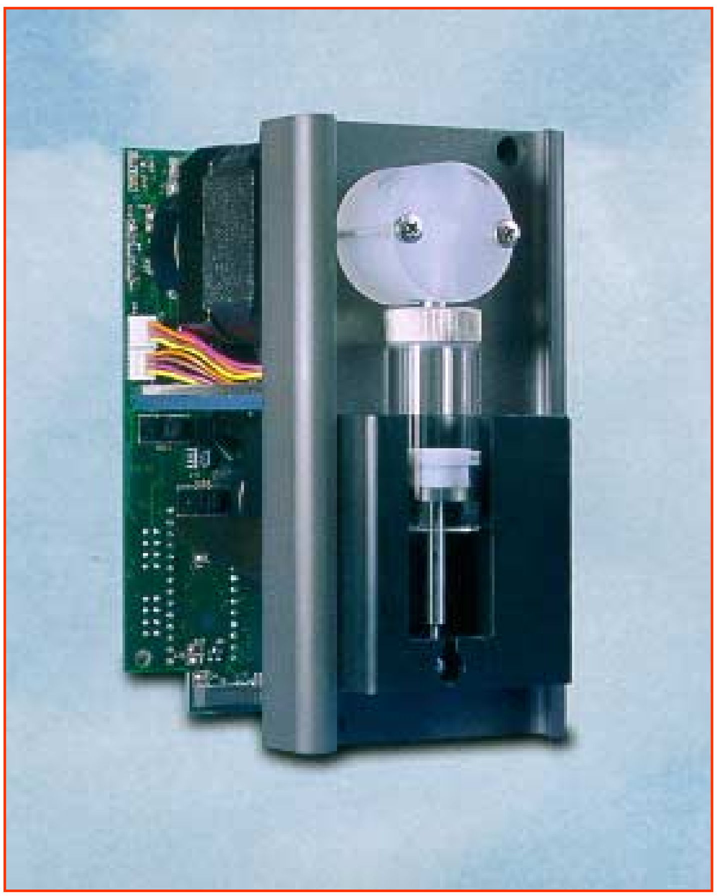
XE 1000 Pump

OPERATOR'S MANUAL

729428 B



FEBRUARY, 1999

CAVRO SCIENTIFIC INSTRUMENTS, INC.
2450 ZANKER ROAD, SAN JOSE, CA 95131
TELEPHONE: (408) 953-3100 • (800) 231-0711 • FAX: (408) 953-3107

Part number: 729428B

Copyright and Trademark Information

Product Warranty Information

Cavro warrants that instruments manufactured and sold by Cavro will be free from defects in materials and workmanship for a period of twelve (12) months from the date of shipment to customer. Cavro's liability for the breach of the foregoing warranty is limited to the repair or replacement of the products found to be other than warranted. Such products will be accepted for return only if customer returns them to Cavro's factory or repair depot within thirty (30) days from the time of discovery of the alleged defect, and prior to return, obtains a return authorization number from Cavro, provides Cavro with the serial number of each instrument to be returned, and prepays freight charges to the factory or a designated Cavro repair depot. No warranty is expressed or implied for:

Breakage	Syringes
Maltreatment	Syringe seals
Unauthorized service	Tubing and tubing connections
Units not returned in original or adequate packaging	Cavro valves
Units which are "life-cycled"	Cavro probes

The foregoing warranties and limitations are customer's exclusive remedies and are in lieu of all other warranties, express or implied, including without limitation any warranty of merchantability or fitness for a particular purpose.

Product Documentation Warranty Information

The information contained in this document is subject to change without notice. Cavro makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose.

Cavro shall not be liable for errors contained in this document or for incidental or consequential damages in connection with the furnishing, performance, or use of this material.

Contents

Figures

1 Getting Started

Congratulations on your purchase of the Model XE 1000 Pump from Cavro Scientific Instruments, Inc.

The XE 1000 is a simple, compact, economical OEM pump module designed for 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

XE 1000 Features at-a-Glance

Unpacking the XE 1000

Functional Description of the XE 1000

Tips for Setting Up the XE 1000

Mating Connector Suppliers

Power and Electrical Considerations

Choosing a Power Supply

• Regulatory Considerations

The XE 1000 is a general laboratory module. Since it is not a medical device, it is not subject to FDA regulatory approval.

• CE

Wherever possible, UL-approved components have been used in the design and manufacturing of the XE 1000. As a module designed for incorporation into larger systems which require independent testing and certification, the XE 1000 does not carry its own CE mark.

Radio Interference

The XE 1000 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 XE 1000 into electronic laboratory systems.

XE 1000 Features at-a-Glance

The XE 1000 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 500 µL to 5 mL

Accuracy < 1.0% at full stroke

Precision ≤ 0.05% at full stroke

Standard dispense/aspirate resolution of 1000 steps

Borosilicate glass, Kel-F® and Teflon® fluid contact

RS-232, RS-485 and CAN interfaces

Programmable plunger speeds from 2-60 sec/stroke

Direct rack and pinion drive with step-loss detection

15 selectable address settings

Manually moveable syringe drive (power off)

Pump diagnostics, self-test, and error reporting

Auxiliary input and output

Operates using a single 24VDC power supply

Unpacking the XE 1000

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 XE 1000 is an electronic device that is sensitive to electrostatic discharge (ESD). Any static discharge can damage sensitive electronic components. To prevent premature failure of pump components, the XE 1000 should be handled using good ESD practices. These include, but are not limited to:

Using wrist or ankle straps

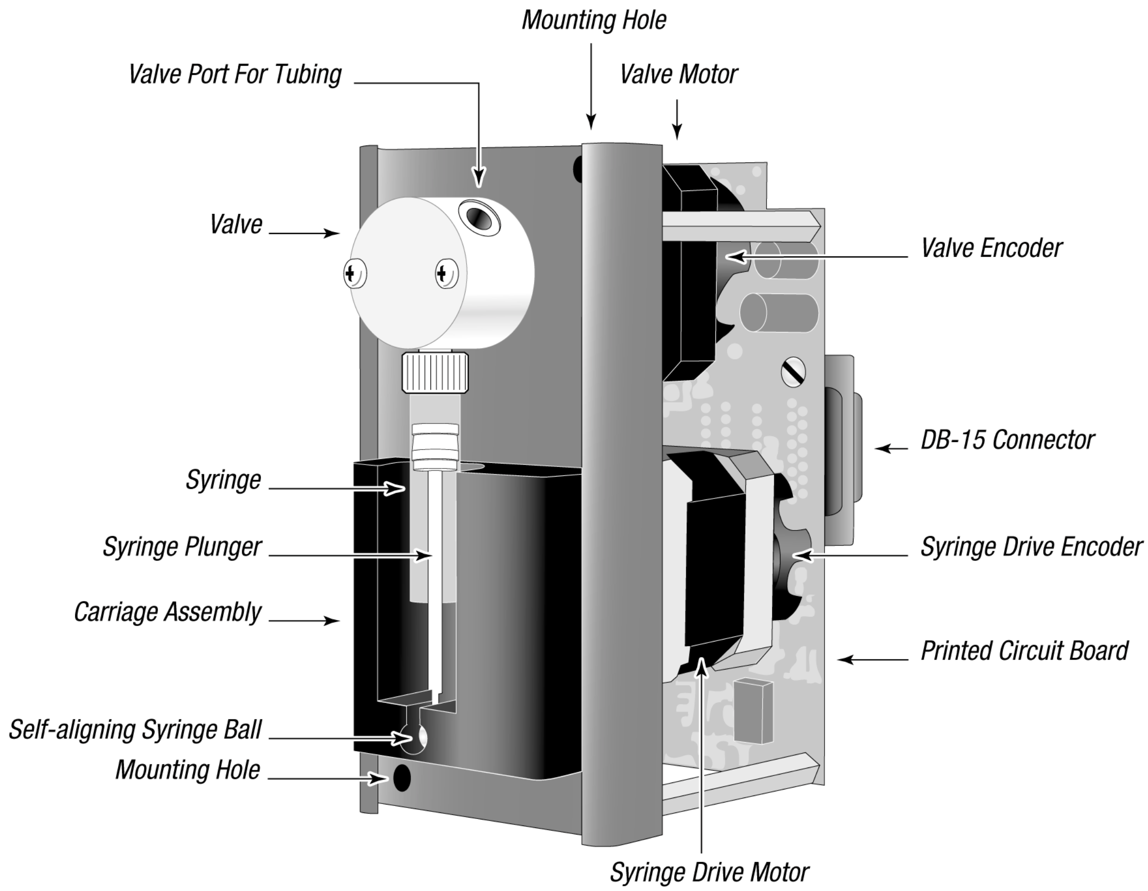
ESD mats or worktables

ESD wax on the floor

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

Functional Description of the XE 1000

The XE 1000 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.



