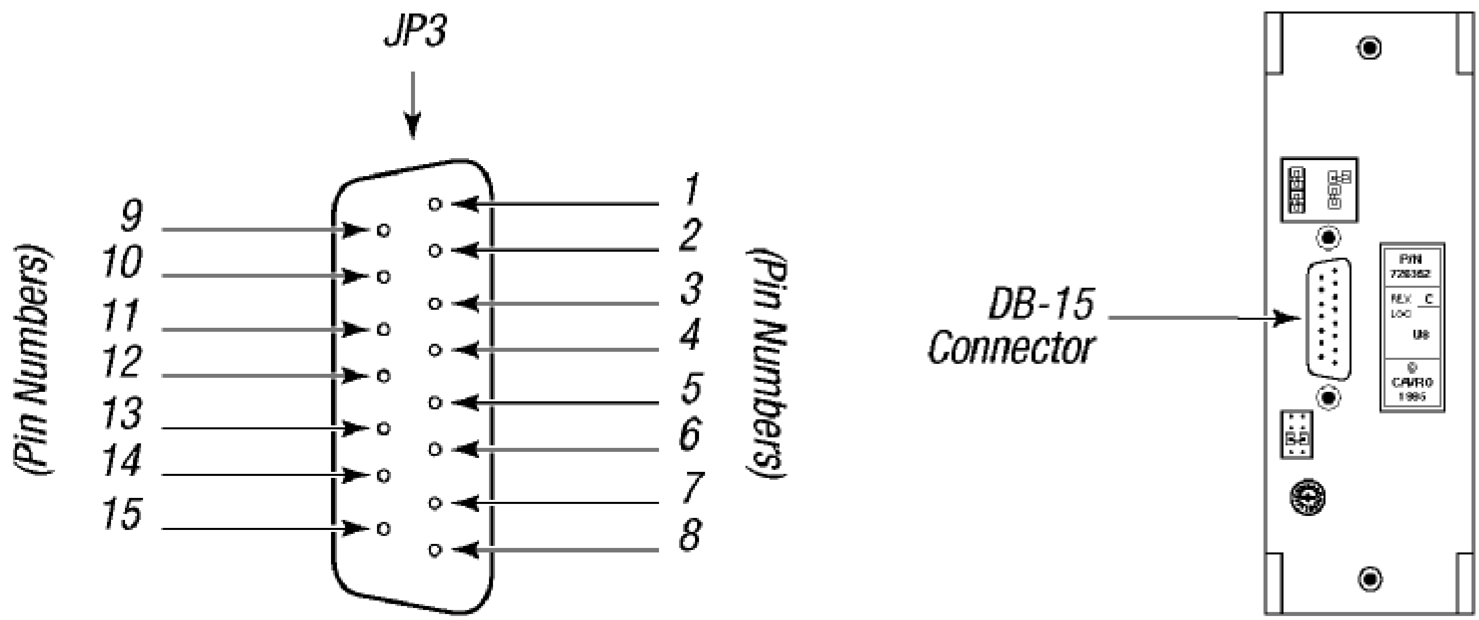


Figure 2-1. DB-15 Connector Pins

Communication Interfaces

The computer or controller communicates with the XP 3000 through an RS-485 interface, RS-232 interface, or CAN (Controller Area Network) interface. The RS-232 interface automatically converts the protocol to RS-485 for the benefit of any other devices which may be connected to the XP 3000’s RS-485 communications bus (this constitutes a so called “multi-drop” device configuration).

NOTE The RS-232 interface does not support hardware handshaking and requires only three lines: RXD, TXD, and Signal Ground.

When using a multi-drop arrangement, up to 15 pumps can be addressed by the controller on the same communications bus (up to 16 pumps for microstep-enabled firmware). Take special care to ensure that the RS-485 A and B lines are not reversed. Special consideration must be given to the position of jumpers on JP2. These jumpers switch termination resistors into the RS-485 A and B line circuits, thereby dampening the signal at the ends of the RS-485 chain. This prevents echoing of the signal back to the listeners on the chain. Multi-drop configurations require jumpers in both positions of JP2 for the first and last pump in the RS-485 chain (i.e., the ends of the chain). Single pump configurations (i.e., only one pump communicating with a controller) always require that jumpers be installed on JP2.

Figure 2-2 shows the termination jumpers on the printed circuit board.

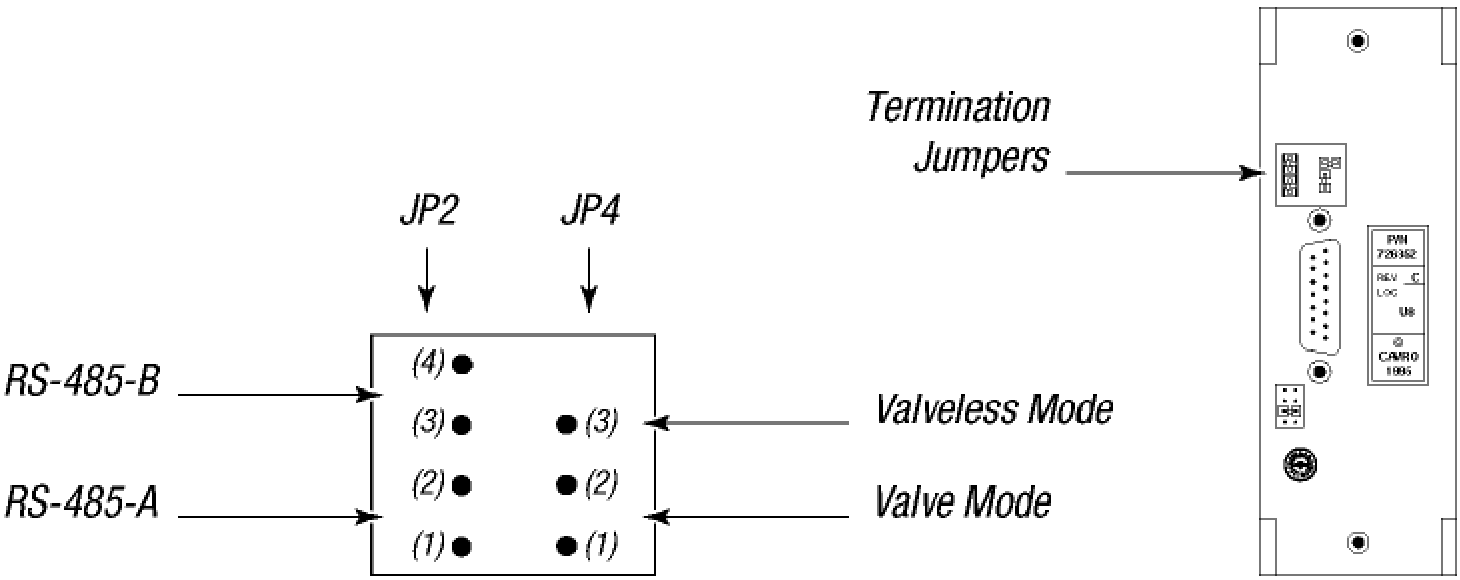


Figure 2-2. Termination Jumpers

> **NOTE** Pumps are shipped with the RS-485 termination jumper installed on JP2. Please remove the jumpers if they are not needed.

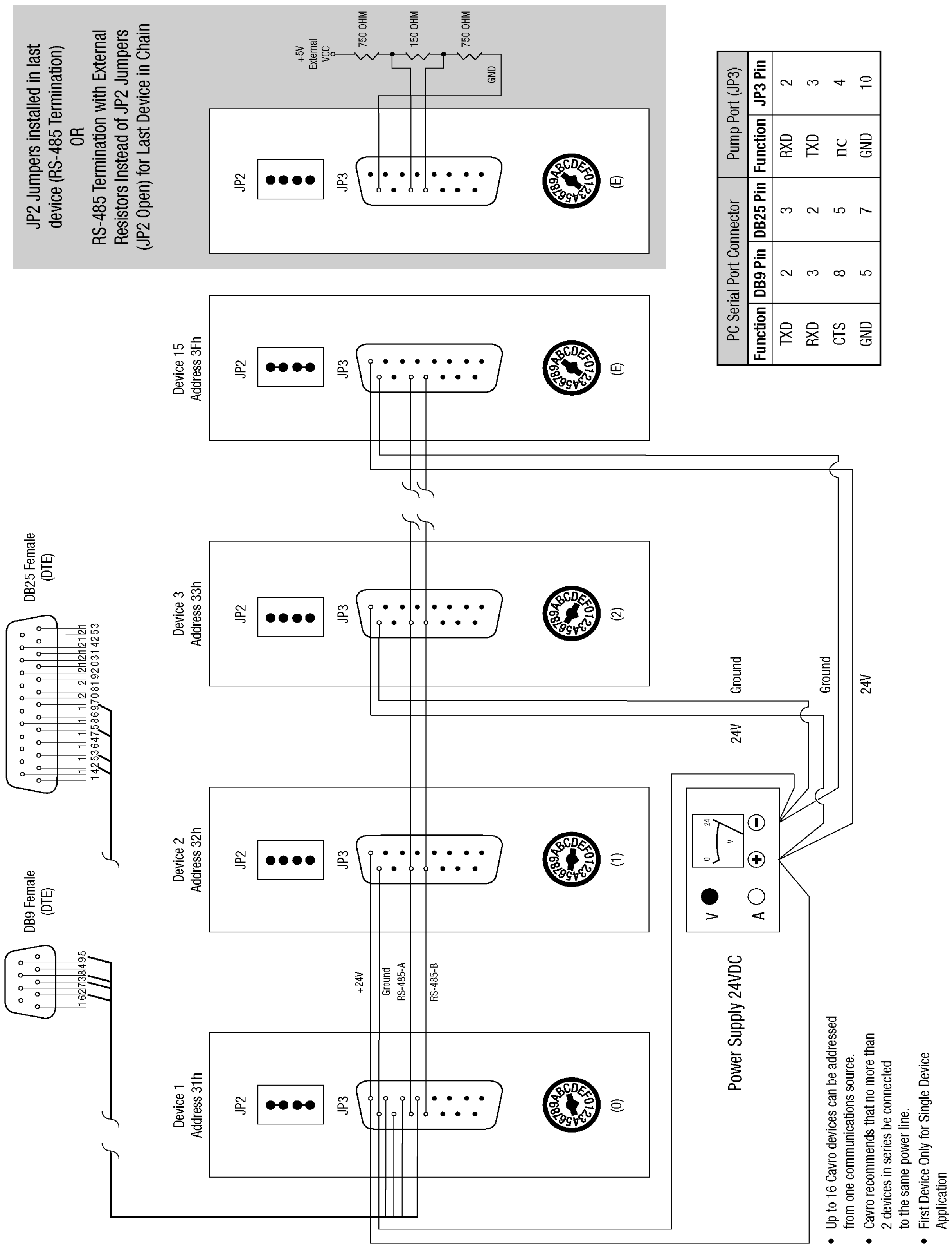
When communicating with the pumps via RS-232, one pump in the chain must be configured for RS-232 communication. This pump receives the RS-232 signal from the PC or controller and converts it to RS-485, then passes the RS-485 signal to all other pumps in the chain.

Refer to the cabling illustrations on the following pages. These illustrations show the multi-pump cabling for RS-232, RS-485, and CAN connections, respectively. Also shown is the external termination scheme for the RS-485 chain. This scheme can be used if the terminators are installed in the system instead of on the pump.

The CAN interface is a two-wire serial system. The bus is driven differentially in a manner similar to RS-485. The major difference is in the protocol. The CAN protocol is designed to allow any device on the bus to send a message at any time. This is unlike other two-wire interfaces in which the slave devices can only transmit in response to a query. Using the CAN interface, the pump can send a message to inform the master that it has completed its task. Anti-collision detection (which reconciles problems that occur when two devices talk at once) is carried out by the CAN controller hardware.

> **NOTE** Always power off pumps before connecting to or disconnecting from the bus. For XP 3000s with microstep-enabled firmware, please refer to “Configuration Jumpers (JP1) for Microstep-Enabled Firmware” and “Termination Jumpers (JP4) for Microstep-Enabled Firmware,” later in this chapter.

RS-232 CABLING



PC Serial Port Connector			Pump Port (JP3)	
Function	DB9 Pin	DB25 Pin	Function	JP3 Pin
TXD	2	3	RXD	2
RXD	3	2	TXD	3
CTS	8	5	nc	4
GND	5	7	GND	10

Figure 2-3. RS-232 Multi-Pump Cabling

RS-485 CABLING

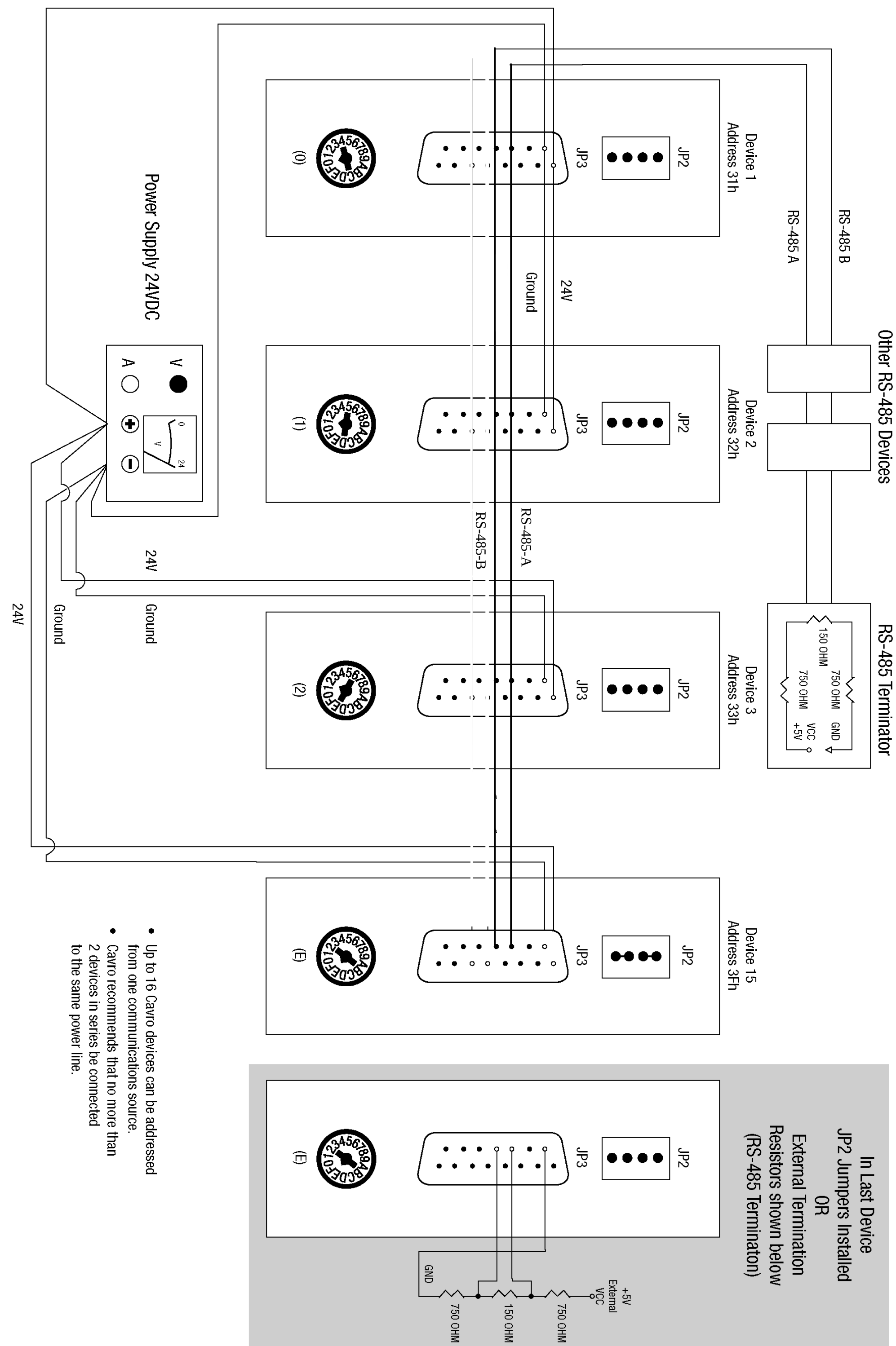


Figure 2-4. RS-485 Multi-Pump Cabling

CAN Cabling

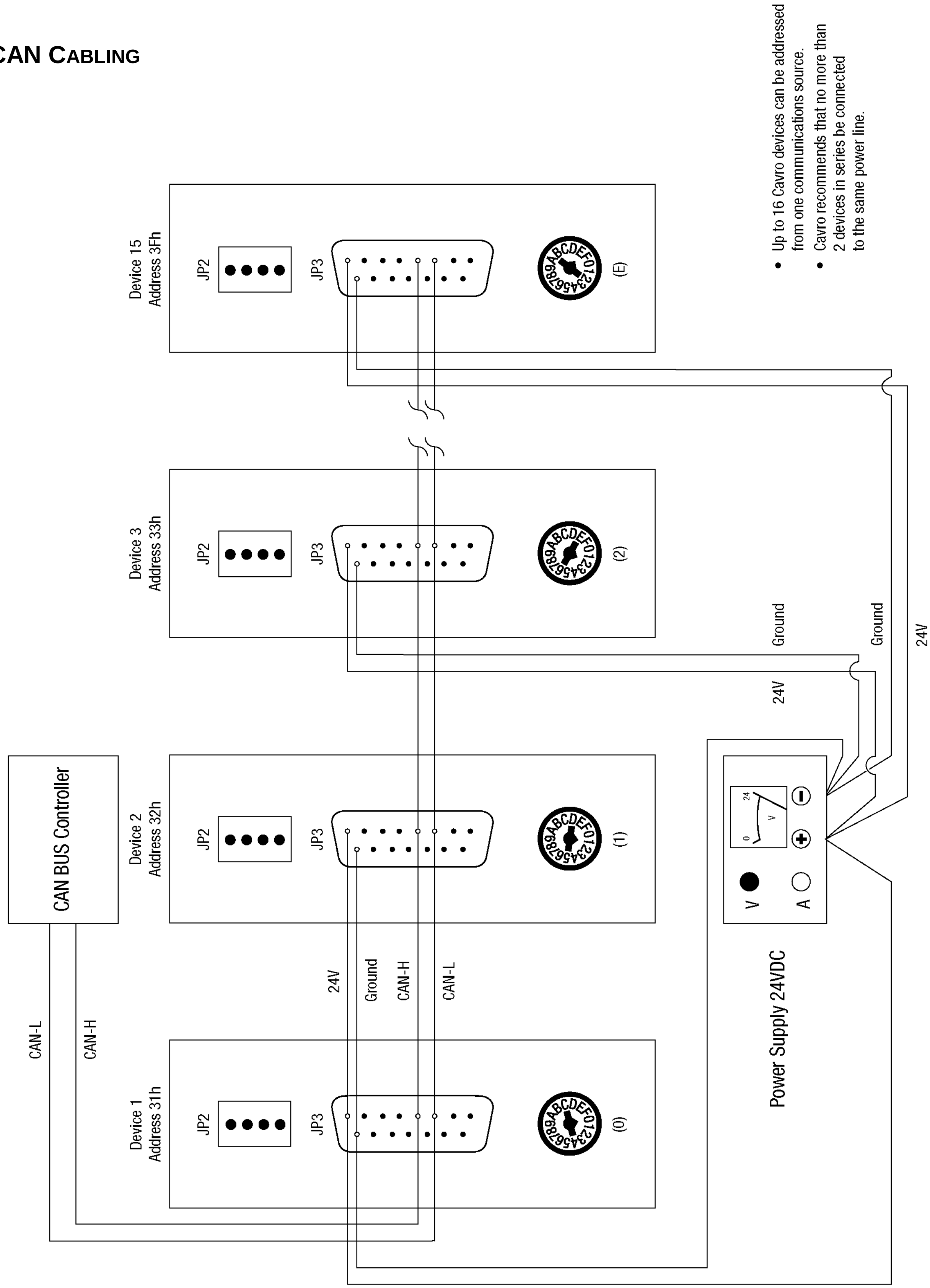


Figure 2-5. CAN Multi-Pump Cabling

Printed Circuit Board Settings and Options

Configuration Jumpers (JP1) for Standard Firmware

Connector JP1 on the XP 3000 printed circuit board is used to configure different modes of operation (see Figure 2-6). Jumpers are added or removed to enable or disable the different modes. The jumpers control set the following:

Plunger overload detection (JP1-1)

Communications protocol (JP1-2)

EEPROM, autostart mode (JP1-3)

Baud rate (JP1-4)

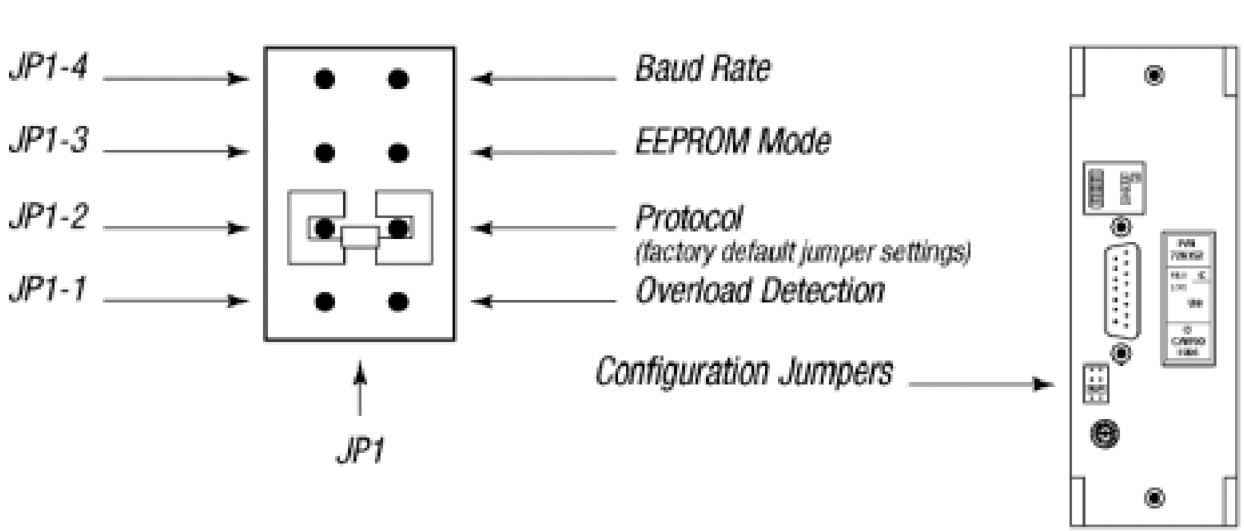


Figure 2-6. Configuration Jumpers

NOTE	Always power off the XP 3000 before changing any of the jumpers on JP1.