The illustrations below show both the front and the back of the XE 1000.

Figure 1-1. XE 1000 Pump, Front View

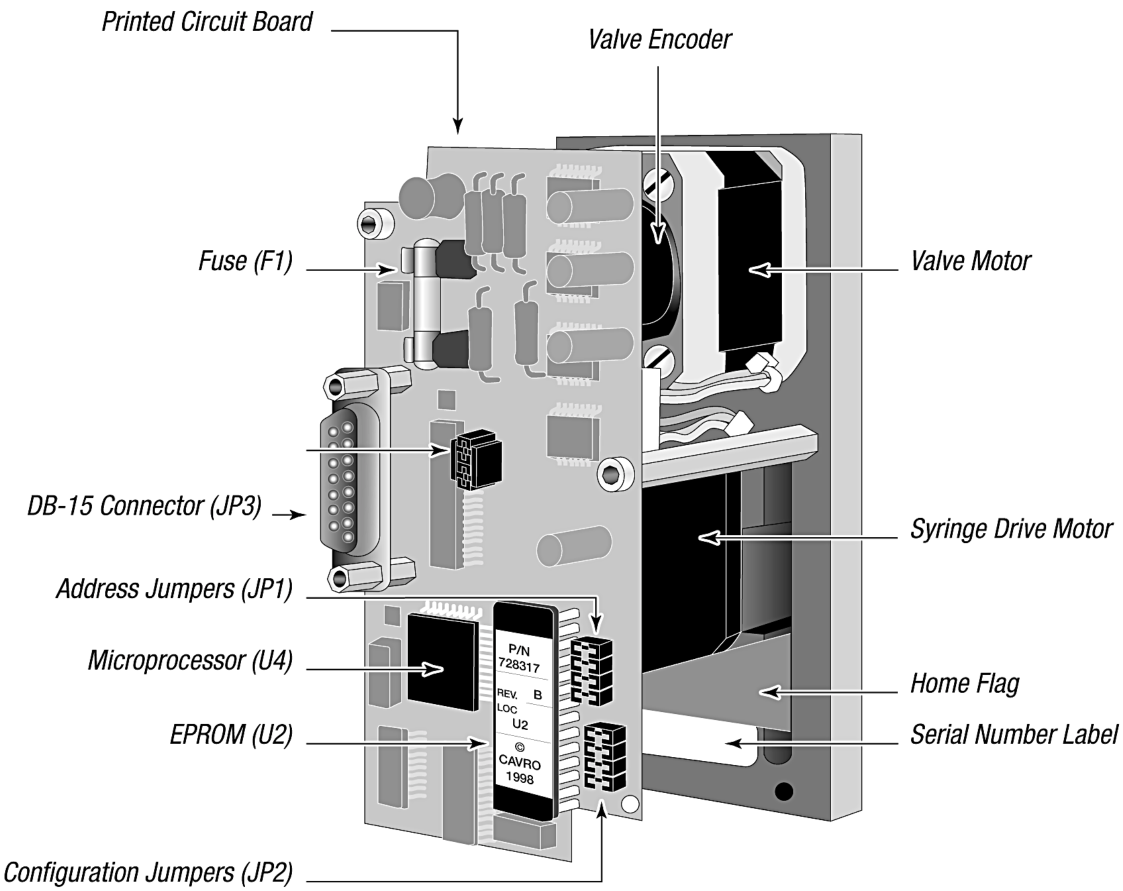


Figure 1-2. XE 1000 Pump, Rear View

Functional descriptions and illustrations of each major XE 1000 component are provided in the sections that follow.

• Syringe and Syringe Drive

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

The syringe drive has a 30 mm travel length and resolution of 1000 steps. 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 self-aligning ball that mates to the carriage. The top of the syringe barrel attaches to the pump valve by a 1/4-28" fitting.

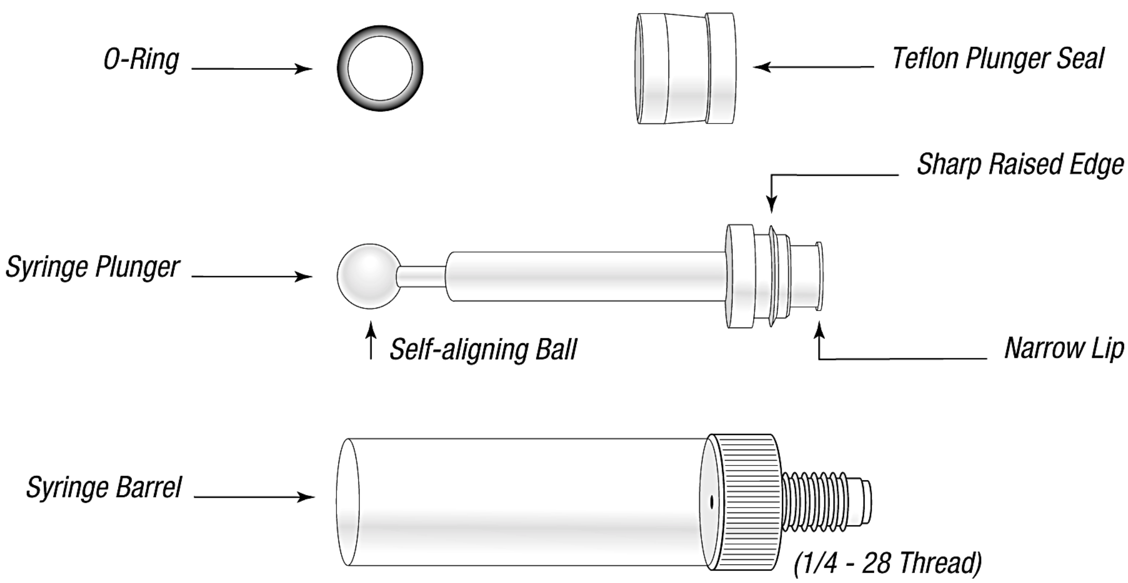


Figure 1-3 shows the components of a typical syringe.

Figure 1-3. Syringe Components

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

NOTE	The pump and syringe are designed to be run at ambient temperatures and pressures. Failure to do so can result in leaking, stalling or damage to the syringe and/or pump.

• 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 input and output ports. Additionally, there is a bypass position. This position “bypasses” the syringe and connects the input and output ports. This position is often used for washing out the probe.The valve is turned by a stepper motor coupled to an encoder to provide positioning feedback.

> **NOTE** The valve is designed to be run at ambient temperatures and pressures. Failure to do so can result in leakage, stalling, or damage to the valve.

Figure 1-4 shows the components of a 3-port valve.

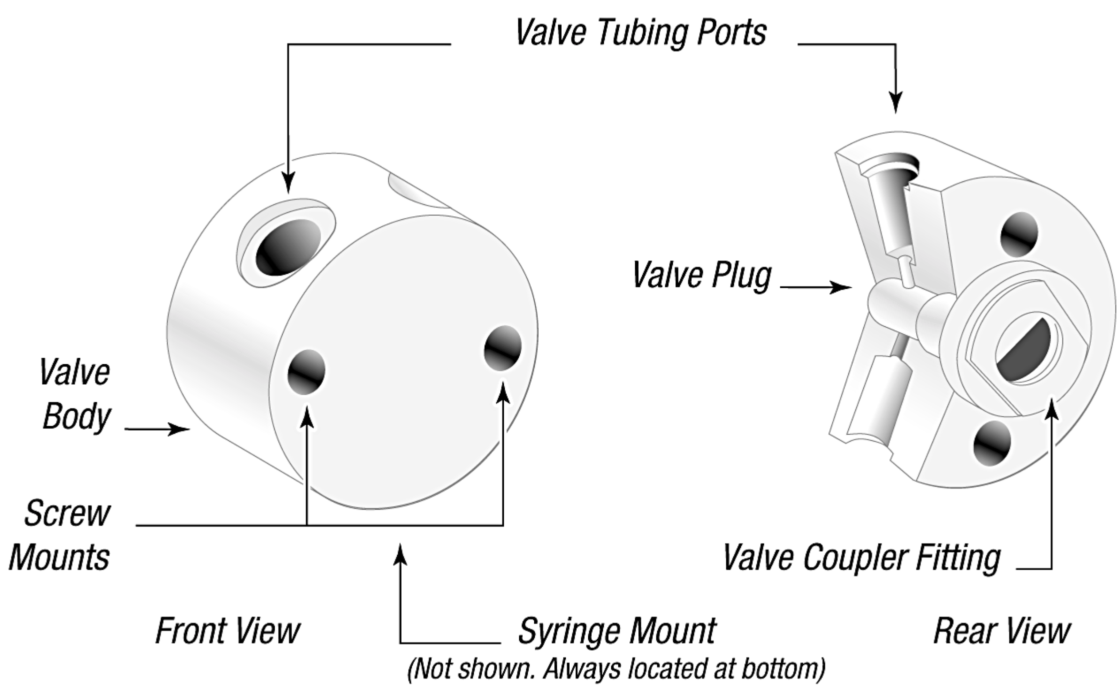


Figure 1-4. 3-Port Valve Components

Printed Circuit Board

The printed circuit board (PCB) holds the microprocessor and circuitry to control the syringe and valve drives. The PCB provides connectors for the auxillary input and output, jumpers for configuring different modes of operation, and communications addresses.

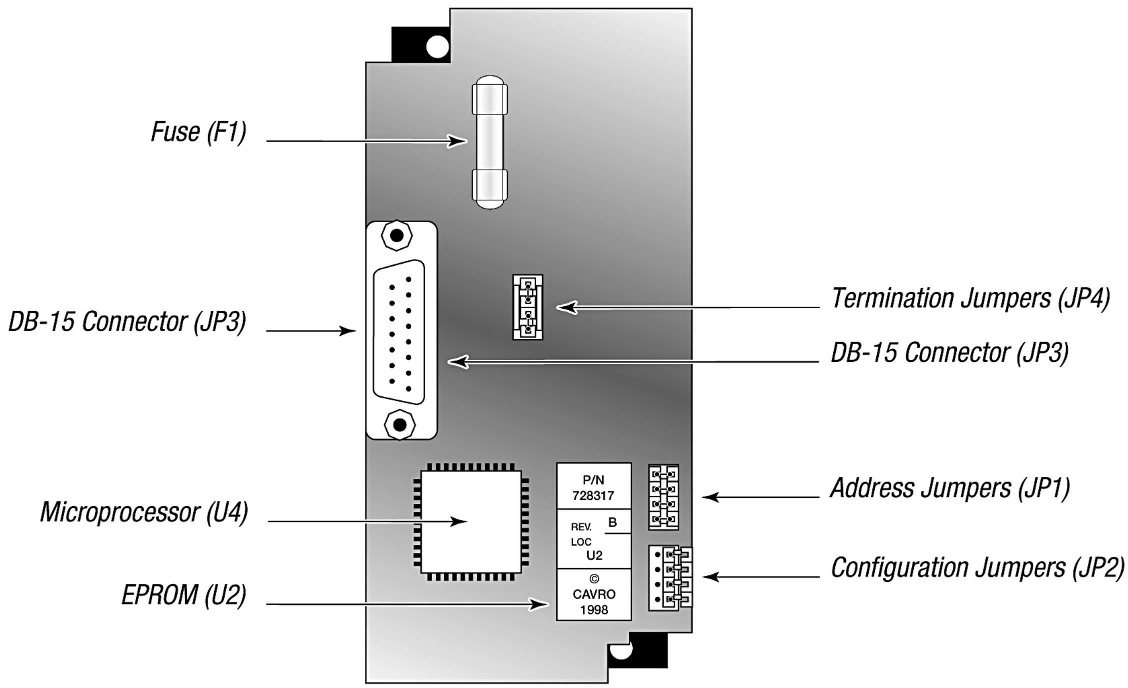


Figure 1-5 shows the major components of the printed circuit board.

Figure 1-5. XE 1000 Printed Circuit Board External Connectors

For more information on the printed circuit board auxillary input/output, jumpers, addresses, and EPROM, see Chapter 2, “Hardware Setup.”

Communication Interfaces

Depending on the pump configuration, the XE 1000 can communicate singly or in a multi-pump configuration through an RS-232, RS-485, and CAN (Controller Area Network) interface. For RS-232 and RS-485, a baud rate of 9600 is supported. For CAN, a baud rate of 100K is supported.

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

Multi-Pump Configurations

Up to fifteen XE 1000s 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 jumpers on the PCB. For more information on setting addresses, see Chapter 2, “Hardware Setup.”

Tips for Setting Up the XE 1000

For complete information on setting up the XE 1000, 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 away from the carriage assembly 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 XE 1000 is powered by a 24VDC line via the DB-15 connector. The 24VDC supply for a single XE 1000 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):

- ≥ 500mA for power supplies with minimal capacitance
- ≥ 500mA for power supplies with internal filter capacitance of at least 1000 µF per amp of output current
- ≥ 500mA 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 XE 1000 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. The peak current for a single XE pump is 500 mA.

For example, if a system incorporates six XE 1000s 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 0.50 = 3.0A; + 4A = 7A (choose a 7A 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 XE 1000. This can result in decreased component life and performance variability. 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 XE 1000. These issues can be avoided by using a properly designed commercial power supply.

Consideration should also be given to the wiring of the XE 1000 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 XE 1000 should be 20AWG or heavier. Multiple XE 1000s 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 XE 1000s 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 XE 1000, switch power to the power supply. Do not use a relay or switch contacts between the 24V supply and the XE 1000 (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 XE 1000 idle current is less than 10% of the full running current.

For example, in a system with multiple XE 1000s, a 24V 5-amp switcher with a minimum load less that 500mA may not provide sufficient current when the XE 1000 motors are idle and all other devices are in a low current state. If the XE 1000 is the only load on the 24V supply, a switcher should have a minimum load specification of 500mA 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 XE 1000 requires a 24VDC power supply with a current rating of at least 500mA, 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 XE 1000. (Power is described in the “Power” section in this chapter.)

Set a unique address to identify each pump module. For more information, see "Address Jumpers (JP1)” 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	TTL level
8	Address 0	
9	Ground	Power and logic
10	Ground	Power and logic
11	RS-485 A line	
12	RS-485 B line	
13	Auxiliary output	TTL level
14	Address 2	
15	Address 1	

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.