JP1-1: PLUNGER OVERLOAD DETECTION

This jumper position allows enabling or disabling of plunger overload detection. There are two settings:

JP1-1 removed	Plunger overload detection enabled (default setting)
JP1-1 installed	Plunger overload detection disabled

CAUTION! Do not disable plunger overload detection; it is used for manufacturing test only. If a jumper is installed at JP1-1, plunger overload will not be detected and the pump will not generate an error code if it is losing steps.

JP1-2: COMMUNICATIONS PROTOCOL (UNUSED FOR CAN)

This jumper position sets the XP 3000 communications protocol. There are two settings:

JP1-2 removed	Data Terminal (DT) protocol
JP1-2 installed	OEM protocol (default setting)

For more information on the XP 3000 communications protocols, see Chapter 3, Software Communication."

JP1-3: EEPROM AUTOSTART

This jumper position activates or inactivates the autostart mode of the EEPROM. For instructions on programming or running the XP 3000 using the EEPROM, see Chapter 3, Software Communication." There are two settings:

JP1-3 removed	EEPROM autostart mode inactivated (default setting)
JP1-3 installed	EEPROM autostart mode activated

JP1-4: BAUD RATE

This jumper position is used to select the baud rate for the RS-232/RS-485 version of the XP 3000. There are two baud rates to select from:

JP1-4 removed	9600 baud (default setting) 100K baud for CAN (for microstep-enabled firmware)
JP1-4 installed	38400 baud 125K baud for CAN (for microstep-enabled firmware)

NOTE The XP 3000 is shipped with spare jumper placed across the top of pin JP4. This can be used to change the default configuration settings.

Configuration Jumpers (JP1) and Termination Jumpers (JP4) for Microstep-Enabled Firmware

> **NOTE** To determine whether or not your XP 3000 carries microstep-enabled firmware, check the part number on the EPROM label. If the part number is 600,*xxx*, this section applies to your pump.

The XP 3000 microstep-enabled firmware automatically detects the mode the user is programming in, OEM or DT. Jumpers are not needed to engage this feature.

Two jumpers on the XP 3000 have new functionality:

- JP1 (configuration jumper)
- JP4 (mode jumper)

Mode Jumper JP4

When pins 1 and 2 are jumpered, the XP 3000 is in standard running mode. In this mode, the pump accepts all commands.

> **CAUTION!** For microstep-enabled firmware, when pins 2 and 3 are jumpered, the XP 3000 is in factory set mode. This mode is reserved for Cavro factory use only. Enabling the factory set mode may cause major functional changes to the unit. Simply moving the jumper back to the standard running mode will not reset the pump to its original configuration. If the factory set mode is accidentally enabled, please call Cavro's Technical Service to reset the unit.

The JP4 jumper settings for each mode are shown below.

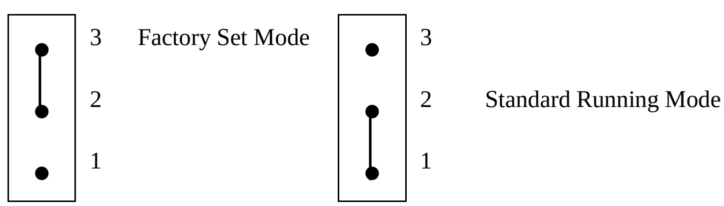


Figure 2-7. JP4 Jumper Settings Per Mode

CONFIGURATION JUMPER JP1

The table below describes the features of JP1.

Jumper	Standard Running Mode
JP1-1	Overload Disable
JP1-2	Reserved
JP1-3	Self-Test and EEPROM
JP1-4	Baud Rate

JP1-1, Plunger Overload Detection

This jumper position allows enabling or disabling of plunger overload detection. There are two possible settings:

JP1-1 removed	Plunger overload detection enabled (default setting)
JP1-1 installed	Plunger overload detection disabled

JP1-2, Reserved

JP1-3, Self-Test and EEPROM AutoStart

When JP1-3 is in and the address switch is set to position “F,” the self-test diagnostic program will be activated. For more information on using the address switch and the self-test, see “Address Switch Settings” in this chapter.

When the address switch is in any position other than “F,” the autostart mode of the EEPROM can be activated or inactivated.

JP1-3 removed	EEPROM, self-test disabled (default setting)
JP1-3 installed	EEPROM self-test enabled

JP1-4, Baud Rate

This jumper position is used to select the baud rate for the RS-232/RS-485 version of the XP 3000. There are two baud rates to select from:

JP1-4 removed	9600 baud (default setting) (100K baud for CAN)
JP1-4 installed	38400 baud (125K baud for CAN)

Figure 2-8 shows the printed circuit board settings for the microstep-enabled firmware.

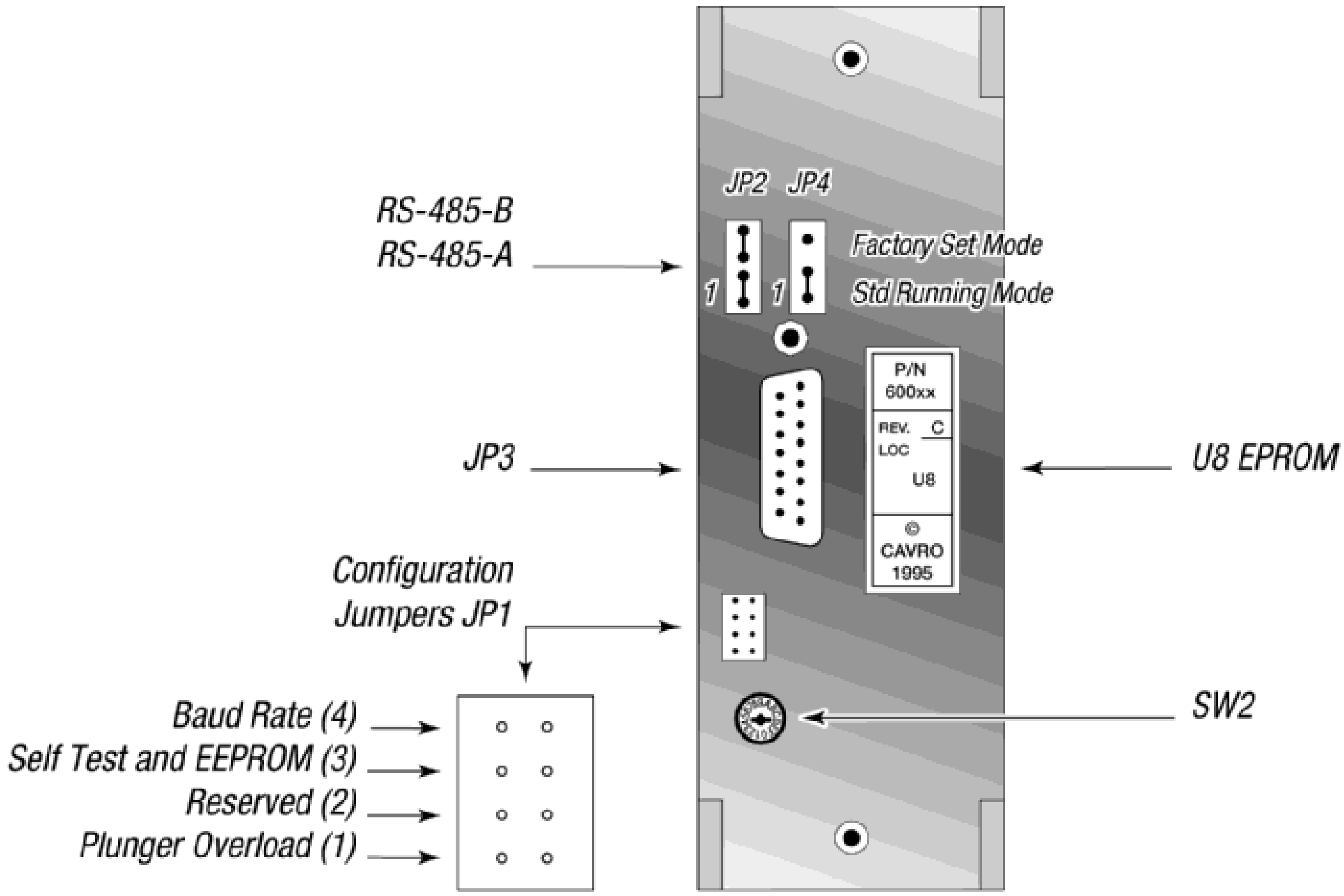


Figure 2-8. Printed Circuit Board Settings for Microstep-Enabled Firmware

Address Switch Settings

The address switch (see Figure 2-9) is located on the lower left of the XP 3000's back panel. It is used to give each XP 3000 in a multi-pump configuration a unique or specific address, allowing the user to direct commands to specific pumps. The address switch has sixteen positions (numbered 0 through F). Fifteen positions (addresses 0 through E) are valid pump addresses for standard firmware modules, sixteen (0 through F) for microstep-enabled firmware modules.

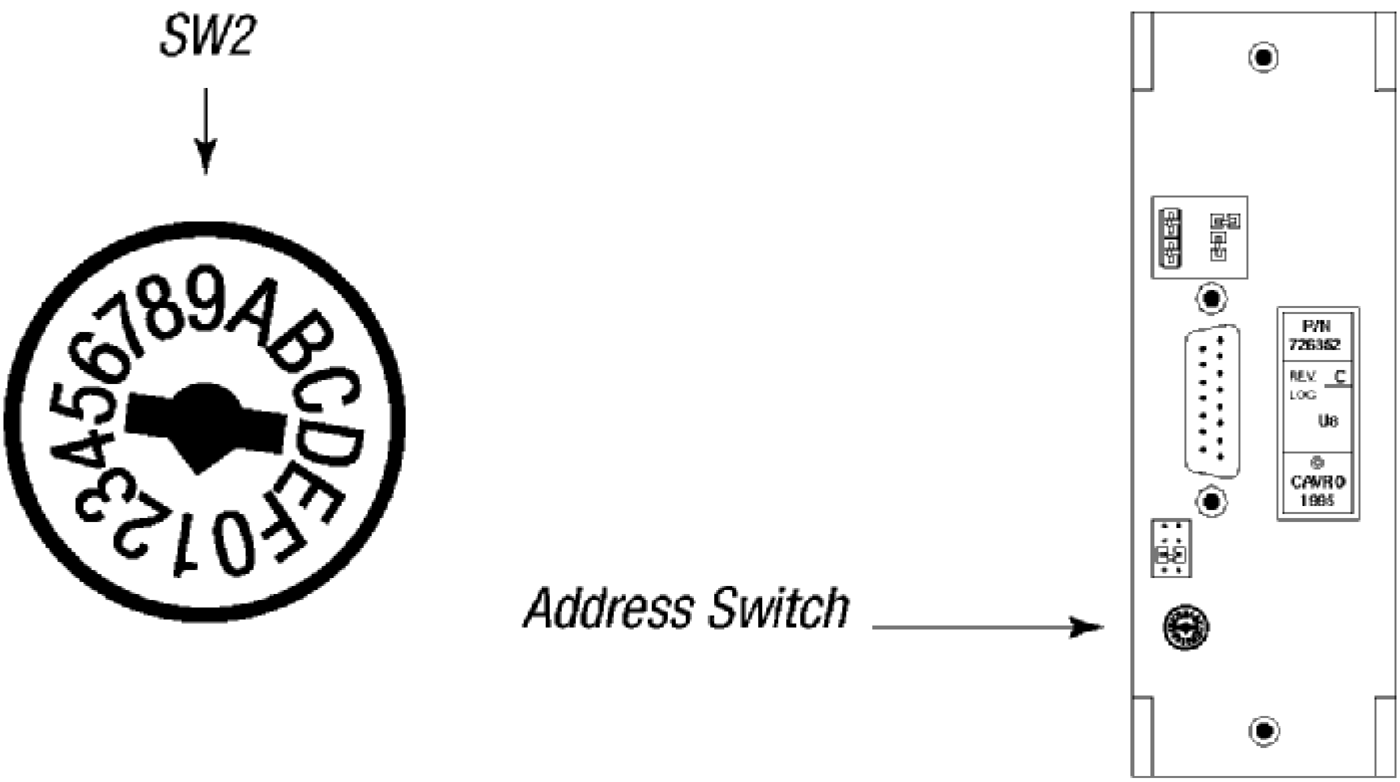


Figure 2-9. Address Switch

To set the address switch:

To set the address switch, use a jeweler's screwdriver or small flat head screwdriver and turn the switch in either direction to the desired position.

NOTE Power cycle (or power up) the pump after setting the address switch.

For information on the addressing schemes for different pump configurations, see Chapter 3, "Software Communication."

Self-Test

The “F” address switch position is used to activate the XP 3000 self-test. Self-test causes the XP 3000 to initialize then cycle repeatedly through a series of plunger movements at fifteen different speeds. If an error condition occurs, the pump stops moving. Typically, the self-test activates the pump at 800 strokes/hour.

To run the self-test, set the address switch to position “F.” If the pump carries microstep-enabled firmware, the configuration jumper JP1-3 must also be installed. Then supply power to the pump.

CAUTION!	Always run liquid through the syringe and valve. Failure to do so can damage the valve and syringe seal. Do not run self-test with a 5.0 mL syringe installed. Remove the valve and 5.0 mL syringe. Failure to do so can result in plunger overloads.

Inputs/Outputs

The XP 3000 provides two auxiliary inputs and three auxiliary outputs that can be accessed through the DB-15 connector, JP3. They provide TTL level signals. The outputs are controlled by the [J] command.

The auxiliary inputs are located on JP3 pins 7 and 8. They can be read back using report commands ?13 and ?14. Additionally, the inputs can be used to externally trigger a command sequence using the [H] command. The commands are described in Chapter 3, “Software Communication.”

The auxiliary outputs are located on JP3, pins 13, 14, and 15.

XP 3000 Without Valve

The XP 3000 without valve is available in an RS-232/RS-485 or CAN/RS-485 configuration. It uses the same components and operates the same as the XP 3000 with valve, except that it does not contain a valve, valve motor, or valve encoder. Syringes are attached using a Kel-F block which replaces the XP 3000 valve. The block has a “Y” configuration with input and output port (available in 1/4-28 or M6 fittings) and a 1/4-28 screw fitting for the syringe. Valveless pumps use the same syringes as pumps with valves.

NOTE When using a valveless pump, remove the additional jumper and set JP4 to pins 2 and 3.

The XP 3000 without valve uses the same commands as the XP 3000 with valve with the exception of the initialize command, valve commands and valve overload error. For more information on the commands, see Chapter 3, “Software Communication.”

NOTE Valveless pumps require a system valve external to the pump. They are commonly used with other Cavro devices.

During power-up, the valve initializes. The valve encoder will make a complete revolution in a clockwise direction. The valve stops at the left-hand port (as viewed from the front of the pump). If the valve is at another position during power-up, the encoder will turn clockwise to the left-hand port, then it will make a complete revolution. *The syringe plunger does not move*.

Installing Components

See Chapter 5, "Maintenance," for the procedures for replacing and maintaining components.

Installing the XP 3000 Valve

NOTE The valves are not interchangeable among pumps. To use a different model valve, contact Cavro Customer Support.

These instructions apply to the 3-port valve, the 3-port distribution valve, and the T-valve.

To install the XP 3000 valve, follow these steps:

1. Place the pump upright on a table surface, with the front facing you.
2. Verify that the offset tab on the encoder in the pump is correctly oriented (vertically with the tab to your right).
3. Rotate the valve coupling to the position shown on the left in Figure 2-10 (vertically with the offset tab to your left).

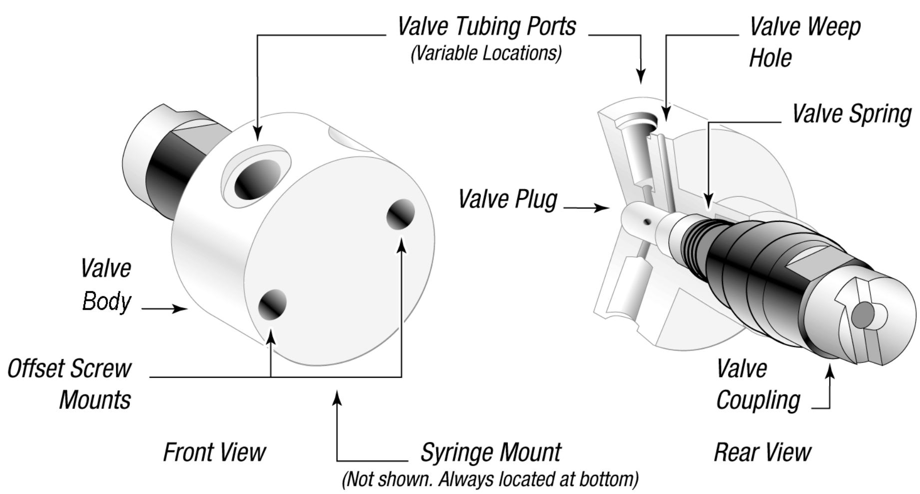


Figure 2-10. XP 3000 Valve Installation (3-Port Valve Shown)

4. Install the valve by inserting the slot in the valve coupling onto the tab of the encoder. The valve should be oriented with the tube fittings on top and the syringe fitting on the bottom.
5. Gently push the valve in place, matching the locating pins on the valve fit the holes on the front of the pump.
6. Secure the valve with two Phillips head valve screws through the mounting holes. After the screws contact the valve body, tighten further ¼ to ½ turn.