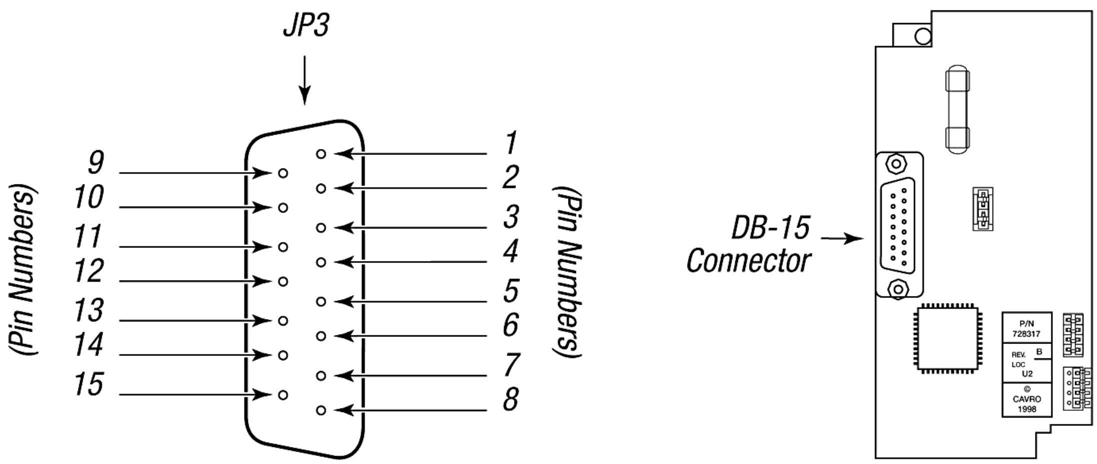


Figure 2-1. DB-15 Connector Pins

Communication Interfaces

The computer or controller communicates with the XE 1000 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 XE 1000’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. 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 JP4. 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 JP4 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 JP4.

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

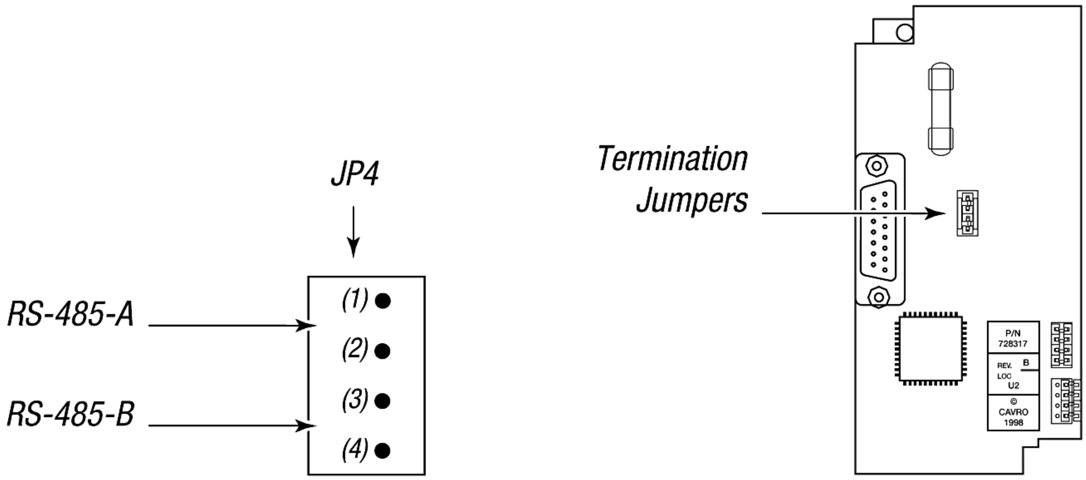


Figure 2-2. Termination Jumpers

NOTE	Pumps are shipped with the RS-485 termination jumper installed on JP4. Please remove the jumpers if they are not needed.

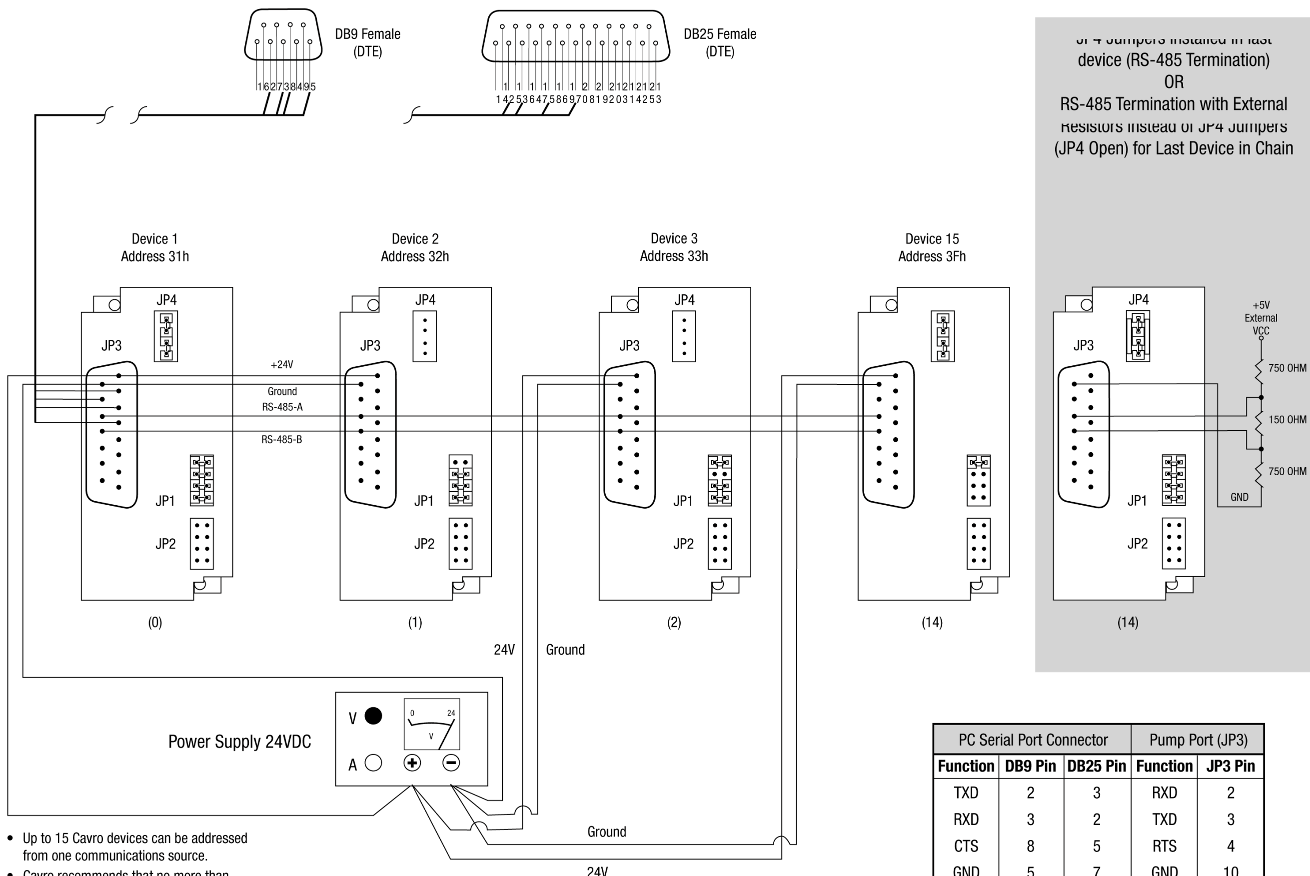
When communicating with the pumps via RS-232, the first pump in the chain must be cabled for RS-232 communication. This pump receives the RS-232 signal from the PC or controller and converts it to RS-485, then passes the RS-485 signal to all other pumps in the chain.

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. 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.

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	RTS	4
GND	5	7	GND	10

- Up to 15 Cavro devices can be addressed from one communications source.
- Cavro recommends that no more than 2 devices in series be connected to the same power line.
- Jumpers should be installed in JP4 for single device applications.

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

RS-485 Cabling

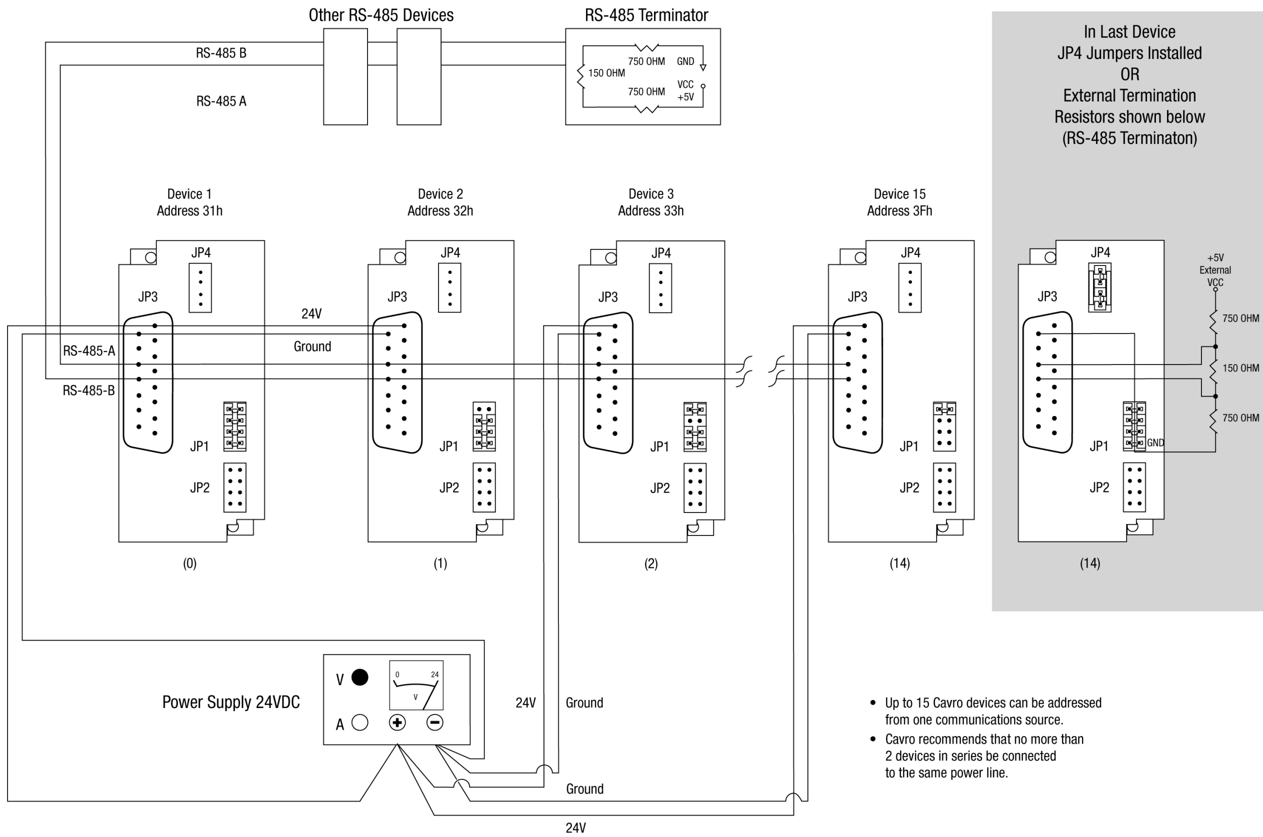


Figure 2-4. RS-485 Multi-Pump Cabling

CAN CABLING

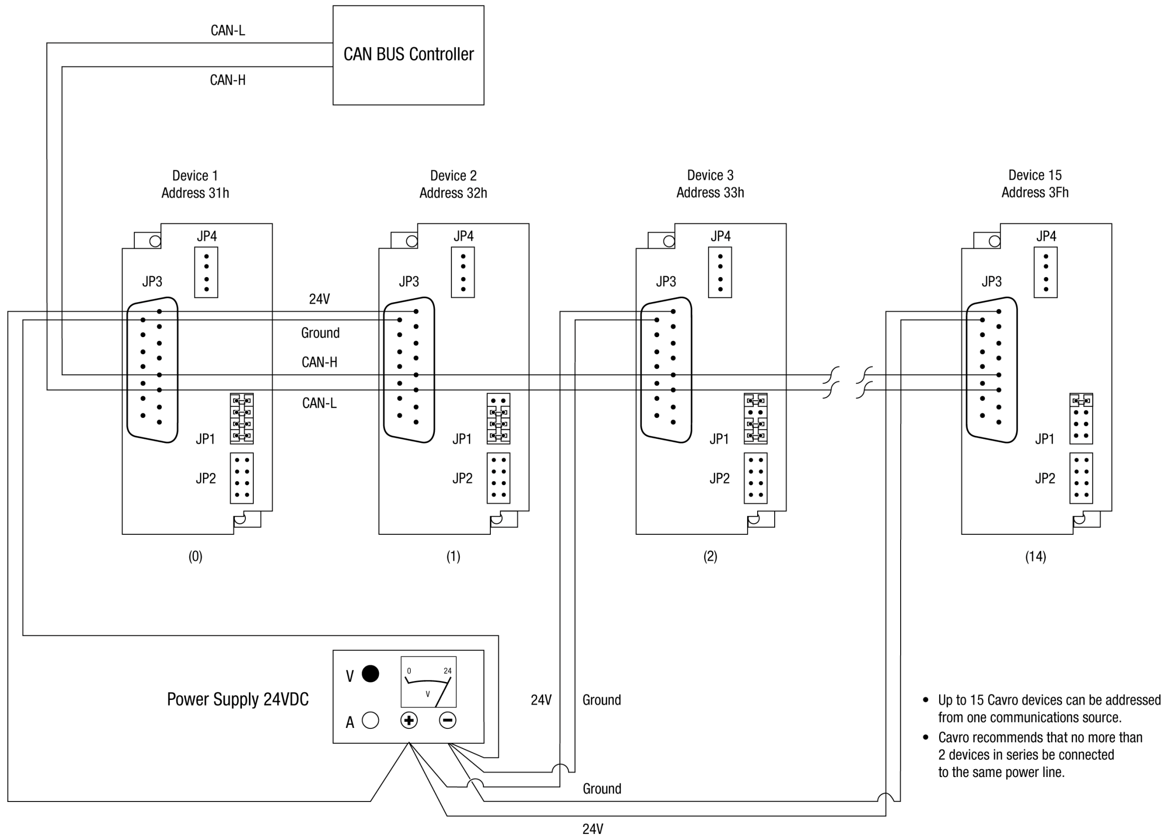


Figure 2-5. CAN Multi-Pump Cabling

Printed Circuit Board Settings and Options

Configuration Jumpers (JP2)

Connector JP2 on the XE 1000 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 (JP2-1)

Holding Current (JP2-2)

Valve diagnostics (JP2-3)

Open (JP2-4)

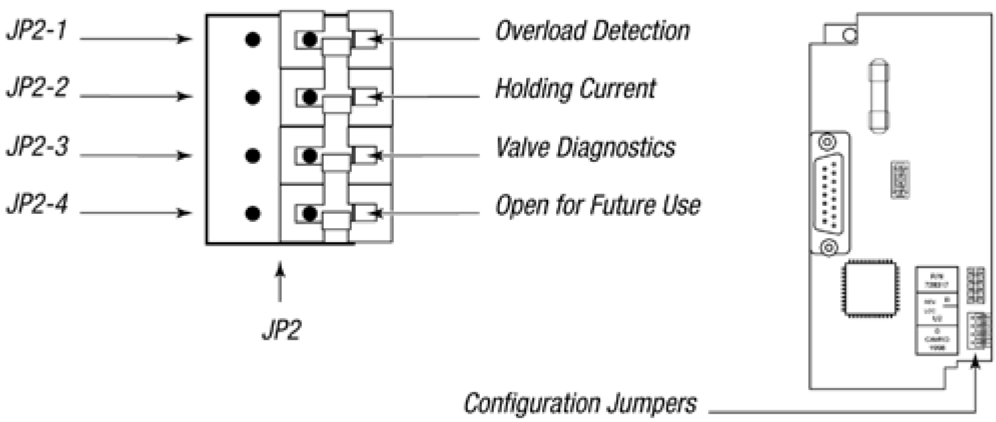


Figure 2-6. Configuration Jumpers

NOTE	Always power off the XE 1000 before changing any of the jumpers on JP2.