Installing a Syringe

To install a syringe, follow these steps:

1 Loosen the plunger lock screw approximately three full turns.

2 Lower the plunger drive by sending the command [A3000R]. If power is not applied, the plunger drive can be manually lowered by pushing down firmly on the plunger holder assembly.

3 To install the syringe, do the following (as shown in Figure 2-11):

a Screw the syringe into the valve.

b Pull the syringe plunger down to the plunger holder assembly.

c Screw the syringe plunger into place.

NOTE Make sure the plunger lock screw is securely tightened.

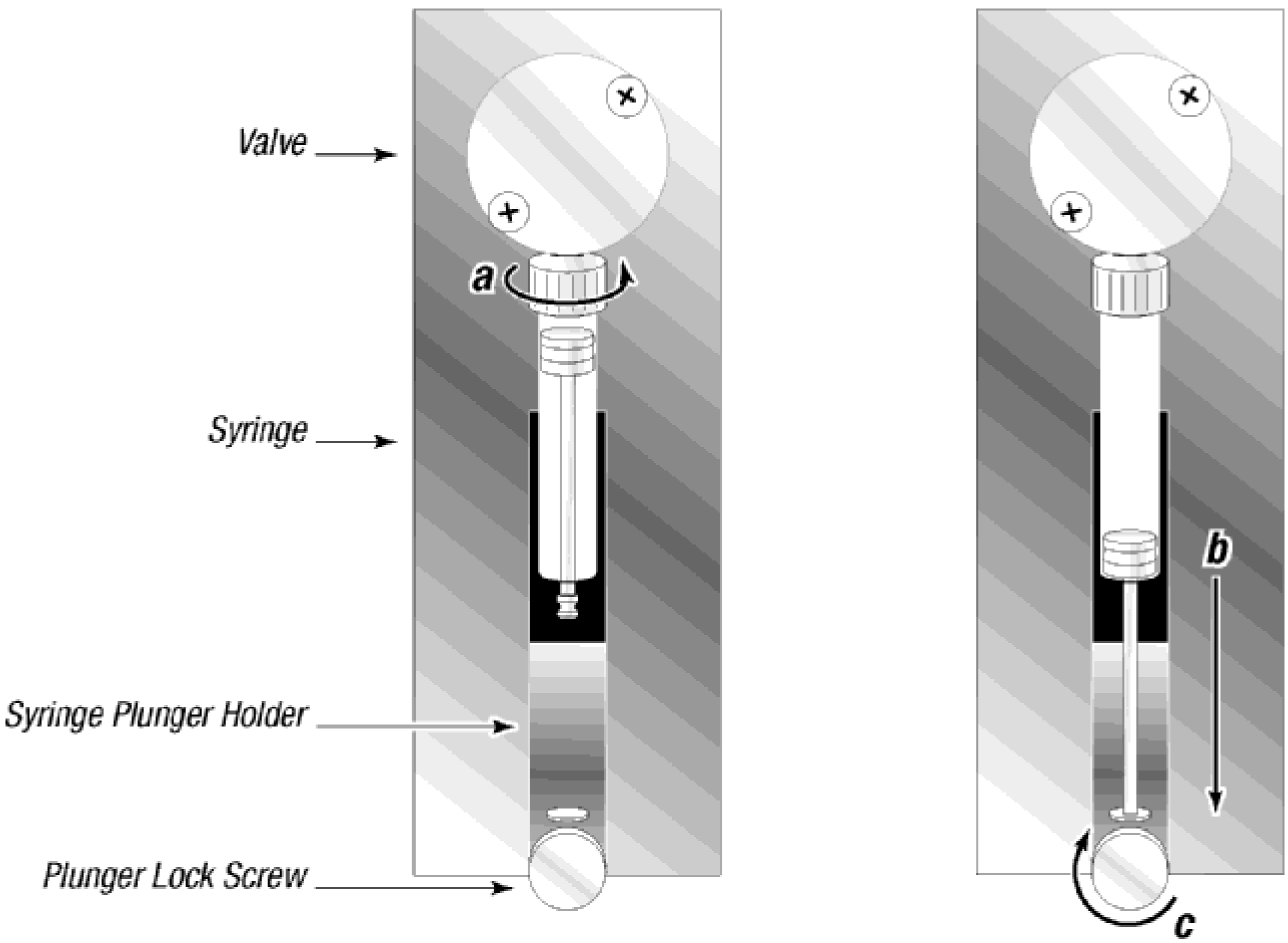


Figure 2-11. Syringe Installation

Mounting the XP 3000

Numerous tapped M3 x 0.5 mounting holes provide flexibility in mounting the XP 3000; there are several mounting options:

- mounting from the bottom
- mounting from the top
- mounting from the sides

Mounting requirements vary for pumps with different valves. For more information, see the specific valve outline drawings. If necessary, custom mounting brackets can be designed, or, the pump can be mounted directly into an instrument.

> **NOTE** Always mount the pump in an upright position. Failure to do so can cause problems in priming the system.

To facilitate mounting, Figure 2-12 shows the locations of the threaded mounting holes (top, bottom, left and right side plates) of the XP 3000.

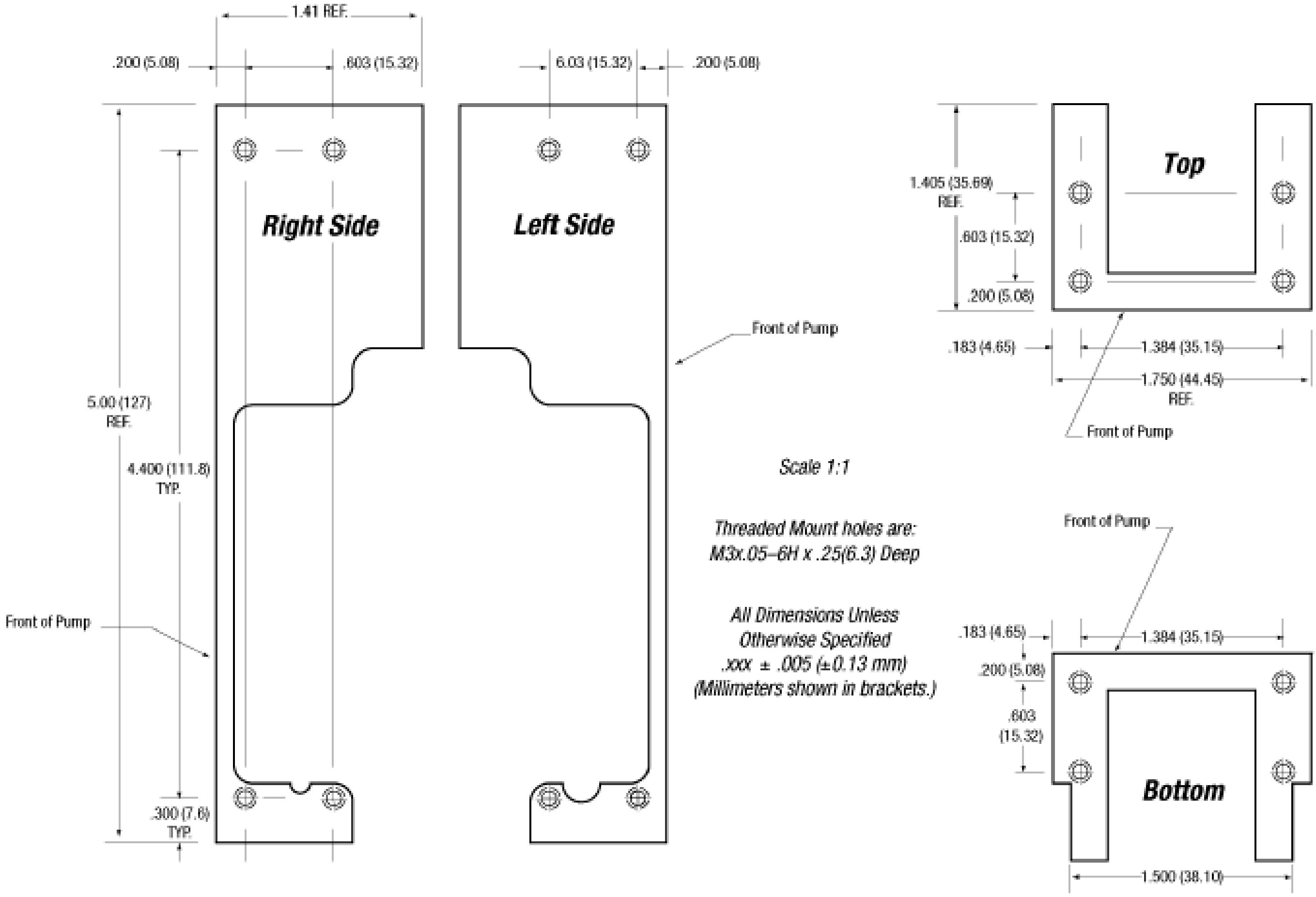


Figure 2-12. XP 3000 Threaded Mount Holes

3 - Software Communication

This chapter describes how to communicate with the XP 3000: through an RS-232, RS-485, or CAN (Controller Area Network) interface, depending on the pump configuration.

This chapter includes these topics:

XP 3000 Addressing Scheme

As part of the communication protocol, an address for each pump must be specified. The user has the option of addressing a single pump, two pumps (dual device), four pumps (quad device), or all 15 pumps (all devices), depending on the address byte used. Each physical address in the address switch corresponds to a hexadecimal value, as shown in Table 3-1.

Table 3-1. Hexadecimal Addressing Scheme

Address (hex)		Device
RS-232/ RS-485	**CAN**	
30	0	Master Address (master controller, personal computer, etc.)
31..3F	1..F	Addresses single device
41..50	11..20	Addresses two devices at a time (dual device)
51..5D	21..2D	Addressed four devices at a time (quad device)
5F	2F	Addresses all devices on the bus

For example, an XP 3000 with address switch set to 0 is addressed as device “31h” in the RS-232 or RS-485 communication protocol, hardware address 1 is addressed as device “32h,” and so on.

Table 3-2 shows the different address switch settings for each of these configurations.

> **NOTE** When using the Pump:Link software to send commands to a device, use the ASCII address values in Table 3-2

Table 3-2. Address Switch Settings in Hex (ASCII)

Switch Setting	Single Device		Dual Device		Quad Device		All Devices	
	Hex Address	**ASCII Address**	**Hex Address**	**ASCII Address**	**Hex Address**	**ASCII Address**	**Address**	**Value to Send**
0	31	1	41	A	51	Q	5F	_
1	32	2						
2	33	3	43	C				
3	34	4						
4	35	5	45	E	55	U		
5	36	6						
6	37	7	47	G				
7	38	8						
8	39	9	49	I	59	Y		
9	3A	:						
A	3B	;	4B	K				
B	3C	<						
C	3D	=	4D	M	5D	]		
D	3E	>						
E	3F	?	4F	O				
F	Self Test							

The user can communicate with all pumps in the chain by using address “5Fh,” for example to initialize all pumps at once. Then each pump can be controlled independently by using addresses “31h” to “3Fh.”

> **NOTE** Multiple address commands cannot be used to determine device status, nor will they respond to Report commands. Each device must be queried separately.

Communication Protocols

Three communication protocols are available:

OEM communications protocol

Data Terminal (DT) protocol

CAN protocol

On standard firmware pumps, select a communication protocol using JP1-2 on the back panel of the XP 3000.

NOTE	Microstep-enabled XP firmware automatically detects the communication protocol. There is no need to select JP1-2 when using this firmware.

The DT protocol can be run via an ASCII data terminal because no sequence numbers or checksums are used. For instructions on using a Microsoft Windows Terminal Emulator, see “Using DT Protocol with Microsoft Windows” in this chapter.

NOTE	Cavro recommends using the OEM protocol. It provides increased error checking, i.e., checksums and sequence numbers are used.

OEM Communication Protocol

OEM communication is a robust protocol that includes automatic recovery from transmission errors. Table 3- describes each setting within the OEM communication protocol.

Table 3-3. OEM Protocol (JP1-2, Jumper IN)

Parameter	Setting
Character Format	
Baud rate	9600 or 38400 (set using JP1-4)
Data bits	8
Parity	None
Stop bit	1
Command Block (see “OEM Protocol Command Block Characters”)	
1	STX (^B or 02h)
2	Pump address
3	Sequence number
3+n	Data block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum
Answer Block (see “OEM Protocol Answer Block Characters”)	
1	STX (^B or 02h)
2	Master address (0 or 30h)
3	Status code
3+n	Data block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum

OEM PROTOCOL COMMAND BLOCK CHARACTERS

The command block characters in the OEM communication protocol are described below. All characters outside the command block are ignored.

When developing a parsing algorithm, the programmer should key on the STX as the beginning of the answer block and the checksum (character after the ETX) as the end of the answer block.

STX (^B or 02h)

The STX character indicates the beginning of a command.

Pump Address

The pump address is a hexadecimal number specific for each pump.

Sequence Number/Repeat Flag

The sequence number is a single byte that conveys both a sequence number (legal values: 1 to 7) and a bit-flag indicating that the command block is being repeated due to a communications breakdown. The sequence number is used as an identity stamp for each command block. Since it is only necessary that every message carries a different sequence number from the previous message (except when repeated), the sequence number may be toggled between two different values (e.g., “1” and “2”) as each command block is constructed. During normal communication exchanges, the sequence number is ignored. If, however, the repeat flag is set, the pump compares the sequence number with that of the previously received command block to determine if the command should be executed or merely acknowledged without executing.

> **NOTE** If the operator chooses not to use this option, the sequence number can be set to a fixed value of 1 (31h).

The following two scenarios should clarify this error detection mechanism.

Scenario 1.

1. The computer sends a command block stamped with sequence #1 to the pump.
2. The pump receives the command, sends an acknowledgement to the PC, and executes it.
3. Transmission of the acknowledgement message is imperfect; the PC does not receive it.
4. The PC waits 100 ms for the acknowledgement, then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.
5. The pump receives the transmission, identified as such by the repeat bit.
6. The pump checks the sequence number against that of the previously received command block. Noting a match, the pump sends an acknowledgement to the PC, but it does not execute the command (since it has already been executed).
7. The PC receives the acknowledgement and continues with normal communications.
8. The next command block is stamped with sequence #2 to indicate a new command.

Scenario 2.

1. The computer sends a command block stamped with sequence #1 to the pump.
2. The pump never receives the command due to a communication error and thus does not send an acknowledgement to the PC.
3. The PC waits 100 ms for the acknowledgement, then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.
4. The pump receives the retransmission, identified as such by the repeat bit.
5. The pump checks the sequence number against that of the previously received command block. Noting a mismatch, the pump recognizes this as a new command block and sends an acknowledgement to the PC. It then executes the command.
6. The PC receives the acknowledgement and continues with normal communications.
7. The next command block is stamped with sequence #2 to indicate a new command.

The sequence number/repeat byte is constructed as follows:

Bit #	7	6	5	4	3	2	1	0
Value	0	0	1	1	REP	SQ2	SQ1	SQ0

REP: 0 for non-repeated / 1 for repeated

SQ0 – SQ2: sequence value, as follows:

Sequence Value	**SQ2**	**SQ1**	**SQ0**
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

NOTE Bits 4 through 7 are always fixed to the values shown.

Data Block (length n)

The data block consists of the data or commands sent to the pump or host (this is an ASCII string). When the pump is responding to a move or [Q] command, the data block length is 0 (i.e., no data string exists).

ETX

The ETX character indicates the end of a command string.

Checksum

The checksum is the last byte of the message string. All bytes (excluding line synchronization and checksums) are XORed to form an 8-bit checksum. This is appended as the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, an error free transmission is assumed; otherwise, a transmission error is assumed.

OEM PROTOCOL ANSWER BLOCK CHARACTERS

The answer block characters in the OEM communication protocol are described below.

Only the unique answer block entries are listed in this section. For common commands and answer block commands (characters), see the previous section, “OEM Protocol Command Block Characters.”

Master Address

The master address is the address of the host system. This should always be 30h (ASCII value “0”).

Status and Error Codes

The status and error codes define pump status and signal error conditions. For a description of status and error codes, see “Error Codes and Query Status” in this chapter.

Data Terminal (DT) Protocol

The DT protocol can be used easily from any terminal or terminal emulator capable of generating ASCII characters at 9600 baud, 8 bits, and no parity.

Table 3-4. DT Protocol (JP1-2, Jumper OUT)

Character Format	
Parameter	**Setting**
Baud rate	9600 or 38400 (set using JP1-4)
Data bits	8
Parity	None
Stop bit	1
Command Block (see "DT Protocol Command Block Characters")	
1	Start command (ASCII "/" or 2Fh)
2	Pump address
2+n	Data block (length n)
3+n	Carriage Return ([CR] or 0Dh)
Answer Block (see "DT Protocol Answer Block Characters")	
1	Start answer (ASCII "/" or 2Fh)
2	Master address (ASCII "0" or 30h)
3	Status character
3+n	Data block (if applicable)
4+n	ETX (03h)
5+n	Carriage Return (0Dh)
6+n	Line feed (0Ah)

DT Protocol Command Block Characters

The command block characters in the DT communication protocol are described below.

Start Block

The start character indicates the beginning of a message block.

Pump Address

The pump address is an ASCII character specific to each pump.

Data Block (length n)

The data block consists of the ASCII data or commands sent to the pump or host.

End Block

The end character indicates the end of a message block.

DT Protocol Answer Block Characters

The answer block characters comprising the DT communication protocol are described below.

Only unique answer block entries are listed in this section. For information on command and answer block commands (characters), see the previous section, “DT Protocol Command Block Characters.”

Master Address

The master address is the address of the host system. This should always be 30h (ASCII “0”).

Status Character

The status and error codes define pump status and signal error conditions. See the description of the [Q] command in “Error Codes and Query Status.”

Data Block

This is the response from all Report commands with the exception of the [Q] command.

Carriage Return (0Dh)/Line Feed (0Ah)

This character terminates the reply block.

Using DT Protocol with Microsoft Windows

The XP 3000 can be controlled in DT protocol mode directly from the Microsoft Windows terminal accessory.

To communicate with the XP 3000 using Windows 3.x, follow these steps:

1. Connect the XP 3000 to a communications port of the PC (for example, COM1).
2. From the Microsoft Program Manager window, select **Terminal** from the Accessories group window.
3. Select the **Settings** menu, and choose **Communications**.
4. Select a baud rate of 9600, 8 data bits, 1 stop bit, no parity, communications port connector, and no flow control.
5. Click **OK**.
6. Set the pump address switch to 0 and remove all configuration jumpers in JP1-2 and JP1-4.
7. Power on the pump.
8. Type /1ZR<CR> to initialize the pump.

   To run the pump, see the commands listed in “Using the XP 3000 Command Set” in this chapter.

To communicate with the XP 3000 using Windows 95/NT, follow these steps:

1. To connect the XP 3000 to a communication ports on the PC, first select the **Start** menu and choose **Run**.
2. In the Run dialog box, type **Hyperterm.exe**. The Connection Description dialog box appears.
3. Enter a name for the connection and select an icon, then click **OK**. The Phone Number dialog box appears.
4. Select the following in the fields provided:

   Connect using: Direct to <*communication port*> (usually COM1 or COM2, depending on how the hardware is set up)

   Click **OK**. The COM Properties dialog box appears.
5. Select the following in the fields provided:

   Bits per second: 9600
   Data bits: 8
   Parity: None
   Stop bits: 1
   Flow control: None

   Click **OK**.

6 Select the **File** menu, and choose **Properties**. The Properties dialog box appears.

7 Select the **Settings** tab, and enter or select these options:

Function, arrow, and Control keys act as:

– Select “Terminal keys”

Emulation:

– Select “Autodetect”

– Enter “500” in Backscroll buffer lines

Click the **ASCII Setup** button. The ASCII Setup dialog box appears.

8 Enter or select these options:

– Select “Send line ends with line feed”

– Select “Echo typed characters locally”

– Enter a Line delay of “0”

– Enter a Charater delay of “0”

– Select “Wrap lines that exceed terminal width”

9 Click **OK** to close the ASCII Setup dialog box, then click **OK** to close the Properties dialog box.

10 Set the pump address to 0 or the appropriate address.

11 Set jumper JP1-2 to DT protocol (JP1-2 removed). Note that no jumper is needed for microstep-enabled firmware. The communication protocol is detected automatically.