NOTE	The XE 1000 is shipped with spare jumpers on the right hand pins of JP2 (refer to above illustration, 2-6). These jumpers are not connected. They can be used to change the default configuration settings.

JP2-1: Plunger overload Detection

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

JP2-1 removed	Plunger overload detection enabled (default setting)
JP2-1 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 JP2-1, plunger overload will not be detected and the pump will not generate an error code if it is losing steps.

JP2-2: Holding Current

This jumper position, when enabled, increases the holding current. There are two settings:

JP2-2 removed	Maximum holding current disabled (default setting)
JP2-2 installed	Maximum holding current enabled

This option is for applications that use viscous solutions or involve backpressure due to smaller ID tubing. When jumper JP2-2 is removed, the current will decrease when the pump is in a holding position. Installing the jumper will increase the holding current.

JP2-3: Valve Diagnostics

This jumper position enables or disables the valve. There are two settings:

JP2-3 removed	Valve enabled (default setting)
JP2-3 installed	Valve disabled

This is a diagnostic test that can be used if the valve drive appears to malfunction. It runs the pump in a “valveless” mode.

JP2-4: Open For Future Use

Address Jumpers (JP1)

The address jumpers are located on the lower right of the XE 1000's printed circuit board (see Figure 2-7). Each pump must be assigned a unique address number from 0 to 14. The address value is determined by the state of the jumpers JP1-1, JP1-2, JP1-3, and JP1-4 as shown below in Table 2-2. They are used to give each XE 1000 in a multi-pump configuration a unique address, allowing the user to direct commands to specific pumps. The address jumpers set the pump to one of 15 different addresses. The address is determined by the state of the jumpers in JP1-1, JP1-2, JP1-3, and JP1-4.

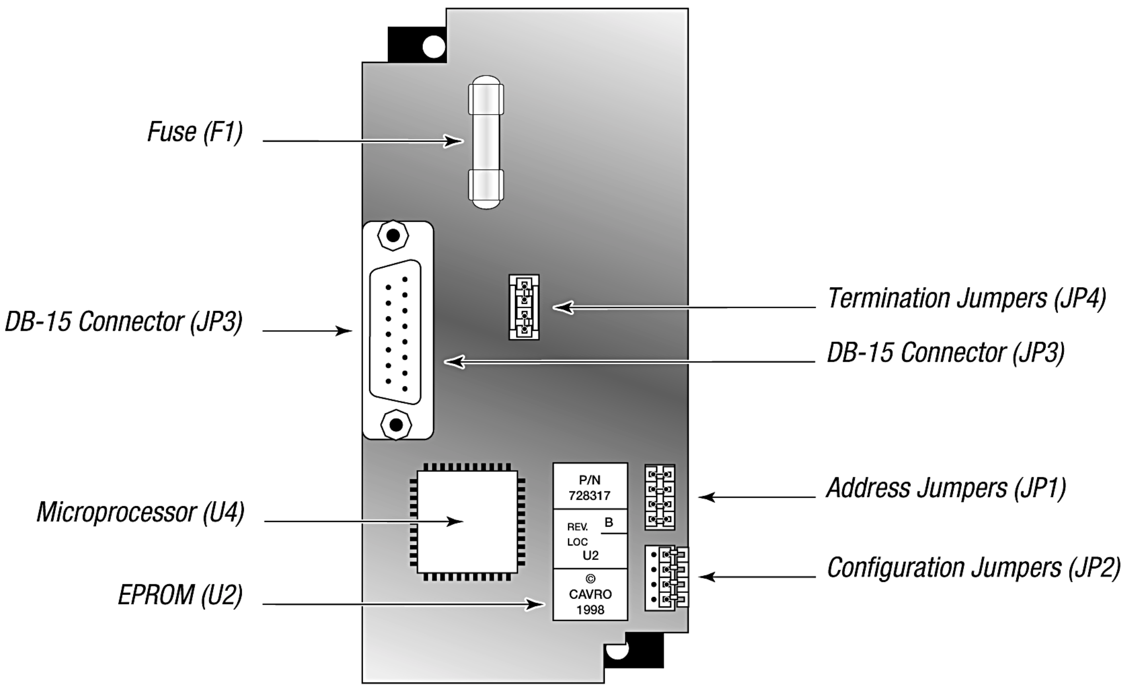


Figure 2-7. Address Jumpers

Table 2-2. Address Jumpers

Address	JP1-1	JP1-2	JP1-3	JP1-4
0	Closed	Closed	Closed	Closed
1	Open	Closed	Closed	Closed
2	Closed	Open	Closed	Closed
3	Open	Open	Closed	Closed
4	Closed	Closed	Open	Closed
5	Open	Closed	Open	Closed
6	Closed	Open	Open	Closed
7	Open	Open	Open	Closed
8	Closed	Closed	Closed	Open
9	Open	Closed	Closed	Open
10	Closed	Open	Closed	Open
11	Open	Open	Closed	Open
12	Closed	Closed	Open	Open
13	Open	Closed	Open	Open
14	Closed	Open	Open	Open
Self Test	Open	Open	Open	Open

NOTE "Closed" means the jumper is in, and "open" means the jumper is out.

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

Self-Test

When all the jumpers in JP1 are left open, the XE 1000 is in self-test. Self-test causes the XE 1000 to initialize then cycle repeatedly through a series of plunger movements at different speeds. If an error condition occurs, the pump stops moving.

To run the self-test, remove all the jumpers in JP1. 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.

Input/Output

The XE 1000 provides one auxiliary input and output that can be accessed through the DB-15 connector, JP3. They provide TTL level signals. The output is controlled by the [J] command.

The auxillary input is located on JP3 pin 7. It can be read back using report command ?I. Additionally, the input can be used to externally trigger a command sequence using the [H] command. The commands are described in Chapter 3, “Software Communication.”

The auxiliary output is located on JP3, pin 13.

Installing Components

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

Installing the XE 1000 Valve

To install the XE 1000 valve:

All XE 1000 pumps are delivered with the valve installed. To install a new valve follow these steps.

Remove the fluid from the pump.

Initialize the pump using the ZR command so that the valve motor shaft is in the correct position.

Remove the syringe and tubing.

Remove the two Phillips head screws on the front of the valve, then remove the valve from the pump.

Install the new valve by placing it on the front panel so that the screw holes line up. The valve coupler fitting mates to the valve motor shaft. The shaft should be in the correct position. If it is not, re-initialize the pump using the command ZR.

Replace the valve screws. Tighten to ¼ to ½ turn after the screws contact the valve body.

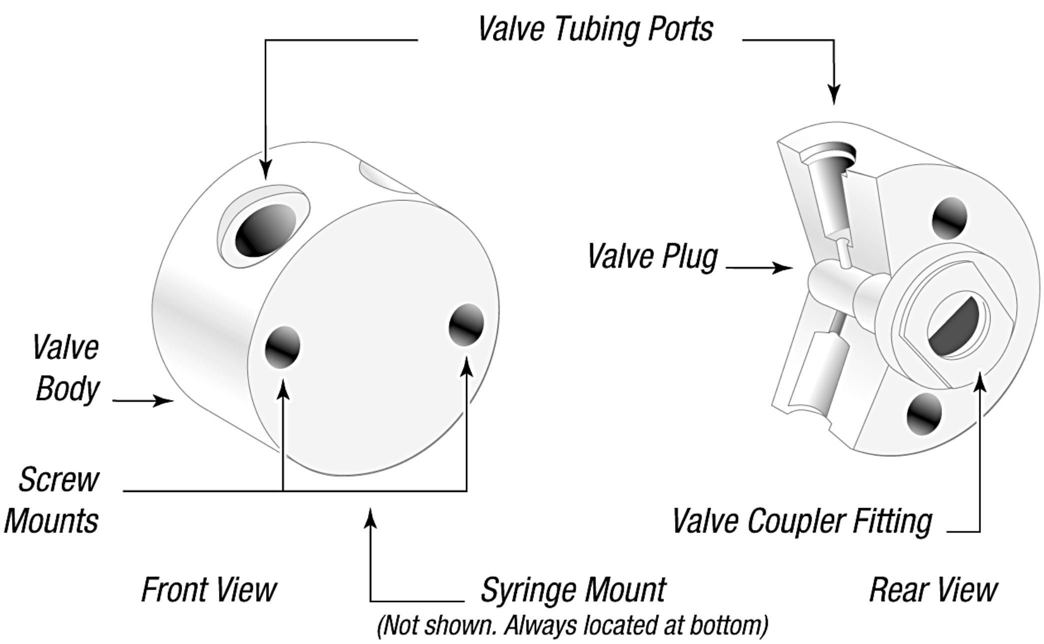


Figure 2-8. XE 1000 Valve Installation (3-Port Valve Shown)