12 Power on the pump and initialize it by typing /1ZR and pressing **Enter**.

To run the pump, see the commands listed in “Using the XP 3000 Command Set” in this chapter.

CAN Interface Communications

CAN (Controller Area Network) is a two-wire, serial communication bus. It eliminates polling sequences that verify task completion. Using CAN, the pumps asynchronously report to the master or host when they have finished the current task.

> **NOTE** All Cavro XP 3000s use CAN controller chip compatible with Philips Semiconductor CAN bus specification, version 2.0.

CAN MESSAGES

CAN messages consist of *frames*. Each frame has an 11-bit Message Identifier (MID). The bits:

indicate to which device on the bus the message is directed

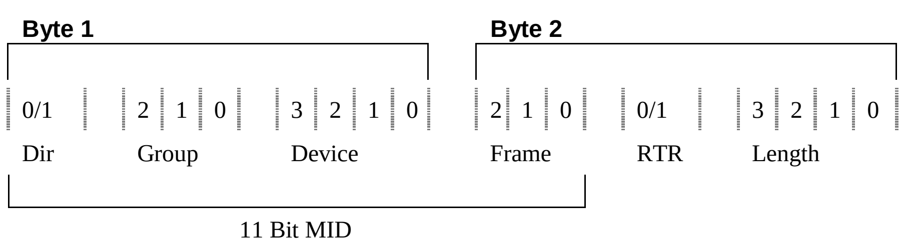
identify the message type

show the direction of the message (to or from the master device)

represent the length of the data block. Data blocks can be from zero to eight bytes in length. Any message that requires more than eight bytes must be sent in a series of multi-frame messages. The receiving unit then assembles the separate frames into one long string.

CAN MESSAGE CONSTRUCTION

Each message frame begins with the MID. The data block (up to 8 bytes in length) follows the MID and length information. This information makes up two bytes that are transmitted first in a message frame. Their bits are grouped as shown:



Dir

This is the direction bit. It lets the devices on the bus know whether the current message is to or from the master. “0” means that the message is from master to slave; “1” means the message is from the slave to the master.

Group

This is the group number (0 - 7). Each type device on the XP 3000 CAN has a group assignment. The XP 3000 is assigned to group 2. The group number “1” is reserved for the boot request procedure.

Device

This is the address of the module in the particular group. Each group can have up to 16 devices. The address value is 0 - 15.

Frames

This lets the device know what type message is coming. See "CAN Frame Types."

RTR

This bit is not used in Cavro's CAN implementation and should always be set to 0.

Length

This is the length of the data block in the message. Data blocks can be from zero to eight bytes in length.

CAN Frame Types

The frame types allow each device to know what type of command is coming in and enables faster processing of commands. Pumps respond to the frame types described below.

"On-the-Fly" Commands (V and T)

Normal commands use a frame type 0 of "1" (i.e., "Action Commands"). Since commands sent over the CAN bus with a particular frame type must complete before a subsequent command using the same frame type can be issued, a different ID must be used when issuing an "on-the-fly" command. For this reason, "on-the-fly" moves must be issued over the CAN bus with a frame type of "0" (zero). Note that a frame type of "0" specifies Set commands.

When issuing "on-the-fly" commands, the "frame type 0" commands will not generate completion messages and thus no pairing code is needed (these commands are simply acknowledged immediately).

Action Frames, Type 1

This frame type is used for action commands, such as Initialization commands, Movement commands, Valve commands, or to set pump operating parameters. All "task-type" commands are sent in this type message frame. When multi-frame messages are used to send an action command, this frame is the end message sent to the pump.

Common Commands, Type 2

This frame is used for commands that are common to every device on the bus. The frame type is set to 2 and the command is a single ASCII character in the data block. The single ASCII character is described below.

Command	Description
0	Reset mode. This resets the pump and begins the boot request procedure.
1	Start loaded command. Just like sending an [R] command after a string has been loaded.
2	Clear loaded command. This clears out the command buffer.
3	Repeat last command. This command does the same thing as the [X] command.
4	Stop action immediately. This acts like a [T] command.

Multi-Frame Start Message, Type 3

This frame type lets the pump know that the next message will be longer than the 8-byte maximum for each frame. Subsequent frames will follow to complete the message.

Multi-Frame Data, Type 4

This frame type is used to identify a frame in the middle of a multi-frame message. The last frame of a multi-frame message for action commands must be type 1. The last frame of a multi-frame message response from the pump for report commands will be type 6.

NOTE There is no type 5 frame.

Report/Answer Commands, Type 6

This frame type is used to get information back from the pump. It is similar in operation to the query commands (i.e., [?]) used in the OEM and DT protocols. The report command is one byte long and is a single ASCII character in the data block. Report commands in ASCII format are:

Command	Description
0	Report plunger position, like the [?] command in OEM or DT protocols
4	Report top velocity, like the [?2] command
6	Report start velocity, like the [?1] command
7	Report cutoff velocity, like the [?3] command
10	Report buffer status, like the [F] command
12	Report backlash
13	Report status of input #1, like the [?13] command
14	Report status of input #2, like the [?14] command
23	Report firmware version, like the [&] command
29	Report current status, like the [Q] command

When the pump responds to a query, the first byte of the data block is the status byte. It is defined like the status byte in the RS-232 and RS-485 protocols. The next byte is a null character. The remaining six bytes are for the response in ASCII. If the pump is only reporting current status, the message is only two bytes long. If the reply consists of more than six bytes, multi-frame messages are used.

CAN Data Block

The data block tells the pump what to do. Pump commands are sent in ASCII just like in RS-232 or RS-485. For command strings that are more than eight bytes in length, multi-frame messages are used. This permits long program strings to be sent as with the other communications interfaces (remember that the XP 3000 buffer size is 256 characters).

HANDLING OF PUMP BOOT REQUESTS

When the pump is first powered up or receives a system reset command (frame type, command 0), the pump notifies the host of this condition by sending a boot request message at 10 to 12 second intervals until it receives a proper response. The group number is 1 for the boot request message. The frame type is 2 when the pump sends messages to the host, and the frame type must be 0 when the host replies to the boot request.

Example 1. The pump is set to address 0

Pump sends:

Dir	Group	Device	Frame	RTR	Length
1	001	0000	010	0	0000

Host acknowledges:

Dir	Group	Device	Frame	RTR	Length	Node ID	Slave ID
0	001	0000	000	0	0010	0010 0000	0010 0000

Host acknowledges the boot request with:

Dir = 0	Host to slave
Group = 1	Boot request response group
Device = 0	Always 0 in boot response
Frame = 0	Boot request response frame
Rtr = 0	Always 0
Length = 2	Two data bytes in return message

Note:
Boot MID is the same for all nodes

Node ID	Group ID (2) + Pump Address (0)	" "	00h	Must respond with Group & Address
Slave ID	Same as Node ID (hex 20)	" "	00h	

Example 2. The pump is set to address 6

Pump sends:

Dir	Group	Device	Frame	RTR	Length
1	001	0110	010	0	0000

Host acknowledges:

Dir	Group	Device	Frame	RTR	Length	Node ID	Slave ID
0	001	0000	000	0	0010	0010 0110	0010 0110

Host acknowledges the boot request with:

Note: Boot MID is the same for all nodes

Dir = 0	Host to slave
Group = 1	Boot request response group
Device = 0	Always 0 in boot response
Frame = 0	Boot request response frame
Rtr = 0	Always 0
Length = 2	Two data bytes in return message

Node ID	Group ID (2) + Pump Address (6)	"&"	Hex	26
Slave ID	Same as Node ID (hex 26)		Hex	26

The pump will save the Node ID to use for message filter Group ID.

CAN Host and Pump Exchanges

When a slave pump receives a command, finishes a command, encounters an error condition, or responds to a query, it sends an answer frame to the host using the same frame type as the command it belongs to. The answer frame format is device dependent. Generally, it will have the following format:

<MID><DLC><Answer>

Where:

<MID>: 11-bit message identifier. The direction bit is 1. The group number and the frame type are the same as received. Device is the current device address.

<DLC>: 4-bit data length code.

<Answer>: Data bytes block. The first byte of the data block is always the status byte. It is defined as in Table 3-. The second byte is a null character. The remaining bytes contain the response in ASCII format. If the reply consists of more than six bytes, the multi-frame messages are used.

> **NOTE** Only one command of a given frame type can be in progress at any one time; e.g., after issuing a command to a slave pump with frame type = 1, the master must wait for the answer with frame type = 1 before issuing the next command with frame type = 1. If the user insists on sending the command, a command overload status results. Several commands with different frame types can be in progress at the same time; e.g., an action command and a query command.

Following are typical exchanges between the host and slave for action commands, multi-frame commands, common commands, and query commands.

Action Command

The host commands [ZR] a pump, and the pump is set to address 0.

Host sends:

0	010	0000	001	0	0010	ZR
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0000	001	0	0000
Dir	Group	Device	Frame type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	001	0	0010	<60h><00h>
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

> **NOTE** The mixed formats ASCII and hexadecimal are used in the data bytes block. The hexadecimal number is bracketed (< >). The rest of the fields are displayed in binary format.

Multi-Frame Command

The host commands [Z2S5IA3000OgHD300G10G5R] to a pump, and the pump is set to address 0.

Host sends:

0	010	0000	011	0	1000	Z2S51A30
Dir	Group	Device	Frame type	RTR	DLC	Data bytes
0	010	0000	100	0	1000	00OgHD30
Dir	Group	Device	Frame type	RTR	DLC	Data bytes
0	010	0000	001	0	0111	0G10G5R
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0000	001	0	0000
Dir	Group	Device	Frame type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	001	0	0010	<60h><00h>
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

> **NOTE** For multi-frame commands, the pump only acknowledges the last frame.

Common Command

After the host has sent command [A1000A0] to the pump, it sends command 0 of frame type 2 to a pump and makes the pump move. The pump is set to address 0.

Host sends:

0	010	0000	010	0	0001	1
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0000	010	0	0000
Dir	Group	Device	Frame type	RTR	DLC

After executing the command, pump reports status:

1	010	0000	010	0	0010	<60h><00h>
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Query Command

The host commands 29 of frame type 6 to a pump, and the pump is set to address 1.

Host sends:

0	010	0001	110	0	0010	29
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump reports:

1	010	0001	110	0	0010	<60h><00h>
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

> **NOTE** For query commands, no acknowledge frame is needed.

The host sends command report 23 of frame type 6 to a pump, and the pump is set to address 1.

Host sends:

0	010	0001	110	0	0010	23
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump reports:

1	010	0001	011	0	1000	<60h><00h><00h>P/N: 6
Dir	Group	Device	Frame type	RTR	DLC	Data bytes
1	010	0001	110	0	0111	00024<00h>A
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

> **NOTE** For a multi-frame reply, the start frame is type 3, the middle frame is type 4, and the last frame is type 6.

Using the XP 3000 Command Set

The XP 3000 features a robust command set which allows a wide range of parameters to be defined by the user. Many of the commands have default values; however, the default values may not provide the optimal settings for your application. Take a moment to familiarize yourself with each command in order to obtain the best performance for your application.

For information on microstep-enabled firmware for the XP 3000, see “XP 3000 Microstep-Enabled Firmware Commands,” in this chapter.

Commands and Valve Types

There are three valve types: 3-port, T-valve, and 3-port distribution. The initialization of valve commands vary depending on the valve type being used.

For a quick summary of all commands, see Appendix G, “Command Quick Reference.”

When problems are detected, the XP 3000 sends an error code. The error codes are described in “Error Codes” at the end of this chapter.

NOTE Some commands are invalid in the CAN interface. For a list of these commands, see Appendix F, “CAN Communication Commands.”

Command Execution Guidelines

To use the commands properly, keep the following in mind:

- ❑ All commands, except Report commands and most Control commands, must be followed by an [R] (Execute) command.
- ❑ Single or multiple command strings can be sent to the pump.

  For example:

  – A single command such as [A3000R] moves the plunger to position 3000.

  – A *multi-command string* such as [IA3000OA0R] moves the valve to the input position, moves the plunger to position 3000, turns the valve to the output position, and finally returns the plunger to position 0.
- ❑ The pump’s command buffer holds a maximum of 256 characters. If a command is sent without the [R] (Execution) command, it is placed into the buffer without being executed. If a second command is sent before the first command is executed, the second command overwrites the first command (i.e., the first command string is erased).
- ❑ Once a command is executed, new commands are not accepted until the sequence is completed. Exceptions to this rule include interruptible (see “T Terminate Command” in this chapter) and Report commands.

- ❑ When a command is sent, the pump answers immediately. If an invalid command has been sent in a command string, the pump reports an error immediately. If there was an invalid parameter in the command, the pump will execute up to the invalid parameter, then it stops. In the case of a [Q] (Query) command, the error is read back to the host computer.
- ❑ It is important to send the velocity commands in the proper order to insure that all parameters are read. The XP 3000 queries for the input of the velocity commands in the following order: backlash [K], slope [L], start velocity [v], top velocity [V], and cutoff velocity [c]. Not inputting these values in the above order causes the XP 3000 to rely on the default values for these commands.
- ❑ Always run liquid through the syringe and valve when issuing a Move command. Failure to do so may damage the valve and syringe seal.
- ❑ Keep fingers out of the syringe slot while the pump is running. Failure to do so can result in injury.

Command Syntax

The syntax for each command in the command set is:

<n>	Numerical value within a given range
0..6000	Range of numerical values allowed
(n)	Default value

NOTE Square brackets, [ ], are used to distinguish commands and should not be sent as part of the command strings.

Control Commands

R   Execute Command or Program String

The [R] command tells the pump to execute a previously sent command or program string.

Commands containing an [R] at the end of the string will execute immediately. If the command or program string is sent without the [R], it is placed in the command buffer.

Sending the [R] alone will execute the last unexecuted command in the buffer. Sending another [R] will not repeat the program string (i.e., the string has been executed).

> **NOTE** The [R] command is invalid in CAN communication. The equivalent command is ASCII 1 for frame type 2.

X   Execute the Last Command or Program String

The [X] command repeats the last executed command or program string.

> **NOTE** The [X] command is invalid in CAN communication. The equivalent command is ASCII 3 for frame type 2.

G <n>   Repeat Command Sequence

The [G] command repeats a command or program string the specified number of times. If a GR or G0R is sent, the sequence is repeated endlessly until a Terminate command [T] is issued. The syntax for this command is:

[G<n>], where <n> = 0..30000

For example:

[A3000A0G10R] moves the syringe plunger to position 3000 then back to position 0. This sequence is repeated 10 times.

g   Mark the Start of a Repeat Sequence

The [g] command is used in conjunction with the [G] command. The [g] command marks the beginning of a repeat sequence (loop) that occurs within a program string (i.e., the entire string is not repeated). Both the [g] and [G] commands can be used to nest up to 10 loops.

Table 3-5 shows the various segments of the command string [A0gP50gP100D100G10G5R].

Table 3-5. Example Program String

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

M <n> DELAY COMMAND EXECUTION

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

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

H <n> HALT COMMAND EXECUTION

The [H] command is used within a program string to halt execution of the string. To resume execution, an [R] command or TTL signal must be sent.

The syntax for this command is:

[H<n>]

Two TTL inputs are available, input 1 (JP3 pin 7) and input 2 (JP3 pin 8). They control execution as follows:

<n> = 0	Waits for [R] or either input 1 or 2 to go low
<n> = 1	Waits for [R] or input 1 to go low
<n> = 2	Waits for [R] or input 2 to go low

NOTE If <n> does not have a value, <n> defaults to 0.

The status of the TTL input lines can also be read using [?13]and [?14]. These commands are described in “Report Commands” in this chapter.

T TERMINATE COMMAND

The [T] command terminates plunger moves in progress ([A], [a], [P], [p], [D], and [d]) and delays [M]).

NOTE The [T] command will not terminate Valve Move commands.

The [T] command will terminate both single commands and program strings. If a program string is terminated before completion, the [R] (Execution) command will resume the program string. If the command was terminated due to a problem or error, the pump must be reinitialized.

When a plunger move is terminated, lost steps may result. Reinitialization is recommended following termination.

NOTE The [T] command is invalid in CAN communication. The equivalent command is ASCII 4 for frame type 2.

J <n> AUXILIARY OUTPUTS

The [J] command sets the TTL ouput lines.

The syntax for this command is:

[J<n>], where <n> = 0..7 (0 is the default)

The XP 3000 provides three TTL outputs on JP3 (pins 13, 14, and 15) that correspond to outputs 1, 2, and 3. They are controlled as follows:

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

(0 = low; i.e., Gnd; 1 = high; i.e., +5VDC)

s <n> LOAD PROGRAM STRING INTO EEPROM

The EEPROM is non-volatile memory within the XP 3000. Once a program string is stored in the EEPROM it provides the user with the option of computer-free operation.

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

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

Up to 15 program strings (numbered 0 through 14) can be loaded into the EEPROM. Each string can use up to 42 commands or 128 bytes. Each command segment requires three bytes in the command buffer. For example, [IA3000OA0R] has five command segments and requires 10 bytes.

> **NOTE** [A3000] and [A0] are considered single command segments.

Example Program String: [s8ZS1gIA3000OA0GR]

Command Segment	Description
s8	Loads string into program 8 of EEPROM (Address switch position 8)
Z	Initializes pump
S1	Sets plunger speed
g	Marks start of loop
I	Turns valve to input position
A3000	Moves plunger to position 3000
O	Turns valve to output position
A0	Moves plunger to position 0
G	Endlessly repeats loop
R	Executes command string

e <n> EXECUTE EEPROM PROGRAM STRING

There are two ways to execute command strings loaded into the EEPROM:

Through the address switch on power up

Through a command sent via the communications port

Address Switch. The address switch setting (0-14) determines which string (0-14) is to be executed on power-up, provided a jumper is installed in JP1-3.

> **NOTE** An Initialization command should always be included in the EEPROM command string if the pump will be used in standalone mode.

Transmitted Commands. EEPROM command strings are executed by sending an [e] command. The executing program string can be terminated using the [T] command.

[e<n>], where<n> = 0..14 (the string number)

Linking Program Strings in the EEPROM

EEPROM program strings can be linked by ending one program string with an [e] command that refers to a second program string.

Example Program Strings: [slZIA3000OA0G5e2R]
[s2gIA3000OgHD300G10GR]

The first string loads an initialization and prime sequence into program 1 of the EEPROM (address switch position 1). It then links to string 2 in the EEPROM.

The second string loads an aspirate and dispense sequence into program 2 of the EEPROM. The second EEPROM program string fills the syringe, then performs 10 dispenses of 300 steps each. The dispenses are triggered by an [R] command. This string is repeated endlessly until the pump is powered down.

On power-up the pump will automatically initialize, prime and perform the multiple dispenses until it is again powered down.

Initialization Commands

INITIALIZATION FORCES

Initialization moves the plunger to the top of the syringe, which is set to position 0. Also, the output position of the valve is assigned to the left or right side, depending upon the Initialization command, and all command parameters are reset to default values.

The top of the syringe is recognized in two ways:

- upward movement of the plunger causes an overload condition
- the home flag has been detected

If either of these conditions is not met, initialization will fail. The force at which the plunger presses against the top of the syringe can be controlled via a parameter after the Initialization command (possible values are 0 and 1).

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

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

Table 3-6. Recommended Initialization Forces by Syringe

Parameter	Force	Syringes
0, 3-40	Full	1.0 mL and larger
1	Half	50, 100, 250, 500 µL

1 Z = Z0

2) 2 - 9 are reserved

3) Z10-Z40 (or Y10-Y40) are initialization speeds which correspond to ([S] commands, Set Speeds) S10-S40 found in “Set Commands (Velocity and Acceleration)” in this chapter. These commands can be used to change the standard initialization speeds. Slower initialization speeds may be useful when working with viscous fluids or small I.D. (inner diameter) tubing.

INITIALIZATION COMMANDS FOR VALVE TYPES 3-PORT, 3-PORT DISTRIBUTION AND T-VALVE

Z <n> Initialize Plunger (Set Output Valve to Right)

The [Z] command initializes the plunger drive and sets valve output to the right (as viewed from the front of the pump). The parameters are described below.

Command	Parameter	Description
Z	<n> = 0	Initializes at full plunger force
	<n> = 1	Initializes at half plunger force

Y <n> Initialize Plunger (Set Output Valve to Left)

The [Y] command initializes the plunger drive and sets valve output to the left (as viewed from the front of the pump). The parameters are described below.

Command	Parameter	Description
Y	<n> = 0	Initializes at full plunger force
	<n> = 1	Initializes at half plunger force

INITIALIZATION COMMANDS FOR VALVELESS OR BLOCK UNITS

W <N> Initialize Plunger (Without Valve)

The [W] command initializes plunger drive for pumps without valves.

Command	Parameter	Description
W	<n> = 0	Initializes at full plunger force
	<n> = 1	Initializes at half plunger force

CAUTION! Once the [W] command is issued to a pump with a valve mounted, the valve will not move until the power is cycled to the pump.

z Set Counter Position (3-Port Distribution Valve Only)

The [z] command sets the pump's position counter to the value contained in the current encoder position. This command is used after a plunger overload error to resynchronize the pump's actual position with its internally recorded position without having to go through the entire initialization sequence.

Plunger Movement Commands

A <n> ABSOLUTE POSITION

The [A] command moves the plunger to the absolute position <n>, where <n> = 0..3000.

For example:

[A300] moves the syringe plunger to position 300.

[A600] moves the syringe plunger to position 600.

a <n> ABSOLUTE POSITION (NOT BUSY)

This is the same as the [A] command, except that the status bit within the reply string indicates that the pump is not busy. This is useful for on-the-fly speed changes.

P <n> RELATIVE PICKUP

The [P] command moves the plunger down the number of steps commanded. The new absolute position is the previous position + <n>, where <n> = 0..3000.

For example:

The syringe plunger is at position 0. [P300] moves the plunger down 300 steps. [P600] moves the plunger down an additional 600 steps to an absolute position of 900. The [P] command will return error 3 (invalid operand) if the final plunger position would be greater than 3000.

p <n> RELATIVE PICKUP (NOT BUSY)

This is the same as the [P] command, except that the status bit of the reply string indicates that the pump is not busy. This is useful for on-the-fly speed changes.

D <n> RELATIVE DISPENSE

The [D] command moves the plunger upward the number of steps commanded. The new absolute position is the previous position <n>, where <n> = 0..3000.

For example:

> The syringe plunger is at position 3000. [D300] will move the plunger up 300 steps to an absolute position of 2700.

The [D] command will return error 3 (invalid operand) if the final plunger position would be less than 0.

d <n> RELATIVE DISPENSE (NOT BUSY)

This is the same as the [D] command, except that the status bit of the reply string indicates that the pump is not busy. This is useful for on-the-fly speed changes.

Valve Commands

NOTE If a Valve command is issued to a valveless pump, the command is ignored.

I MOVE VALVE TO INPUT POSITION

The [I] command moves the valve on the XP 3000 to the input position set by the [Y] and [Z] commands.

For example:

> If the [I] command is sent after the [Z] command, the valve will be open on the left side (as viewed from the front of the pump).

O MOVE VALVE TO OUTPUT POSITION

The [O] command moves the valve on the XP 3000 to the output position set by the [Y] and [Z] commands.

For example:

> If the [O] command is sent after the [Z] command, the valve will be open on the right side (as viewed from the front of the pump).

The illustration below shows the positions of the valves in relation to the Initialization command and valve movement used.

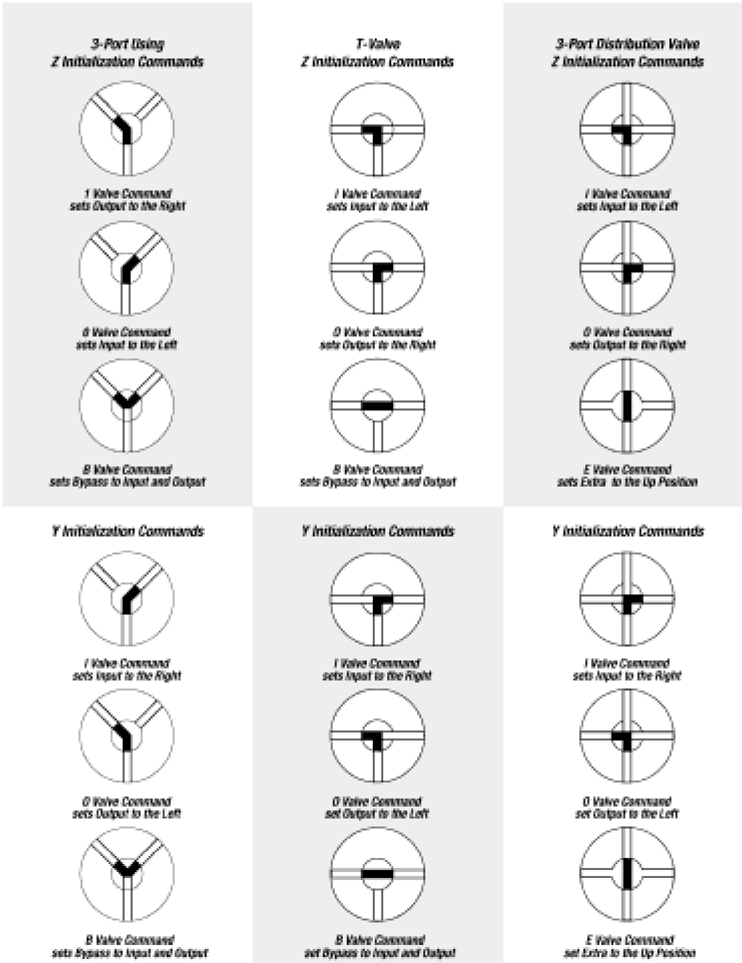


Figure 3-1. Valve Positions for all Valve Types

B MOVE VALVE TO BYPASS (THROUGHPUT POSITION)

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

CAUTION!	When the valve is in this position, do not move the syringe plunger. Sending a Plunger Movement command causes an error 11 (plunger move not allowed).

E MOVE VALVE TO EXTRA POSITION (3-PORT DISTRIBUTION VALVE ONLY)

The [E] command moves the valve on the XP 3000 to the extra position (port) relative to the [Y] and [Z] commands.

Valve Leakage Detection Commands

^<n> SET THRESHOLD VALUE FOR FLUID DETECTION

The [^] command is used to set a fluid detection value that best suits the application and fluids used. The syntax is:

[^<n>], where <n> = 0..255

The higher the value, the more sensitive the detector. A setting of 150 detects water leakage. Detection limits depend upon the application and the humidity of the environment.

NOTE Setting the value to 0 disables error reporting.

Set Commands (Velocity and Acceleration)

Set commands are used to control the speed of the plunger. Plunger movement is structured into three phases:

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

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

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

> **NOTE** The Cutoff command is only active in a dispense move. During aspiration the move will end at the start velocity [v].

For each plunger move, the firmware calculates how many steps the plunger must travel during each phase in order to move the total number of steps commanded. If the plunger is moving less than 1024 Hz, the pump automatically microsteps to reduce the pulsation.

The top velocity can be changed on-the-fly (while the plunger is moving) providing the initial speed is less than the start velocity. Ramps are not included in on-the-fly speed changes; therefore, large speed changes (100 Hz to 1000 Hz) are not recommended.

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

K <n> BACKLASH STEPS

The [K] command sets the number of backlash steps. The syntax for this command is:

[K<n>], where <n> 0..31 (0 is the default)

When the syringe drive motor reverses direction, the carriage will not move until the backlash due to mechanical play within the system is compensated. To provide this compensation, during aspiration, the plunger moves down additional steps, then backs up the set number of backlash steps. This ensures that the plunger is in the correct position to begin a dispense move. Note that a small volume of fluid flows out the “input” side of the valve during this operation.

Changing Speed on the Fly

Speed changes can be made while the syringe plunger is moving. This is called “changing speed on the fly.”

Speeds can be decreased or increased between 5 and 1024 Hz (i.e., in the microstepping region).

To change speed on the fly:

1 Issue speed commands with identical start and top velocities (e.g., [v100V100]), followed by a lowercase Plunger Move command. Ramping is not allowed in on-the-fly changes.

2 Issue a new top velocity in the range 5 to 1024 while the plunger is moving to change the speed on the fly.

NOTE When the move completes, speed values revert to original values (i.e., value sent on-the-fly is temporary).

L <n> SET SLOPE

During the beginning and end of a move, the plunger ramps up and down to top speed. The ramp is programmed using the Slope command. It is calculated as <n> x 2.5 kHz/sec. The syntax for this command is:

[L<n>], where <n> = 1..20 (14 is the default)

The corresponding slopes in kHz/sec are listed below.

Slope Code	kHz/Sec
1	2.5
2	5.0
3	7.5
4	10.0
5	12.5
6	15.0
7	17.5
8	20.0
9	22.5
10	25.0
11	27.5
12	30.0
13	32.5
14	35.0
15	37.5
16	40.0
17	42.5
18	45.0
19	47.5
20	50.0

v <n> START VELOCITY

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

[v<n>], where <n> = 50..1000 Hz
(900 is the default; 901 is the default on the 3-port distribution valve)

V <n> SET TOP VELOCITY

The [V] command sets the peak speed in Hz (half-steps/second). The syntax for this command is:

[V<n>], where <n> = 5..5800 Hz (1400 is the default)

> **NOTE** Syringes 2.5 mL and larger may require slower speeds. Users must determine the appropriate speeds for their applications.

S <n> SET SPEED

The [S] command sets a predefined top plunger speed. As <n> increases, the plunger speed decreases. The syntax for this command is:

[S<n>], where <n> = 1..40 (11 is the default)

These speeds do not cover the full range of speeds the plunger can travel. They are commonly used velocities provided for the convenience of the user. All times are approximate and will vary with different ramp speeds and cutoffs. Cavro also provides a utility for performing theoretical speed calculations in Pump:Link Evaluation Software (in the Utility menu on the user interface). For information on determining timing for specific applications, see Appendix B, "Plunger Information."

The [S] command sets top velocity without changing start velocity, slope, and cutoff velocity, except:

- If the start velocity is higher than the (new) top velocity, start velocity is set = top velocity.
- If the cutoff velocity is higher than the (new) top velocity, cutoff velocity is set = top velocity.

Speed codes, the Hz (half-steps/second) equivalent, and seconds per stroke are listed below. Seconds/stroke values are based on default ramping.

Speed Code	Pump Freq (Hz)	Seconds/Stroke
1	5600	1.2
2	5000	1.3
3	4400	1.4
4	3800	1.6
5	3200	1.9
6	2600	2.2
7	2200	2.6
8	2000	2.9
9	1800	3.3
10	1600	3.7
11	1400	4.3
12	1200	5.0
13	1000	6.0
14	800	7.5
15	600	10.0
16	400	15.0
17	200	30.0
18	190	31.0
19	180	33.0
20	170	35.5
21	160	37.5
22	150	40.0
23	140	43.0
24	130	46.0
25	120	50.0
26	110	55.0
27	100	60.0
28	90	67.0
29	80	75.0
30	70	86.0
31	60	100.0
32	50	120.0
33	40	150.0
34	30	200.0
35	20	300.0
36	18	333.3
37	16	375.0
38	14	428.6
39	12	500.0
40	10	600.0

> **NOTE** To achieve maximum stroke time (20 minutes or 1200 seconds), you must use the [V5] command.

c <n> CUTOFF VELOCITY IN HZ

The [c] command sets the velocity at which the plunger ends its movement. The plunger will ramp down (slope) from the peak velocity. The [c] command overwrites the [C] command. The syntax for this command is:

[c<n>], where <n> = 50..2700 Hz
(900 is the default; 901 is the default on the 3-port distribution valve)

> **NOTE** [c] is only valid in a dispense move. During aspiration [c] = [v].

C <n> CUTOFF VELOCITY IN STEPS

During the last phase of a plunger move, the speed ramps down (as defined by the programmed slope) toward the cutoff velocity [c]. When cutoff steps are specified, the plunger stops at <n> steps before reaching the cutoff velocity. The total number of steps required by the plunger movement is maintained by adding <n> steps to the second phase (top velocity) of the plunger move. The syntax of this command is:

[C<n>], where <n> = 0..25 steps (0 is the default)

The [C] command overwrites the [c] command and resets cutoff velocity to start velocity.

For example, [C5] stops the plunger five steps short of the final velocity. The total number of steps is automatically maintained by adding five steps to the second phase of plunger movement. In other words, the deceleration phase of the move is shortened by five steps and the constant speed phase is lengthened by five steps.

Report Commands

Report commands do not require an [R] command.

> **NOTE** All Report commands are invalid in CAN communication. The frame type 6 is provided to retrieve information from the pump. For more information, see Appendix F, “CAN Communication Commands.”

? Report Absolute Plunger Position

The [?] command reports the absolute position of the plunger in steps [0..3000], [0..24000 in microstep mode].

?1 Report Start Velocity

The [?1] command reports the start velocity in kHz/sec [50..1000].

?2 Report Top Velocity

The [?2] command reports the set top velocity in kHz/sec [5..5800].

?3 Report Cutoff Velocity

The [?3] command reports the cutoff velocity in kHz/sec [50..2700].

NOTE Velocities reported back may not reflect the exact programmed value due to rounding within the control routine.

?4 Report Actual Position of Plunger

The [?4] command reports the actual position of the plunger in steps.

?12 Report Number of Backlash Steps

The [?12] command reports the number of backlash steps.

?13 Report Status of Auxiliary Input #1 (JP3, Pin 7)

0 = low
1 = high

?14 Report Status of Auxiliary Input #2 (JP3, Pin 8)

0 = low
1 = high

?22 REPORT CURRENT VALUE FROM FLUID SENSOR

The [?22] command reports the current value read from the fluid sensor [0..255].

0 = very wet
255 = very dry

F REPORT BUFFER STATUS

The [F] command reports the command buffer status. If the buffer is empty, the pump returns status code 0. If the buffer is not empty, the pump returns a 1. If a program string is sent to the pump without an [R] command, the string is loaded into the buffer and the buffer status becomes 1. An [R] command will then execute the command stored in the buffer.

& REPORT FIRMWARE VERSION

The [&] command returns the XP 3000 firmware revision in ASCII.

REPORT FIRMWARE CHECKSUM

The [#] command reports back the firmware checksum. The checksum is the same for all part numbers at the same revision level.

XP 3000 Microstep-Enabled Firmware Commands

> **NOTE** To determine whether or not your XP 3000 carries microstep-enabled firmware, check the part number on the EPROM label. If the part number is 600,*xxx*, this section applies to your pump.

N <n> SET MICROSTEP MODE OFF/ON

The [N] command enables or disables microstepping. The syntax for this command is:

[N<n>], where <n> = 0 or 1

When <n> = 0, the microstep mode is off and the XP 3000 uses the standard 3000 increments/full stroke. If <n> = 1, microstep mode is on and the XP 3000 uses 24,000 increments/full stroke. Velocities are programmed in increments per second. The default is 0.

k <n> Syringe Dead Volume Command

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

[k<n>], where <n> = the offset in steps from zero position
<n> = 0..80
<n> = 0..640 in microstep mode

Under default initializations, the plunger moves upward until it contacts the top of the syringe, causing a forced stall initialization. The plunger then moves downward and upward, leaving a small gap between the syringe seal and the top of the plunger. This small gap was designed so that the Teflon seal does not hit the top of the plunger each time the syringe moves to the "home" position. This maximizes the life of the syringe seal.

The [k] command must be followed by the Initialization command [Z], [Y], or [W]. Each time the unit is powered down, the "k" value will return to the default condition.

For example, to offset 10 steps away from the zero position, send the following commands:

1. k10R
2. ZR

> **NOTE** Commands are case-sensitive.

Expanded Parameter Ranges

S <n>	Set speed	[<n>=0..40]	
V <n>	Set end velocity in HS/s	[<n>=5..6000]	default: 900
v <n>	Set start velocity in HS/s	[<n>=50..1000]	default: 900
c <n>	Set cutoff velocity in HS/s	[<n>=50..2700]	default: 900
L <n>	Set ramp slope where slope = n * 2500 (HS/s)/s	[<n>=1..20]	default: 7
K <n>	Set backlash	[<n>=1..31	default: 11 microstep off
		[<n>=1..255]	default: 88 microstep on

Error Codes and Query Status

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

> **NOTE** The Query command ([Q]) is the only valid method of obtaining status.

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

STATUS BIT

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

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

In response to uppercase Move commands ([A], [P] and [D]), the [Q] command reports that the pump is busy. In response to lowercase Move commands ([a], [p] and [d]), the [Q] command reports that the pump is not busy. Additionally, commands addressed to multiple pumps at once cannot be used to obtain pump status; pumps must be queried separately.

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

ERROR CODES

Error codes describe problem conditions that may be detected in the XP 3000 (excluding error code 0). Error codes are returned in the least significant four bits of the status byte. If an error occurs, the pump stops executing commands, clears the command buffer, and inserts the error code into the status byte. Some errors continue to appear, such as syringe overloads, until they are cleared by the Initialization command. On a plunger overload, the device will not execute another valve or syringe Move command until it is reinitialized. The last error has precedence in the status byte. For example, if a command overflow occurs, an error 15 results. If the next command causes an error #3, the status byte reflects the error #3 (invalid operand).

Table 3-7. Error Codes

Error Code	Description
0 (00h)	Error Free Condition.
1 (01h)	Initialization error. This error occurs when the pump fails to initialize. Check for blockages and loose connections before attempting to reinitialize. The pump will not accept commands until it has been successfully initialized. This error can only be cleared by successfully initializing the pump.
2 (02h)	Invalid Command. This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally.
3 (03h)	Invalid Operand. This error occurs when an invalid parameter (<n>) is given with a command. Correct the parameter and pump operation will continue normally.
4 (04h)	Invalid Command Sequence. This error occurs when the command structure or communication protocol is incorrect. Review the information describing the communication protocol then repeat the command sequence.
5 (05h)	Fluid Detection. This error occurs when the sensor board detects fluid, which is caused by fluid leaking out the back of the valve. To clear the error: **1** Power off the pump. **2** Remove the valve. **3** Wipe up any detectable fluid on the sensor board using a cotton swab. You can insert the swab through the valve opening on the front panel, and gently wipe the circuit. **4** Assuming the valve is leaking fluid, put a new valve on the pump following the instructions in Chapter 5, “Maintenance.” **5** Reinitialize the pump.
6 (06h)	EEPROM Failure. This error occurs when the EEPROM is faulty. If you receive this error, please call Cavro Technical Service.
7 (07h)	Device Not Initialized. This error occurs when the pump is not initialized. To clear the error, initialize the pump.
9 (09h)	Plunger Overload. This error occurs when movement of the syringe plunger is blocked by excessive back pressure. The pump must be reinitialized before normal operation can resume. This error can only be cleared by reinitializing the pump.
10 (0Ah)	Valve Overload. This error occurs when the valve drive loses steps by blockage or excess back pressure. The pump must be reinitialized before normal operation can resume. Sending another Valve command reinitializes the valve and sets it to the correct location. Continual valve overload errors are an indication the valve should be replaced.
11 (0Bh)	Plunger Move Not Allowed. When the valve is in the bypass or throughput position, Plunger Movement commands are not allowed.
15 (0Fh)	Command Overflow. This error occurs when the command buffer contains too many characters. Commands in the buffer must be executed before more commands can be sent.

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

Immediate Errors. These include “Invalid Command” (error 2), “Invalid Operand” (error 3), “Invalid Command Sequence” (error 4), and “Plunger Move Not Allowed” (error 11). After the command is sent, the answer block immediately returns an error. Once a valid command is sent, the pump will continue to function normally. Since the [Q] command is a valid command, the pump will not return an error. In this case, the [Q] command is not required.

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

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

> If the [Q] command indicates both a successful initialization and that the pump is ready, subsequent Move commands can be sent.
>
> If the [Q] command indicates the pump has not initialized, the pump must be reinitialized until the [Q] command indicates successful initialization.
>
> If initialization is not successful, a “Device Not Initialized” error is returned as soon as the next Move command is sent.