Installing a Syringe

To install a syringe, follow these steps:

1 Lower the plunger drive by sending the command [A1000R]. If power is not applied, the plunger drive can be manually lowered by pushing down on the carriage assembly until it reaches the bottom of travel.

To install the syringe, do the following (as shown in Figure 2-9):

Place the self-aligning ball on the syringe plunger into the matching space in the carriage assembly.

Pull up on the the syringe barrel and screw the 1/4-28 fitting into the valve until it is finger tight. Using pliers on the syringe 1/4-28 fitting, turn the syringe an additional quarter turn.

NOTE Make sure the syringe is securely screwed into the valve.

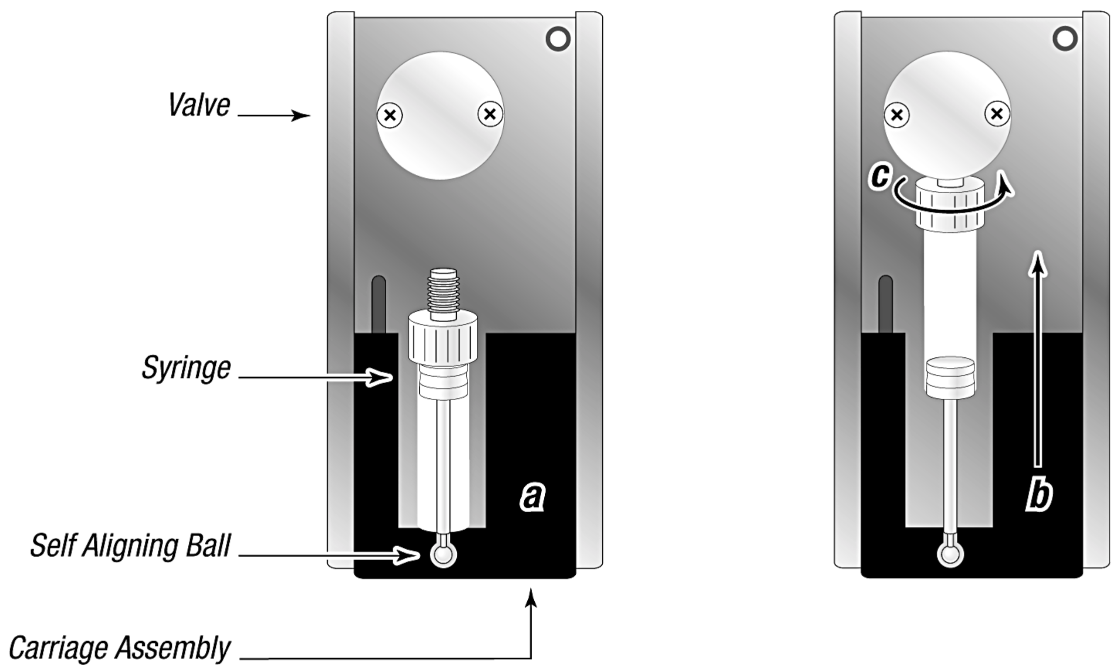


Figure 2-9. Syringe Installation

Mounting the XE 1000

The XE 1000 contains mounting holes in the top right and bottom left corners of the pump face. It is designed to mount to a panel using two M3 socket head cap screws.

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

Figure 2-10 is an outline drawing of the pump. It contains dimensions to help in mounting the pump.

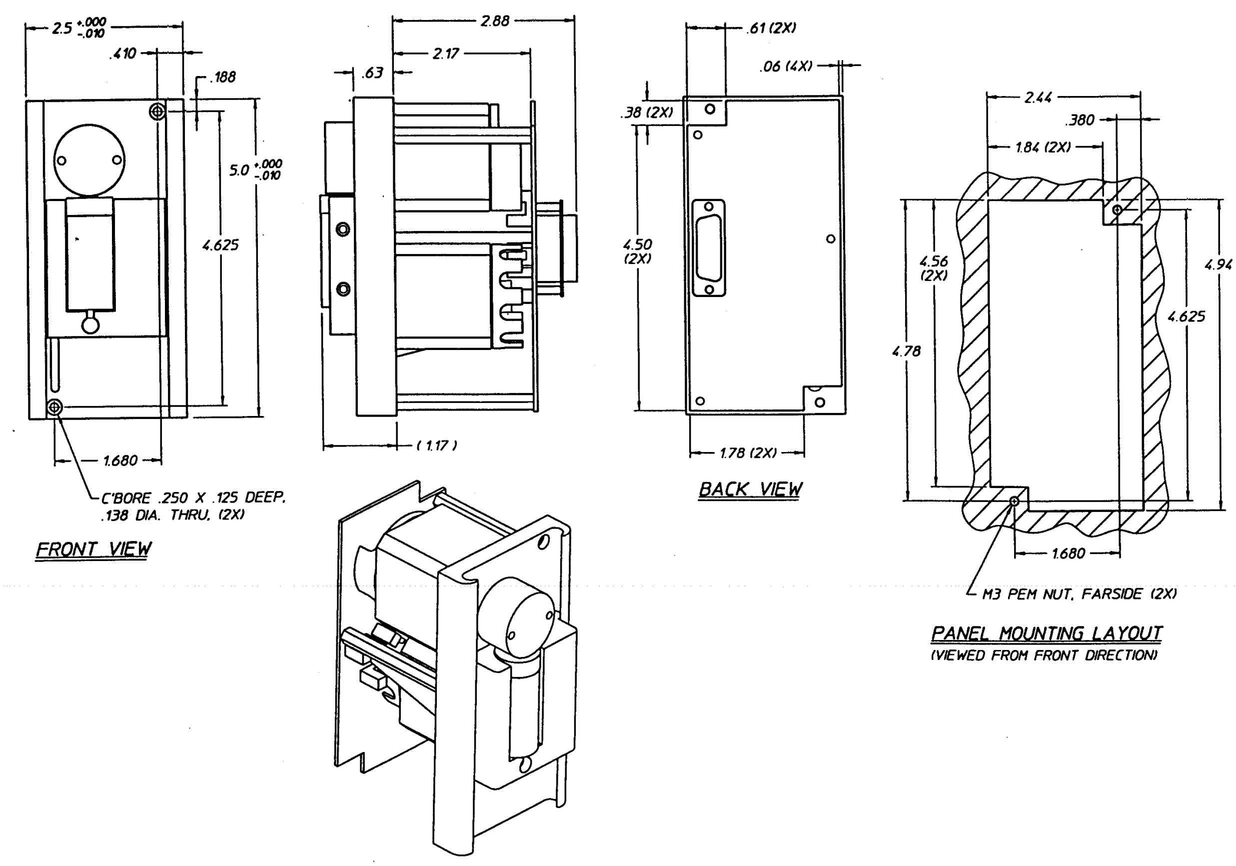


Figure 2-10. XE 1000 Outline Drawing

3 Software Commun ication

This chapter describes how to communicate with the XE 1000 through an RS-232, RS-485, and CAN (Controller Area Network) interface.