Overload Errors. These include the “Plunger Overload” and “Valve Overload” errors (errors 9 and 10). If the pump returns either a plunger or valve overload, the pump must be reinitialized before continuing. If another command is sent without reinitializing the pump, another overload error will be returned when the next Move command is issued. The [Q] command clears the error; however, if a successful initialization has not occurred, an initialization error is returned.

Command Overflow Error. This is error 15, and it occurs if a Move command, Set command (except [V]), or Valve command is sent while the plunger is moving. The pump ignores the command and issues an error 15. The [Q] command allows the controller to determine when the command is complete and the pump is ready to accept new commands.

Report commands, Control commands, and the Top Velocity command [V] will not return an error 15. Report and Control commands are considered valid commands during a Move. Because the pump can change speed while the plunger is moving in the 5-1024 Hz range, the [V] commands will not return a “Command Overflow” error.

Table 3-8. Error Codes and ASCII and Hexadecimal Values

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
7 6 5 4 3 2 1 0	**0**	**or 1**	**0**	**or 1**	**Number**	**Error**
0 1 X 0 0 0 0 0	40h	60h	64	96	0	No Error
0 1 X 0 0 0 0 1	41h	61h	65	97	1	Initialization
0 1 X 0 0 0 1 0	42h	62h	66	98	2	Invalid Command
0 1 X 0 0 0 1 1	43h	63h	67	99	3	Invalid Operand
0 1 X 0 0 1 0 0	44h	64h	68	100	4	Invalid Command Seq.
0 1 X 0 0 1 0 1	45h	65h	69	101	5	Fluid Detection
0 1 X 0 0 1 1 0	46h	66h	70	102	6	EEPROM Failure
0 1 X 0 0 1 1 1	47h	67h	71	103	7	Device not Initialized
0 1 X 0 1 0 0 1	49h	69h	73	105	9	Plunger Overload
0 1 X 0 1 0 1 0	4Ah	6Ah	74	106	10	Valve Overload
0 1 X 0 1 0 1 1	4Bh	6Bh	75	107	11	Plunger Move Not Allowed
0 1 X 0 1 1 1 1	4Fh	6Fh	79	111	15	Command Overflow

Error Reporting Examples

[A4000R]	Does not return an error immediately after the command, but when queried ([Q] command), returns an “Invalid Parameter” error.
[A3000A3500R]	Moves to position 3000, then stops. A [Q] command returns an error.
[E2000R]	Returns an invalid command error immediately. The pump status is “Not Busy.”
[A3000E2000R]	Returns an invalid command error immediately. The pump is “Not Busy.”
Valve in Bypass [A1000R]	Does not return an error immediately, but when queried ([Q] command), returns a “Plunger Move Not Allowed” error.

4 - Setting Up the XP 3000 for Your Application

The XP 3000 is capable of providing precision pumping in a wide variety of hardware and fluid systems. The interplay of fluid viscosity, aspiration and dispense speeds, and system geometry [syringe size, tubing inner diameter (I.D.), and valve I.D.] determines the behavior of the XP 3000 in a particular application. Following is a description of the hardware, fluid, and pump control parameters to be evaluated and optimized in managing these interdependencies for optimal pump performance.

Glossary

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

aspirate/dispense tubing
: Connects the valve output port (1/4-28 thread or M6 fitting) to a sample source and destination. To ensure good breakoff, aspirate/dispense tubing tends to have a smaller I.D. than reagent tubing, and a necked-down or tapered end.

backlash
: Mechanical play in the syringe drive created by accumulated mechanical clearances. To maintain accuracy and precision when the syringe drive changes direction, the XP 3000 incorporates programmable backlash compensation.

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

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

breakup
: Undesired air gaps created by overly rapid aspiration.

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

cavitation
Formation of air bubbles due to rapid pressure changes.

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

I.D. ("inner diameter")
Diameter of the constraining wall of a fluid path.

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

reagent tubing
Connects the valve input port (1/4-28 thread or M6 fitting) to a reagent source. Reagent tubing is used to fill the pump syringe; it tends to have a larger I.D. than aspirate/dispense tubing, and a blunt-cut end which extends into the reagent.

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

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

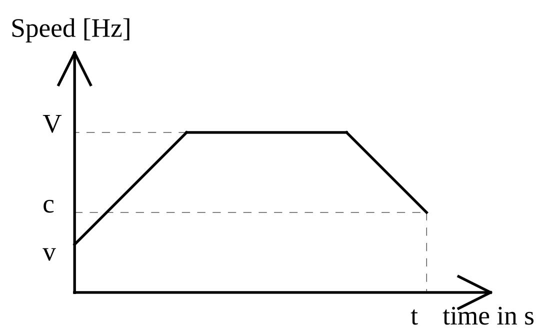


Figure 4-1. Syringe Speed

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

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

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

slope (L)

Acceleration (deceleration) of the syringe plunger between start velocity, top velocity, and cutoff velocity.

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

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

For example, to aspirate 100 µL using an XP 3000 pump with 1 mL syringe, move the plunger as follows:

$$\text{\# of steps} = \frac{3000 \text{ steps} \times 100\ \mu L}{1 \text{ mL} \times 1000\ \mu L/mL} = 300 \text{ steps}$$

Optimizing XP 3000 Performance

CAUTION!	Run the pump only in the upright position. Do not move the pump valve or syringe plunger without first wetting or priming the pump.

For command details, see Chapter 3, “Software Communication.”

To optimize XP 3000 performance, follow these steps:

1 Check chemical compatibility.

Check the chemical compatibility chart in Appendix D, “Chemical Resistance Chart,” to determine if the fluids in your application are compatible with the XP 3000 syringe and valve materials. If not, a system fluid is required. Complete the optimization procedure with the fluids you will use in your final system.

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

2 Select syringe size.

Determine your volume and flowrate requirements. Select a syringe that accommodates the smallest and largest volumes to be dispensed without refill, as well as the desired flowrate (see Table 4-1). While smaller syringes allow better accuracy and precision, a larger syringe allows more aliquots when multiple aspirations or multiple dispenses are required, and they allow better breakoff and longer seal life.

Table 4-1. Flowrate Ranges

Syringe Size	Minimum Flowrate (mL/min)	Maximum Flowrate (mL/min)
50 µL	0.0025	2.6
100 µL	0.0050	5.23
250 µL	0.012	13.1
500 µL	0.025	26.2
1 mL	0.050	52.3
5 mL	0.25	261.6

3 Select tubing.

In tubing selection, the general rule is that smaller syringes work best with smaller I.D. tubing and larger syringes with larger I.D. tubing. Most XP 3000 valve styles have an internal I.D. of 0.059" (approx. 1/16"). For aspirate/dispense tubing a thermal-drawn tip or tapered tip is most common, providing good breakoff and excellent accuracy and precision for most applications. A necked-down tip may be used when aspirating very small volumes of sample, i.e., 1 - 5 µL. A blunt-cut tip is better suited for large volume applications. For tubing recommendations, see Table 4-2; for a description of the various types of tubing, see Appendix A, “Ordering Information.”

Table 4-2. Tubing Recommendations

Syringe Size	Aspirate/Dispense Tubing P/N	Reagent Tubing P/N
50 µL, 100 µL, 250 µL	5133	721370
	5723	*
500 µL, 1 mL, 2.5 mL	5133	4609
	720595	5729
	720597	721370
5 mL	4333	720592
	720595	721370

4 Make pump connections.

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

5 Check communications to the pump.

a) Open the Pump:Link program to the XP 3000 menu (full page), or use your own communications program.

b) Send the command [&] to read the pump's firmware revision number. Successful communication will return the revision number and a "Ready" status.

Possible errors:

No response. Check for loose or incorrectly connected cables, or connection to the wrong computer COM port. Retry.

6 Initialize pump and set initialization speed.

The following information assumes that your input tubing connects to the right valve port. If your input tubing connects to the left valve port, exchange [Y] for all instances of [Z] in the following commands.

Send the command [ZR] to initialize the pump. Successful initialization will move the syringe plunger to the position "0" (fully dispensed) and return a "Ready" status.

Possible errors:

Error 1 (initialization error). Check for tubing blockage and reinitialize. If you are using very narrow I.D. tubing or pumping a viscous fluid, the initialization speed may need to be reduced.

This is accomplished (only if using a 1 mL or larger syringe) by sending the command [Z16R] (initializes at full-force, reduced speed). Repeat with decreasing initialization speed (increase "Z_" value) until the pump successfully initializes.

7 Prime the syringe.

a) Send the command [IA3000OA0R] to pull fluid through the valve input position and into the syringe.

b) Inspect the pump tubing and syringe for bubbles and re-prime until all bubbles are completely gone.
If bubbles remain after several priming strokes, disassemble the syringe and clean it with alcohol. Also check to ensure the fittings are tight and the syringe is tight within the Teflon fitting.

c) Re-prime.

Possible errors:

Error 9 (plunger overload). See step 8.

8 Check aspirate/dispense.

Send the command [IA3000OA0R] to aspirate a full syringe stroke (3000 steps) from input and dispense it to output. Successful execution will move the syringe plunger to position “3000” then back to “0,” then it will return a “Ready” status.

Possible errors:

Error 9 (plunger overload). The stepper motor is unable to move the syringe plunger, probably because of excessive backpressure caused by excessive flowrate, narrow tubing I.D., or valve or tubing blockage. Note whether the error occurred during aspiration or dispensing. To differentiate between blockage and flowrate limitation, reduce syringe plunger speed by sending the command [S12IA3000OA0R]. Repeat with decreasing plunger speed (increase “S_” value) until the pump aspirates and dispenses successfully.

9 Set start velocity and top velocity.

The XP 3000 plunger speed can be controlled from 1.2 seconds per stroke to 20 minutes per stroke (top speed) using the [S] command. (The [V] command allows a slightly larger speed range.) As a general rule, aspiration should be slow (to avoid cavitation) and dispense fast (to promote breakoff). Since cavitation and breakoff will affect both accuracy and precision, velocity settings may be optimized separately for aspiration and dispense.

Using aspirate/dispense commands, set start velocity [v] and top velocity [V] to meet application throughput goals.

a) Send the command [v50IA3000OA0R]. Repeat with increasing start velocity (increase “v_” value) to find the maximum value.

b) Send the command [v*x*V*x*IA3000OA0R] to set top velocity equal to start velocity (*x*). Repeat with increasing top velocity (increase “V_” value) to the maximum value that does not overload the plunger or cause cavitation.

Now optimize start velocity and top velocity for dispensing using a similar approach.

10 Set cutoff velocity and slope.

Using aspirate/dispense commands, set slope [L] and cutoff velocity [c] to attain reproducible breakoff. Note that cutoff velocity controls only dispensing.

To optimize the slope, send the command [v*x*V*y*L14IA3000OA0R]. Repeat with modified slope (“L_” value) to achieve the overall time suited to your application without plunger overload.

To optimize the cutoff velocity, start with the maximum cutoff velocity allowed for your application (the lower of 2700Hz or the top velocity). Send the command [cxIA3000OA0R] and monitor the dispense for plunger overload or any splattering of the fluid dispensed outside of the dispense vessel. If any of these conditions occurs, lower the cutoff velocity until the pump can dispense the fluid with clean breakoff.

Another condition that affects breakoff is the formation of inertial air gaps. This is seen as a small air gap inside the tubing at the tip. This occurs to a greater extent on larger reagent syringes, and it enhances the breakoff of liquid from the tip of the tubing. If an inertial air gap is not desired in the application, lowering the cutoff velocity and/or the top velocity will remove the inertial air gap. However, this may not give a clean breakoff of the fluid.

In some instances it may not be possible to improve fluid breakoff. Clean breakoff is important to accuracy and precision; it is a concern especially when using slow speeds because drops will usually adhere to the tip.

For example, using a 2.5 mL reagent syringe (P/N 5133, dispense tubing and deionized water with a surfactant added):

* [S24IA3000OA0R] - will leave a drop on the tip

* [S24IA3000OA5S1A0R] - no drop will be left

* [V100IA3000OA0R] - will leave a drop on the tip

* [V100IA3000OA5V5500A0R] - no drop will be left

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

NOTE It may not be possible to achieve good fluid breakoff under all circumstances, especially with syringes smaller than 500 µL or with some fluids.

11 Set backlash compensation.

The XP 3000 pump control includes backlash compensation during aspiration. The backlash compensation causes the plunger to move down to the calculated stopping point, then down an additional set number of steps. On reversing direction, the plunger moves back up the same number of steps. Backlash compensation maintains accuracy and precision in the syringe plunger movement when the plunger changes direction.

Aspirate, then perform multiple dispenses. Compare the first aliquot to others; if low, increase backlash and retest. Set backlash as low as possible, but keep the first aliquot equal to subsequent aliquots.

Helpful Hints

To maintain pump performance, keep the following in mind when operating the XP 3000:

- ❑ Wipe up all spills immediately.
- ❑ Pumping cold fluids may cause leaks, the result of differing coefficients of expansion of Teflon and glass. Leaks may occur when pumping fluids that are at or below 15°C (61°F).
- ❑ To reduce the amount of carryover, a ratio of three parts reagent to one part sample is recommended.
- ❑ Use organic solvents in the XP 3000 with caution. Using organic solvents may reduce tubing and seal life.

5 - Maintenance

Although required maintenance may vary with your application, the following procedures are recommended for optimal performance and maximum life of the XP 3000.

Perform maintenance tasks in these intervals:

- daily
- weekly
- periodically

Daily Maintenance

To ensure proper operation of the XP 3000, perform these tasks daily:

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

> Do not allow the pump(s) to run dry for more than a few cycles.

Weekly Maintenance

The fluid path of the XP 3000 must be cleaned weekly to remove precipitates such as salts, eliminate bacterial growth, and so on. Any of the three following cleaning procedures can be used:

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

The procedures using these solutions are described in the sections that follow.

Weak Detergent Cleaning

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

1 Prime the pump with a weak detergent solution (e.g., 2% solution of CONTRAD®, RoboScrub, or flo-kleen) and allow the solution to remain in the pump with the syringe fully lowered for 30 minutes.

2 After the 30-minute period, remove the reagent tubing from the detergent and cycle all the fluid from the syringe and tubing into a waste container.

3 Prime the pump a minimum of 10 cycles with distilled or deionized water. Leave the fluid pathways filled for storage.

> CONTRAD can be purchased through Curtis Matheson Scientific, Inc. Order P/N 117-655 for 500 mL syringe size.
>
> flo-kleen can be purchased through Ciba Corning Gilford Systems. Order P/N 402342 for 400 mL syringe size.
>
> RoboScrub is a phosphate-free detergent for cleaning and conditioning liquid handling systems. RoboScrub rinses away chemicals, solvents, blood, and corrosive acids.

Weak Acid-Base-Sequence Cleaning

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

1 Prime the pump with 0.1 N NaOH and allow the solution to remain in the pump(s) for 10 minutes with the syringes fully lowered.

2 Flush the pump with distilled or deionized water.

3 Prime the pump with 0.1 N HCl, and allow the solution to remain in the pump for 10 minutes with the syringes fully lowered.

4 After a 10-minute period, remove the reagent tubing from 0.1 N HCl solution and cycle all the fluid from the syringes and tubing into a waste container.

5 Prime the pump a minimum of 10 cycles with distilled or deionized water.

10% Bleach Cleaning

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

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

Periodic Maintenance

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

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

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

- input and output tubing
- plunger seal
- valve

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

Quality Control Assurance

Check the accuracy and precision of the XP 3000 on a regular basis.

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

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

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

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

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

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

where:

sg = specific gravity of H_20 @ 25°C = 0.99707

$Vol_{expected}$ = Expected volume to be dispensed

n = number of replicate

X = individual result

$\overline{X}$ = mean of all results

Replacing Dispense or Reagent Tubing

To replace dispense or reagent tubing, follow these steps:

1 To remove the tubing, use a 5/16" wrench and gently loosen the fittings.

2 Unscrew the fittings and remove the tubing.

3 To install new tubing, insert the fitting into the valve and tighten it finger tight.

4 Using a 5/16" wrench, turn the fitting another ¼ to ½ turn.

Replacing a Syringe

To replace a syringe, follow these steps:

1 Remove the liquid from the syringe.

2 Loosen the plunger lock screw approximately three full turns.

3 Lower the plunger drive by sending the [A3000R] command. If power is not applied, the plunger drive can be manually lowered by firmly pushing down on the plunger holder assembly.

4 Unscrew the syringe from the valve.

5 To install the syringe, do the following, as shown in Figure 5-1:

a Screw the syringe into the valve.

b Pull the syringe plunger down to the plunger holder assembly.

c Screw the syringe plunger into place.

NOTE Make sure the plunger lock screw is securely tightened.

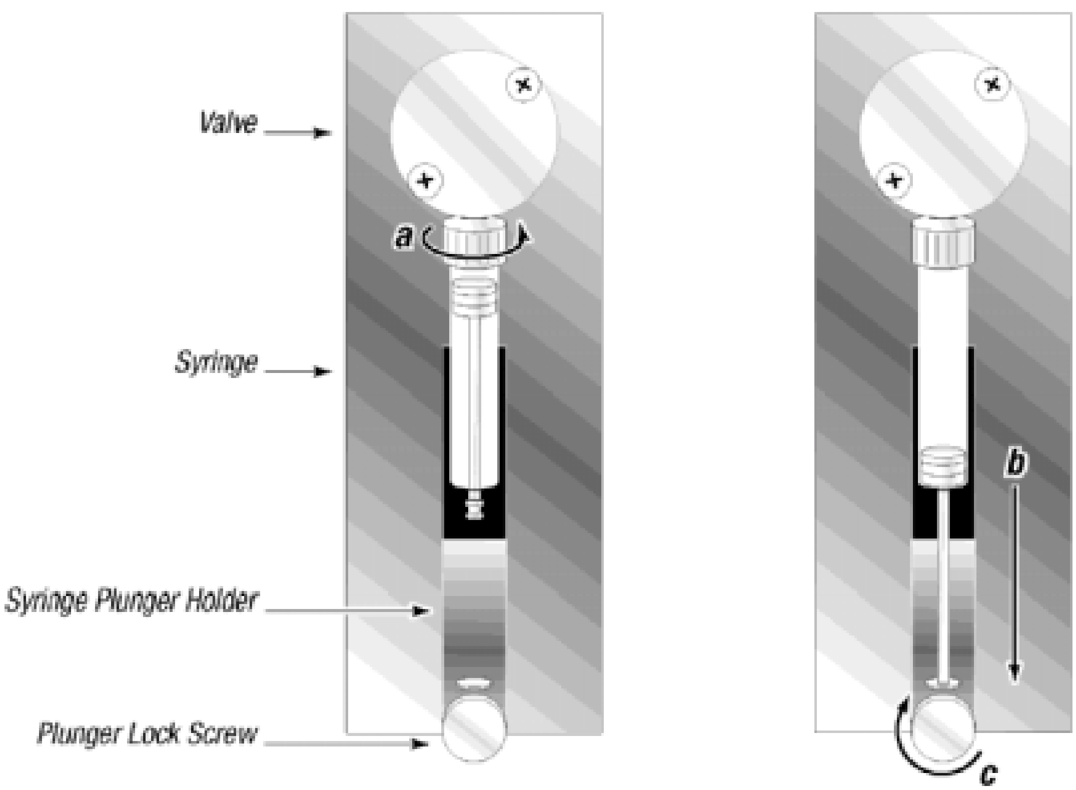


Figure 5-1. Syringe Replacement

6 Re-initialize the pump.

Replacing the Reagent Syringe Seals

NOTE	See Chapter 2, "Hardware Setup," for an illustration of the syringe components.

To replace the reagent syringe seals, follow these steps:

1. Remove the syringe from the pump.
2. Remove the syringe plunger from the barrel.
3. Using a single edged razor or precision knife, carefully slice the old seal lengthwise and remove it from the plunger. Care must be taken not to damage the plunger or "O"-rings beneath the seal.
4. Wet the "O"-ring (if present) and plunger tip with distilled or deionized water.
5. Place the seal on a flat surface with the open end facing up. Press the plunger tip firmly into the hole until it snaps into position.
6. Lay the plunger on a flat table top, and position it so that the seal (from the "O"-ring up) hangs over the edge.
7. Slowly roll the plunger along the table edge pressing firmly on the portion of the seal below the "O"-ring. See Figure 5-2.

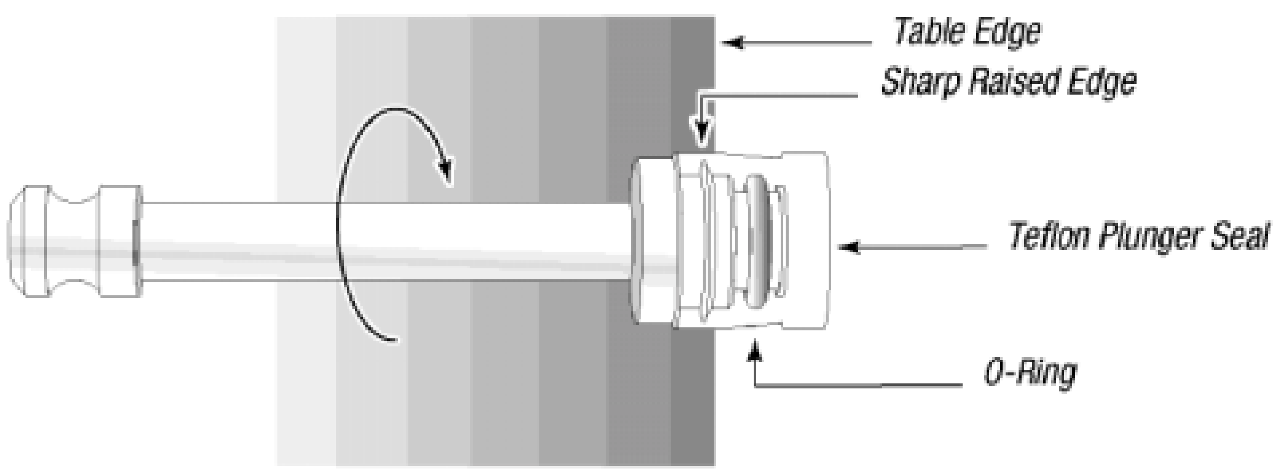


Figure 5-2. Syringe Seal Assembly

8. Rotate the plunger three complete turns. This is necessary to make the sharp raised edge of the plunger bite into the seal for a secure fit.
9. Wet the seal with distilled or deionized water, replace the plunger, then replace the syringe.

NOTE	Syringe sizes 250 µL, 500 µL, 1 mL, 2.5 mL, and 5.0 mL have "O"-rings.

Replacing the XP 3000 Valve

To replace the XP 3000 valve, follow these steps:

1. Remove the fluid from the pump.
2. Initialize the pump using the [ZR] command so that the offset tab on the encoder is in the correct orientation (vertically and to your right).
3. Remove the syringe and tubing.
4. Remove the two Phillips head screws on the front of the valve, then remove the valve from the pump.
5. To install the valve, first rotate the valve coupling to the position shown on the left in Figure 5-3 (vertically with the tab to your left).

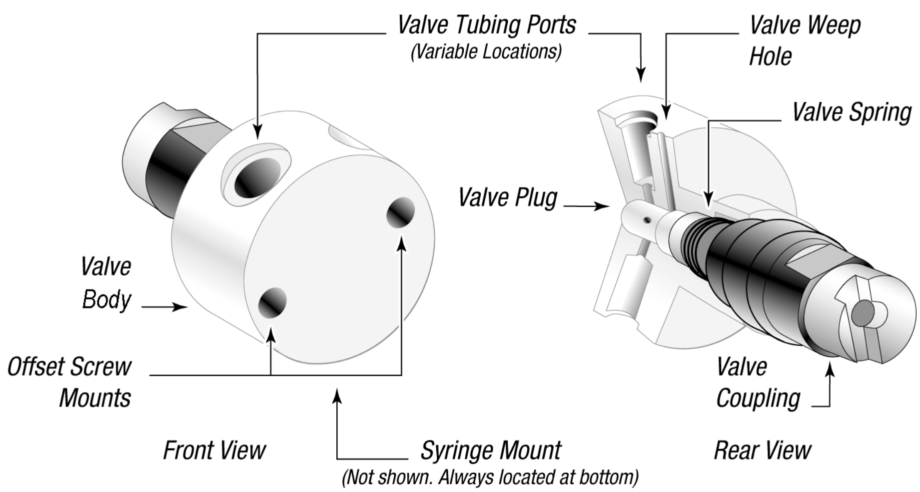


Figure 5-3. XP 3000 Valve Replacement (3-Port Valve Shown)

6. Verify that the offset tab on the encoder in the pump is correctly oriented (vertically with the tab to your right).
7. Install the new valve by inserting the slot in the valve coupling onto the tab of the encoder. The valve should be oriented with the tube fittings on top and the syringe fitting on the bottom.
8. Gently push the valve in place, matching the locating pins on the valve with the holes on the pump front.
9. Replace the valve screws. Tighten ¼ to ½ turn after the screws contact the valve body.

On-Site Replacements

Replacing the Printed Circuit Board (PCB)

To replace the printed circuit board, follow these steps:

1. Power off the pump.
2. Remove the back panel by unscrewing the four hex side panel screws and the two standoff screws holding the DB-15 connector.
3. Remove the two hex screws that hold the printed circuit board to the pump.
4. Note the cable connection locations and unplug the cable from the board.
5. Plug the cables into the new board.
6. Install the new board and screw it into place.
7. Reinstall the DB-15 connector using the two standoff screws, then replace the back panel using the four back panel screws.
8. Power on and reinitialize the pump.

Replacing the EPROM

To replace the EPROM, follow these steps:

1. Power down the pump.
2. Remove the back panel by unscrewing the four hex side panel screws and the two standoff screws holding the DB-15 connector.
3. Remove the old EPROM by using a PROM puller. The EPROM is located in position U8 on the printed circuit board. (See Chapter 2, “Hardware Setup.”)
4. To install the new EPROM, position the notched end of the EPROM so that it faces the bottom of the pump. Make sure all metal pins are aligned with the holes on the receptacle.
5. Once the pins are seated in the holes, press the EPROM firmly into place. If the two rows of pins are too far apart to match the hole on the receptacle, gently press the side of a complete row of pins against a table top to push the row slightly toward the center.

NOTE Care must be taken not to bend any of the pins on the EPROM.

6. Replace the back panel and DB-15 connector.
7. Power on and reinitialize the pump.

6 - Technical Service

For information or questions regarding ordering or operating the XP 3000, please contact Cavro Technical Service using one of the methods listed below.

By phone	408-953-3100 or 800-231-0711
By fax	408-953-3107
By e-mail	cavro@cavro.com

Our mailing address is:

Cavro Scientific Instruments, Inc.
2450 Zanker Road
San Jose, CA 95131
USA

When calling for technical service, have the following information ready:

- Part number
- Serial number
- Model type
- Description of the problem

A - Ordering Information

This appendix is a summary of available XP 3000 configurations, other Cavro liquid handling components, and spare parts for the XP 3000.

Available Configurations

The available configurations and their respective part numbers for both standard firmware and microstep-enabled firmware are listed below.

Table A-1. XP 3000 with Microstep-Enabled Firmware Configurations

Description	Part Number	Communication Protocol	Fittings	Valve	Is Similar to Part Number
XP 3000 with 3-port valve with microstepping (RS232/485, 1/4-28")	728925	RS 232/485	1/4-28"	3-Port	725644
XP 3000 with 3-port valve with microstepping (RS232/485, M6)	728927	RS 232/485	M6	3-Port	725643
XP 3000 with 3-port distribution valve with microstepping (RS232/485, 1/4-28")	728964	RS 232/485	1/4-28"	3-Port Distribution	726349
XP 3000 with T- valve with microstepping (RS232/485, 1/4-28")	728878	RS 232/485	1/4-28"	T-Valve	New Product
XP 3000 with 3-port valve with microstepping (CAN, 1/4-28")	728922	CAN	1/4-28"	3-Port	725586
XP 3000 with 3-port valve with microstepping (CAN, M6)	728924	CAN	M6	3-Port	725585
XP 3000 with 3-port distribution valve with microstepping (CAN, 1/4-28")	728966	CAN	1/4-28"	3-Port Distribution	728187
XP 3000 with T- valve with microstepping (CAN, 1/4-28")	728896	CAN	1/4-28"	T-Valve	New Product
Microstep-enabled firmware for 3-port valves	600002	Both	NA	3-Port	725436
Microstep-enabled firmware for 3-port distribution valves	600004	Both	NA	3-Port Distribution	726352
Microstep-enabled firmware for T-valve	600005	Both	NA	T-Valve	726336

Table A-2. XP 3000 Standard Firmware Configurations

Configuration	Part Number	Communication Protocol
XP 3000 with 3-port valve, 1/4-28" fittings	725644	RS-232/RS-485
	725586	CAN/RS-485
XP 3000 with valve, M6 fittings	725643	RS-232/RS-485
	725585	CAN/RS-485
XP 3000 without valve (with “Y” block, 1/4-28" fittings)	725658	RS-232/RS-485
	725660	CAN/RS-485
XP 3000 without valve (with “Y” block, 1/4-28" fittings)	725659	RS-232/RS-485
	725661	CAN/RS-485
XP 3000 with 90º 3-port distribution valve, 1/4-28" fittings	726349	RS-232/RS-485
XP 3000, T-90, 1/4-28" fittings	728878	RS-232/RS-485

NOTE This table is provided for customers who are not using Cavro’s microstep-enabled firmware.

XP 3000 Spare Parts

The following spare parts are available:

- Syringes
- Syringe Seals
- Syringe “O”-Rings
- Valves
- Printed Circuit Board
- Interconnect Tubing
- Pump Evaluation Accessories
- Miscellaneous Parts

Syringes

Table A-3. Syringes

Part Number	Description
725676	Syringe, 50 µL
725682	Syringe, 100 µL
725589	Syringe, 250 µL
725590	Syringe, 500 µL
725591	Syringe, 1.0 mL
725592	Syringe, 2.5 mL
725593	Syringe, 5.0 mL

Syringe Seals

Table A-4. Seals

Part Number	Description
3225	Seal, 50 µL
725684	Seal, 100 µL
1469	Seal, 250 µL
725707	Seal, 500 µL
725712	Seal, 1.0 mL
6740	Seal, 2.5 mL
6739	Seal, 5.0 mL

Syringe “O”-Rings

Table A-5. “O”-Rings

Part Number	Description
720396	“O”-Ring, 250 µL
9321	“O”-Ring, 500 µL
9322	“O”-Ring, 1.0 mL
6633	“O”-Ring, 2.5 mL
6634	“O”-Ring, 5.0 mL

Valves

Table A-6. Valves

Part Number	Description
725587	Valve, 3-Port (1/4-28" fitting)
725588	Valve, 3-Port (M6 fitting)
725727	“Y” Block (1/4-28" fitting)
725729	“Y” Block (M6 fitting)
726273	T-valve (1/4-28" fitting)
726346	3-port distribution (1/4-28" fitting)

Printed Circuit Board

Table A-7. Printed Circuit Board

Part Number	Description
725688	PCB, RS-232/RS-485
725689	PCB, CAN/RS-485

NOTE When ordering spare PCBs, request the EPROM part number to be installed on the board at no charge.

Interconnect Tubing

Table A-8. Interconnect Tubing

Part Number	Description	Material	Length (Inches)	Units	Tube Ends
1067	Reagent tube	TFE	60"	.063	1/4-28" to blunt cut
4333	Aspirate/Dispense tube	TFE	30"	.053	Necked
4410	Aspirate/Dispense tube	FEP	40"	.031	Thermal drawn
4609	Reagent tube	FEP	12"	.031	1/4-28" to blunt cut
5133	Aspirate/Dispense tube	FEP	29"	.031	Thermal drawn
5723	Aspirate/Dispense tube	FEP	29"	.031	Necked
5729	Reagent tube	TFE	20"	.031	1/4-28" to blunt cut
5402	Aspirate/ Dispense coiled tube	FEP	64"	.031	Thermal drawn
6865	Interconnect tube	FEP	3"	0.054	1/4-28" to 1/4-28"
720592	Reagent tube	TFE	60"	.063	1/4-28" to blunt cut
720595	Aspirate/Dispense tube	FEP	60"	.053	Necked
720597	Aspirate/Dispense tube	FEP	60"	.031	Thermal drawn
721370	Reagent tube	TFE	27"	.053	1/4-28" to blunt cut
722540	Reagent tube	FEP	35"	.079	M6 to blunt cut
722541	Interconnect tube	FEP	20"	0.059	M6 to M6
723114	Aspirate/Dispense tube	FEP	6"	0.079	1/4-28" to M6
724169	Aspirate/Dispense tube	FEP	29"	.031	Thermal drawn, M6
724170	Reagent tube	TFE	27"	.053	M6 to blunt cut
724275	Aspirate/Dispense tube	FEP	22"	0.079	1/4-28" to M6
724780	Aspirate/Dispense tube	FEP	39"	0.079	1/4-28" to 1/4-28"
725788	Interconnect tube	FEP	8"	0.054	1/4-28" to 1/4-28"
725876	Aspirate/Dispense tube	FEP	29"	0.059	1/4-28" to M6
725896	Interconnect tube	TFE	20"	0.062	1/4-28" to 1/4-28"
726172	Aspirate/Dispense tube	TFE	24"	0.062	1/4-28" to 1/4-28"

NOTE Custom tubing is available upon request.

Pump Evaluation Accessories

Table A-9. Evaluation Software

Part Number	Description
727899	Pump:Link Software [package includes manual, programmer’s kit, 3.5" diskettes (4)]
723914	AC power supply, 24V (120V). Evaluation, two pumps.
723942	AC power supply, 24V (220V). Evaluation, two pumps.
725744	DB-15 adapter. (Order two adapters per power supply).

Miscellaneous Parts

Table A-30. Miscellaneous Parts

Part Number	Description
1590	Fitting, Tube, 0.076 ID, (2/pk)
1589	Fitting, Tube, 0.138 ID, (2/pk)
724757	Wrench, 5/16" and 9/64"
725730	Manual, Operator's, XP 3000
725731	Packaging
725772	Connector, XP mating
973309	Fitting, Tube, 0.085 ID, M6
973308	Fitting, Tube, 0.100 ID, M6
973307	Fitting, Tube, 0.125 ID, M6
972395	Jumper

Other Cavro Products

RSP 9000 Robotic Sample Processor

An XYZ robotic arm module, the RSP 9000 automates OEM liquid handling applications and is available with one or two arms, liquid level sensing, and step loss detectors on all three axes. The electronics support a number of auxiliary devices including diluters, valves, I/O boards, disposable tips, and multi-channel probes.

MSP 9000/9500 Mini Sample Processors

One- or two-arm robotic benchtop workstations designed for automating sample preparation or assay methods. Cavro's modular component technology allows both flexibility and quick customization. A variety of liquid-handling modules and a choice of standard cap-piercing, disposable tip, or multi-channel probes are available. All instruments include liquid-level sensing and step-loss detection.

XL Series Smart Valve

A compact, stepper motor driven module for OEM liquid handling applications, the Smart Valve is available with 3-, 4-, or 6-port valves. It uses the same communication characteristics as the XL 3000 Modular Digital Pump: RS-232 or RS-485 interfaces and a choice of two communication protocols. Up to fifteen devices can be addressed individually from a single communication port. The Smart Valve uses a single 24 VDC power supply and contains a buffered output which can be used to drive an additional relay or solenoid.

XL Series Smart Peristaltic Pump

A compact, eight roller unit with 1, 2, 3, or 4 channels. Smart Pump modules are stepper motor driven and are designed to provide highly reproducible flow rates with minimum pulsing and long tubing life. The SP modules use the same interface characteristics as the XL 3000 Modular Digital Pump: RS-232 or RS-485 interfaces and a choice of two communication protocols. Up to fifteen devices can be addressed individually from a single communication port. The Smart Pump uses a single 24 VDC power supply and contains a buffered output which can be used to drive an additional relay or solenoid.

XL 3000 Series Multi-Channel Pumps

These pumps are based on the single channel XL 3000 and are available in 2, 3, 4, 5, 6, or 8 channels. Each channel has an independently operated solenoid valve and can accommodate syringes ranging from 500 µL to 2.5 mL. The pumps use an RS-232 or RS-485 interface and a simple command set. They can aspirate and dispense fluids and are specifically designed for OEM applications in the liquid handling, instrumentation, and systems markets.

XL 3000 Modular Digital Pumps

An advanced stepper motor driven syringe pump designed for OEM precision liquid handling applications, the XL 3000 automates pipetting, diluting, and dispensing with excellent accuracy and precision over a wide range of speeds using a variety of syringe sizes. The XL 3000 is an intelligent device, programmable through an RS-232 or RS-485 interface, and it operates from a single 24 VDC power supply.

The XL 3000 with 8-port distribution valve minimizes the amount of space needed to distribute up to eight fluids in a system.

XE 1000 Pump

A simple, compact, economical pump module, the XE 1000 is designed for high volume OEM instrument manufacturers who need to perform pipetting and diluting functions such as reagent additions or aspirating and dispensing fluids.

Smart I/O Board

The Smart I/O board is a microprocessor driven PC board that allows the operation of a number of I/O ports from an external serial line. The board can be controlled by RS-232 or RS-485. It can also be placed on an RS-485 bus with other Cavro pumps and smart devices. The I/O signal is CMOS (0-5 volts). I/O lines include 16 inputs, 16 outputs, and four analog inputs. The board uses a standard Cavro OEM communications protocol.

Cavro MiniWash

A compact, OEM module for rapidly aspirating or dispensing fluids, this module consists of a control board and a small diaphragm pump attached to a small mounting frame (similar to the Cavro Smart Valve). The module has many uses including: as a pump for aspirating and/or dispensing fluids with a wash head; for rapidly pumping fluid through a dispense probe for washing; and as a pump for moving fluid in and out of the Active Wash Station.

Accessories

Tubing, syringes, evaluation power supply, and evaluation software are available for all Cavro modules.

B - Plunger Information

Plunger Force

Figure B-1 shows a typical XP 3000 force curve for reference use only. Forces were determined by hanging weights from the plunger pin and pulling them up at various speeds. The plunger speed in Hz is shown on the X axis of the graph; plunger force is shown on the Y axis.

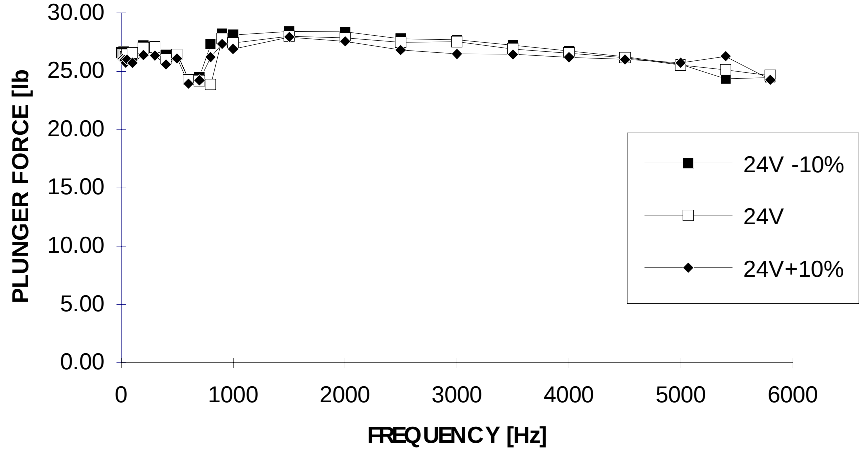


Figure B-1. Plunger Force Curve

Plunger Time Calculations

Following are calculations for determining XP 3000 plunger speeds. Four different cases are presented below.

1 Start, top, and cutoff velocities are equal, or top velocity is less than 50 Hz.

2 Typical move with ramp up, constant speed and ramp down.

3 Move is too small to reach cutoff velocity.

4 Move is too small to reach top velocity.

Symbol Definitions

Table B-1. Symbol Defintions

Symbol	Name	Range (n)	Unit
v	Start Velocity	50..1000	Half Steps/sec or Hz
V	Top Velocity	5..5800	Half Steps/sec or Hz
c	Cutoff Velocity	50..2700	Half Steps/sec or Hz
L	Slope	1..20	n*2500 Half Steps/sec^2 or Hz
A	Move Distance	0..3000	Full Steps
t_1	Ramp Up Time		Seconds
t_2	Constant Speed Time		Seconds
t_3	Ramp Down Time		Seconds
t	Total Move Time	$t_1+t_2+t_3$	Seconds
A_1	Ramp Up Steps		Half Steps
A_2	Ramp Up Steps		Half Steps
A_3	Ramp Up Steps		Half Steps

NOTE Cutoff velocity cannot be smaller than start velocity.

During aspiration, v is used in place of c.

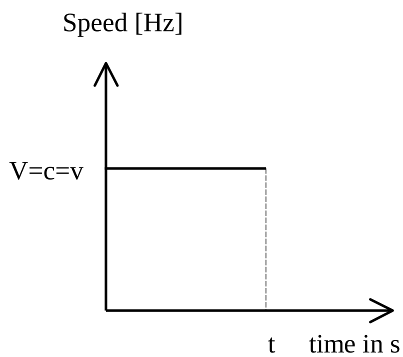
The XP 3000 uses 3000 full steps per stroke.

Move Calculations

CASE 1. START, TOP, AND CUTOFF VELOCITIES ARE EQUAL OR TOP VELOCITY IS SMALLER THAN 50 HZ

Case 1 is used when $v = V = c$ or $v = <50$

Diagram of move:



Calculation:

v = 900 Hz   L = 14

V = 900 Hz A = 3000 full steps

c = 900 Hz

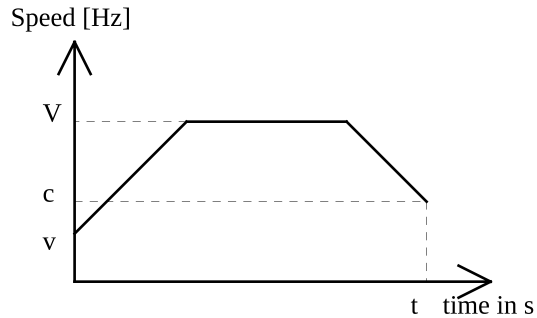
Total Move Time

$$t = \frac{2*A}{V} = \frac{2*3000}{900} = 6.67\,\text{seconds}$$

CASE 2. RAMP UP, CONSTANT SPEED, RAMP DOWN

Case 2 is used when $A_1 + A_3 < 2\,A$

Diagram of Move:



Calculation:

v = 50 Hz   L = 14

V = 5800 Hz   A = 3000 full steps

c = 500 Hz

Ramp Up Steps

$$A_1 = \frac{V^2 - v^2}{2L} = \frac{5800^2 - 50^2}{2*14*2500} = 481 \text{ half steps}$$

Ramp Down Steps

$$A_3 = \frac{V^2 - c^2}{2L} = \frac{5800^2 - 500^2}{2*14*2500} = 477 \text{ half steps}$$

If $A_1 + A_3 < 2A$ (481 + 477 < 6000) then:

Ramp Up Time

$$t_1 = \frac{V - v}{L} = \frac{5800 - 50}{14*2500} = .16 \text{ seconds}$$

Ramp Down Time

$$t_3 = \frac{V - c}{L} = \frac{5800 - 500}{14*2500} = .15 \text{ seconds}$$

Constant Speed Steps

$$A_2 = 2A - A_1 - A_3 = 2*3000 - 481 - 477 = 5042 \text{ half steps}$$

Constant Speed Time

$$t_2 = \frac{A_3}{V} = \frac{5042}{5800} = .87 \text{ seconds}$$

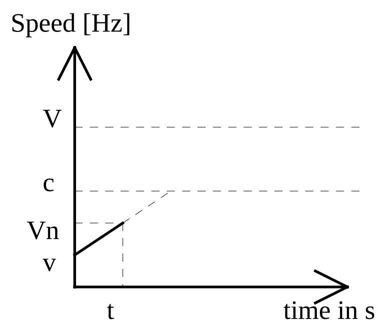
Total Move Time

$$t = t_1 + t_2 + t_3 = .16 + .87 + .15 = 1.18 \text{ seconds}$$

CASE 3. MOVE TOO SMALL TO REACH CUTOFF VELOCITY

Case 3 is used when Vn < c

Diagram of Move:



Calculation:

v = 50 Hz L = 14

V = 5800 Hz A = 5 full steps

c = 900 Hz

Theoretical Top Velocity

$$Vn = \sqrt{4AL + v^2} = \sqrt{4*5*14*2500 + 50^2} = 838\,\text{Hz}$$

if $Vn < c$ then

Total Move Time

$$t = \frac{Vn - v}{L} = \frac{838 - 50}{14*2500} = .023\,\text{seconds}$$

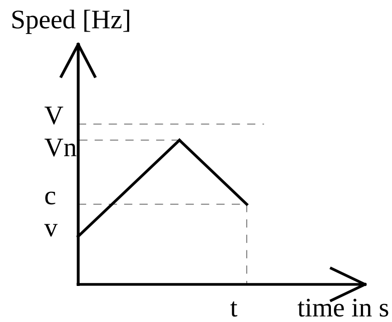
Ramp Up Steps

$$A_1 = A = 5 \text{ full steps}$$

CASE 4. MOVE TOO SMALL TO REACH TOP VELOCITY

Case 4 is used when Vn < V and Vn > c

Diagram of Move:



Calculation:

v = 50 Hz   L = 14

V = 5800 Hz   A = 350 full steps

c = 900 Hz

Top Velocity

$$Vn = \sqrt{2AL + \frac{v^2 + c^2}{2}} = \sqrt{2 * 350 * 14 * 2500 + \frac{50^2 + 900^2}{2}} = 4991\text{Hz}$$

Total Move Time

$$t = \frac{1}{L}(2Vn - v - c) = \frac{1}{L}(2 * 4991 - 50 - 900) = .26 \text{ seconds}$$

C - ASCII Chart of Codes for U.S. Characters

Table C-1. ASCII Chart of Codes for U.S. Characters

Decimal	Hexadecimal	Character or Function	Decimal	Hexadecimal	Character or Function
0	00	none	65	41	A
1	01	SOH	66	42	B
2	02	STX	67	43	C
3	03	ETX	68	44	D
4	04	EOT	69	45	E
5	05	ENQ	70	46	F
6	06	ACK	71	47	G
7	07	BEL	72	48	H
8	08	BS	73	49	I
9	09	HT	74	4A	J
10	0A	LF	75	4B	K
11	0B	VT	76	4C	L
12	0C	FF	77	4D	M
13	0D	CR	78	4E	N
14	0E	SO	79	4F	O
15	0F	SI	80	50	P
16	10	DLE	81	51	Q
17	11	DC1	82	52	R
18	12	DC2	83	53	S
19	13	DC3	84	54	T
20	14	DC4	85	55	U
21	15	NAK	86	56	V
22	16	SYN	87	57	W
23	17	ETB	88	58	X
24	18	CAN	89	59	Y
25	19	EM	90	5A	Z
26	1A	SUB	91	5B	[
27	1B	ESC	92	5C	\ (backslash)
28	1C	FS	93	5D	]
29	1D	GS	94	5E	^ (control)
30	1E	RS	95	5F	— (emdash)
31	1F	US	96	60	` (tick)
32	20	SP	97	61	a
33	21	!	98	62	b
34	22	"	99	63	c
35	23	#	100	64	d
36	24	$	101	65	r
37	25	%	102	66	f
38	26	&	103	67	g

Decimal	**Hexadecimal**	**Character or Function**	**Decimal**	**Hexadecimal**	**Character or Function**
39	27	' (apostrophe)	104	68	h
40	28	(	105	69	i
41	29	)	106	6A	j
42	2A	*	107	6B	k
43	2B	+	108	6C	l
44	2C	, (comma)	109	6D	m
45	2D	- (en dash)	110	6E	n
46	2E	. (period)	111	6F	o
47	2F	/	112	70	p
48	30	0	113	71	q
49	31	1	114	72	r
50	32	2	115	73	s
51	33	3	116	74	t
52	34	4	117	75	u
53	35	5	118	76	v
54	36	6	119	77	w
55	37	7	120	78	x
56	38	8	121	79	y
57	39	9	122	7A	z
58	3A	:	123	7B	{ (left brace)
59	3B	;	124	7C	| (vertical bar)
60	3C	<	125	7D	} (right brace)
61	3D	=	126	7E	~ (tilde)
62	3E	>	127	7F	DEL
63	3F	?			
64	40	@			

D - Chemical Resistance Chart

Table D-1, which starts on the following page, provides a summary of chemical compatibility information provided by the manufacturers of components in the XP 3000 fluid path. Cavro recommends that you use this information as a guideline only, and that you test each application fluid for chemical compatibility.

CAUTION! Failure to test chemicals used in individual applications with the XP 3000 may result in damage to the pump and/or test results.

The materials listed in Table D-1 are used in the following areas of the XP 3000:

Telfon® (PTFE, TFE, FEP)	Tubing, Valve Plug, Seal
Kel F®	Valve Body
Polypropylene	Fittings for Tubing

The codes and symbols in Table D-1 are as follows:

- \- No Data
- 0 No effect – excellent
- 1 Minor effect – good
- 2 Moderate effect – fair
- 3 Severe effect - not recommended
- * Polypropylene - Satisfactory to 22° C (72° F)
- ** Polypropylene - Satisfactory to 49° C (120° F)

Table D-1. Plastic Materials Used in Cavro Pumps

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

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

E - XP 3000 Physical Specifications

Table E-1. XP 3000 Physical Specifications

Dimensions	Height	5.0 in (127 mm)
	Width	1.8 in (45.7 mm)
	Depth	4.5 in (114.3 mm) from front panel to connector
	Weight	2.5 lbs (1.1 kg)
Resolution		3000 steps (24000-step capability when using microstep-enabled firmware)
Plunger Drive	Principle	Rack and pinion drive with quadrature encoder and home flag
	Travel	30 mm
	Plunger Speed	Variable from 1.2 secs/stroke to 20 min/stroke
Syringes	Sizes	50 µL, 100 µL, 250 µL, 500 µL, 1.0 mL, 2.5 mL and 5.0 mL
	Barrel Material	Borosilicate Glass
	Plunger Material	Stainless Steel
	Seal Material	Virgin Teflon (PTFE, TFE)
	Precision	≤0.05% CV at full stroke (250 µL syringe and above) ≤0.1% CV at full stroke (50 µL and 100 µL syringe)
	Accuracy	<1% at full stroke
Valve Drive	Turn time	≈250 ms between adjacent ports (3-port valve)
	Drive	Stepper motor with optical encoder for positioning feedback
Valves	Plug Material	Virgin Teflon
	Body Material	Kel-F
	Fittings	1/4-28 tubing and syringe fittings
		M6 or 1/4-28" syringe fitting
	Valve Positions	120° 3-port, 3-port Distribution, T-Valve, Y-Block
	Fluid Contact	Glass, Kel-F, Teflon
Power Requirements	Voltage	24VDC ± 10%
	Current	1.5 A (peak)

Interface	Type	RS-232, RS-485 or CAN
	Baud Rate	9600 or 38400 (RS-232 and RS-485 only)
	Format	Data Bits: 8
		Parity: No
		Stop Bit: 1
		Half Duplex
Communications	Addressing	Up to 15 pumps can be addressed individually (up to 16 pumps w/ microstep FW)
	Communications	Data terminal and OEM protocol (with error recognition)
Firmware		Programmable Ramps
		Programmable Backlash Compensation
		Programmable Plunger Speeds
		Programmable Delays
		Programmable Loops
		Change Speed on the Fly
		Terminate Moves
		Diagnostics
		Absolute or Relative Positions
		Programmable EEPROM
Inputs		Two TTL level inputs with 4.7k pull ups
Outputs		Three outputs, CMOS (HC) level
Environmental	Operating Temperature (mechanism)	59°F (15°C) to 104°F (40°C)
	Operating Humidity (mechanism)	20-95% RH at 104°F (40°C)
	Storage Temperature	-4°F (20°C) to 149°F (65°C)

F - CAN Communication Commands

Command Type	Command	Valid/Invalid	CAN Equivalent
Initialization	Z, Y	Valid	None
Initialization	z	Valid	None
Plunger Movement	A, a, P, p, D, d	Valid	None
Valve	I, O, B	Valid	None
Valve	E, ^	Valid	None
Set	S, V, v, C, c, L, K	Valid	None
Command for microstep-enabled firmware	N	Valid	None
Control	G, g, M, H	Valid	None
Control	X	Valid	Frame type = 2 Command = “3” (ASCII)
Control	R	Invalid	Frame type = 2 Command = “1” (ASCII)
Control	T	Invalid	Frame type = 2 Command = “4” (ASCII)
Control	J, s, e	Valid	None
Report	?	Invalid	Frame type = 6 Command = “0” (ASCII)
Report	?1	Invalid	Frame type = 6 Command = “6” (ASCII)
Report	?2	Invalid	Frame type = 6 Command = “4” (ASCII)
Report	?3	Invalid	Frame type = 6 Command = “7” (ASCII)
Report	?4	Invalid	Frame type = 6 Command = “1” (ASCII)
Report	?5	Invalid	Frame type = 6 Command = “2” (ASCII)
Report	?6	Invalid	Frame type = 6 Command = “3” (ASCII)
Report	?7	Invalid	Frame type = 6 Command = “8” (ASCII)
Report	?8	Invalid	Frame type = 6 Command = “5” (ASCII)
Report	?9 through ?24	Invalid	Frame type = 6 Command = “9” through “24” (ASCII)
Report	F	Invalid	Frame type = 6 Command = “10” (ASCII)
Report	&	Invalid	Frame type = 6 Command = “23” (ASCII)
Report	Q	Invalid	Frame type = 6 Command = “29” (ASCII)

G - Command Quick Reference

Control Commands

Command	Value	Description
R		Executes command or command string
X		Repeats last command string
G <n>	<n> = 0..30000	Repeats command sequence
G		Marks start of a repeat sequence
M <n>	<n> = 5..30000	Delay in milliseconds
H <n>	<n> = 0..2	Halts command execution
T		Terminate command
J <n>	<n> = 0..7	Auxillary outputs
s <n>	<n> = 0..14	Loads common string in EEPROM
e <n>	<n> = 0..14	Executes EEPROM common string

Initialization Commands for 3-Port Valve and T-Valve

Command	Value	Description
Z <n>	<n> = 0, 10-40 = full plunger force 1 = half plunger force	Initializes the plunger drive and sets the valve to the right or output position.
Y <n>	<n> = 0, 10-40 = full plunger force 1 = half plunger force	Initializes the plunger drive and sets the valve to the left or output position.
W <n>	<n> = 0, 10-40 = full plunger force 1 = half plunger force	Initializes the plunger drive. This command is used for pumps without valves.

Initialization Commands for 3-Port Distribution Valve

Command	Value	Description
Z <n>	<n> = 0, 10-40 = full plunger force 1 = half plunger force	Initializes the plunger drive and sets the valve output to the right. 10 – 40 refers to Set speed commands S10 to S40.
Y <n>	<n> = 0, 10-40 = full plunger force 1 = half plunger force	Initializes the plunger drive and sets the valve output to the left.
Z	none	Sets the pump’s position counter to the valve contained in the current encoder position. This command is used after a plunger overload error to resynchronize the pump’s actual position with its internally recorded position without having to go through the entire initialization sequence.

Plunger Movement Commands/Status Bit Reports

Command	Value	Description	Status
A <n>	<n> = 0..3000	[A]bsolute Position	Busy
a <n>	<n> = 0..3000	[a]bsolute Position	Ready
P <n>	<n> = 0..3000	Relative [P]ickup	Busy
p <n>	<n> = 0..3000	Relative [p]ickup	Ready
D <n>	<n> = 0..3000	Relative [D]ispense	Busy
d <n>	<n> = 0..3000 <n> = 0..24,000 in microstep mode	Relative [d]ispense	Ready

Valve Commands

Command	Description
I	Moves valve to input position
O	Moves valve to output position
B	Moves valve to bypass position
E	Moves valve to extra position (3-port distribution valve only)

Valve Leakage Detection Commands

Command	Value	Description
^	<n> = 0..255	Sets threshold value for fluid detection

Set Commands

Command	Value	Description	Default Setting
S <n>	<n> = 1..40	Set speed	(11)
V <n>	<n> = 5..6000	Peak velocity	(1400)
v <n>	<n> = 50..1000	Start velocity	(900)
C <n>	<n> = 0..25	Cutoff steps	(0)
c <n>	<n> = 50..2700	Cutoff steps	(900)
L <n>	<n> = 1..20	Slope	(14)
K <n>	<n> = 0..31 <n> = 0..255 in microstep mode	Backlash	(10)

Microstep-Enabled Firmware Commands

Command	Value	Description
N	<n> = 0 or 1	Sets the microstep mode off or on.
S	<n> = 0..40	Sets speed
V	<n> = 5..6000	Sets end velocity in HS/s
v	<n> = 50..1000	Sets start velocity in HS/s
c	<n> = 50..2700	Sets cutoff velocity in HS/s
L	<n> = 1..20	Sets ramp slope
K	<n> = 0..31 (default 11)	Backlash
k	<n> = 0..80 or 0..640 in microstep mode	

Report Commands

Command	Description
Q	Query, Status and Error Bytes
?	Reports absolute plunger position
?1	Reports start velocity
?2	Reports top velocity
?3	Reports cutoff velocity
?4	Reports actual position of plunger
?12	Reports number of backlash steps
?13	Reports status of input #1
?14	Reports status of input #2
?22	Reports current value from fluid sensor
F	Reports buffer status
&	Reports firmware version
#	Reports firmware checksum

Error Codes

Command	Description	Notes
0	Error free condition	
1 (01h)	Initialization error	Fatal error. Reinitialize pump before resuming normal operation.
2 (02h)	Invalid command	
3 (03h)	Invalid operand	
4 (04h)	Invalid command sequence	
6 (06h)	EEPROM failure	
7 (07h)	Device not initialized	
9 (09h)	Plunger overload	Fatal error. Reinitialize pump before resuming normal operation.
10 (0Ah)	Valve overload	Fatal error. Reinitialize pump before resuming normal operation.
11 (0Bh)	Plunger move not allowed	
15 (0Fh)	Command overflow	

Error Codes and Status Byte

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
7 6 5 4 3 2 1 0	**0**	**or 1**	**0**	**or 1**	**Number**	**Error**
0 1 X 0 0 0 0 0	40h	60h	64	96	0	No error
0 1 X 0 0 0 0 1	41h	61h	65	97	1	Initialization
0 1 X 0 0 0 1 0	42h	62h	66	98	2	Invalid command
0 1 X 0 0 0 1 1	43h	63h	67	99	3	Invalid operand
0 1 X 0 0 1 0 0	44h	64h	68	100	4	Invalid command seq.
0 1 X 0 0 1 0 1	45h	65h	69	101	5	Fluid detection
0 1 X 0 0 1 1 0	46h	66h	70	102	6	EEPROM failure
0 1 X 0 0 1 1 1	47h	67h	71	103	7	Device not initialized
0 1 X 0 1 0 0 1	49h	69h	73	105	9	Plunger overload
0 1 X 0 1 0 1 0	4Ah	6Ah	74	106	10	Valve overload
0 1 X 0 1 0 1 1	4Bh	6Bh	75	107	11	Plunger move not allowed
0 1 X 0 1 1 1 1	4Fh	6Fh	79	111	15	Command overflow

DB-15 Connector Pin Assignments

Pin	Function	Remarks
1	24 VDC	
2	RS-232 TxD line	Output data
3	RS-232 RxD line	Input data
4	Unused	
5	CAN high signal line	
6	CAN low signal line	
7	Auxiliary input #1	TTL level
8	Auxiliary input #2	TTL 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	TTL level
14	Auxiliary output #2	TTL level
15	Auxiliary output #3	TTL level

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