This chapter includes these topics:

• Communication Protocols

Three software communication protocols are available:

OEM communications protocol

Data Terminal (DT) protocol

CAN protocol

OEM and DT software protocols use RS-232 or RS-485 hardware protocols. CAN software protocol uses CAN hardware protocol. The XE 1000 automatically detects the OEM or DT software communication protocols.

The DT protocol can be implemented 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.

- ## RS-232/RS-485 Hardware Protocol

OEM Software Communication Protocol

OEM communication is a robust protocol that includes automatic recovery from transmission errors. Table 3-1 describes each setting within the OEM communication protocol.

Table 3-1. OEM Protocol

Parameter	Setting
Character Format	
Baud rate	9600
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/Repeat flag
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. It also automatically specifies that the pump is using OEM protocol.

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 whether 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 Pump Status" in this chapter.

Data Terminal (DT) Protocol

The DT protocol can be used easily from any terminal or terminal emulator capable of generating 7-bit, printable ASCII characters.

Table 3-2. DT Protocol

Character Format	
Parameter	**Setting**
Baud rate	9600
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)

Character Format	
Parameter	**Setting**
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. It also automatically specifies that the pump is using DT protocol.

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. (ASCII string of ≤ 32 characters)

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 Pump Status."

Data Block

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

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

These characters terminate the reply block.

Using DT Protocol with Microsoft Windows

The XE 1000 can be controlled in DT protocol mode directly from the Microsoft Windows terminal accessory.

To communicate with the XE 1000 using Windows 95/NT, follow these steps:

1 To connect the XE 1000 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, then click **OK**:

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

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

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

Function, arrow, and Control keys act as:

– Select "Terminal keys"

Emulation:

– Select "Autodetect"
– Enter "500" in Backscroll buffer lines

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

8 Enter or select these options:

– Select "Send line ends with line feed"
– Select "Echo typed characters locally"
– Enter a Line delay of "0"
– Enter a Character delay of "0"
– Select "Wrap lines that exceed terminal width"

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

10 Set the pump address to 1 or the appropriate address.

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

To run the pump, see the commands listed in "

12 Using the XE 1000 Command Set” in this chapter.

• CAN Interface Communications

CAN (Controller Area Network) is a two-wire, serial communication bus. It does not require polling sequences that verify task completion as do DT and OEM protocols. Using CAN, the pumps asynchronously report to the master or host when they have finished the current task. This improves communications throughput.

> **NOTE** All Cavro XE 1000s use CAN controller ICs compatible with Philips Semiconductor CAN 2.0, version B.

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 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:

Byte 1								**Byte 2**							
0/1	2	1	0	3	2	1	0	2	1	0	0/1	3	2	1	0
Dir	Group			Device				Frame			RTR	Length			

11 Bit MID (Dir, Group, Device, Frame)

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.

NOTE	Peer-to-peer messaging is not supported.

Group

This is the group number (0 - 7). Each type device on the XE 1000 CAN has a group assignment. The XE 1000 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 15 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.

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. Equivalent to 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 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 [?S] command
10	Report buffer status, like the [F] command
12	Report backlash, like the [?K] command
13	Report status of input #1, like the [?I] 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 serves the same purpose as 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 ASCII strings as with OEM and DT protocols. 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 XE 1000 buffer size is 32 characters).

Handling of Pump Boot Requests

When the pump is first powered up or receives a reset command (frame type 2, command 0), it notifies the host of this condition. The pump sends 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 master, and the frame type must be 0 when the master replies to the boot request.

Example 1. The pump is set to address 1

Pump sends:

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

Master acknowledges:

Dir	Group	Device	Frame	RTR	Length	Data Bytes
0	001	0000	000	0	0010	0010 0000

Master acknowledges the boot request with:

Dir = 0	Master to pump
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
Data Bytes	The two data bytes are the same. The first four bits are the same as the group number, i.e., 1 and the last 4 bits are the same as the address, i.e., 1.

Note:
Boot MID is the same for all nodes

Example 2. The pump is set to address 6

Pump sends:

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

Master acknowledges:

Dir	Group	Device	Frame	RTR	Length	Data Bytes
0	001	0000	000	0	0010	0010 0110

Master acknowledges the boot request with:

Note:
Boot MID is the same for all nodes

Dir = 0	Master to pump
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
Data Bytes	The two data bytes are the same. The first four bits are the same as the group number, i.e., 1 and the last 4 bits are the same as the address, i.e., 6.

CAN Host and Pump Exchanges

When a pump receives a command, finishes a command, encounters an error condition, or responds to a query, it sends an answer frame to the master 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 begins the MID. 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 3-5. 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, 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 master and pump for action commands, multi-frame commands, common commands, and query commands.

Action Command

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

Master 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 following examples to represent data bytes. The hexadecimal number is bracketed (< >). The rest of the fields are displayed in binary format.

Multi-Frame Command

The master commands [Z2S50IA1000OgHD100G10R] to a pump, and the pump is set to address 0.

Master sends:

0	010	0001	011	0	1000	Z250IA10
Dir	Group	Device	Frame type	RTR	DLC	Data bytes
0	010	0001	100	0	1000	00OgHD10
Dir	Group	Device	Frame type	RTR	DLC	Data bytes
0	010	0001	001	0	0111	0G10R
Dir	Group	Device	Frame type	RTR	DLC	Data bytes

Pump acknowledges:

1	010	0001	001	0	0000
Dir	Group	Device	Frame type	RTR	DLC

After executing the command, pump reports status:

1	010	0001	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 master has sent command [A1000A0] to the pump, it sends command 0 of frame type 2 to execute the pump move. The pump is set to address 0.

Master sends:

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

Pump acknowledges:

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

After executing the command, pump reports status:

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

Query Command

The master sends report command 29 of frame type 6 to a pump, and the pump is set to address 0.

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

Master 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 XE 1000 Command Set

The XE 1000 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 a quick summary of all commands, see Appendix G, “Command Quick Reference.”

When problems are detected, the XE 1000 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 [A1000R] moves the plunger to position 1000.

  – A *multi-command string* such as [IA1000OA0R] turns the valve to the input position, moves the plunger to position 1000, turns the valve to the output position, and finally returns the plunger to position 0.
- The pump’s command buffer holds a maximum of 32 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.
- 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 away from the carriage assembly 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..30,000	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.

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.

During initialization the top of the syringe is recognized in two ways:

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

If either of these conditions fails to occur, an error is triggered.

The speed at which the plunger initializes can be controlled via a parameter sent with the initialization command (possible values are 2 - 20). Slower initialization speeds may be useful when working with viscous fluids, with small ID tubing or probes.

The default initialization speed is 4 seconds/stroke.

NOTE The syringe should be installed for initialization.

Initialization Commands

Z <n> Initialize Plunger (Sets Input at Left Port, Output at Right Port)

The [Z] command initializes the plunger and valve. It defines the left port as the input port (from which fluid is drawn into the syringe) and the right port as the output port (from which fluid is dispensed).

The speed at which initialization occurs is defined by parameter <n> and is in the range of 2-20 seconds.

For example: [Z10] initializes the plunger and valve drives and moves the plunger at a rate of 10 seconds/stroke.

The default initialization speed is Z4 or at a rate of 4 seconds/stroke.

Y <n> Initialize Plunger (Sets Input at Right Port, Output at Left Port)

The [Y] command initializes the plunger and valve. It defines the right port as the input port (from which fluid is drawn into the syringe) and the left port as the output (from which fluid is dispensed).

The speed at which initialization occurs is defined by parameter <n> and is in the range of 2-20 seconds.

For example: [Y10] initializes the plunger and valve drives and moves the plunger at a rate of 10 seconds/stroke.

The default initialization speed is Y4 or at a rate of 4 seconds/stroke.

• Valve Commands

I Move Valve to Input Position

The [I] command moves the valve on the XE 1000 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 to the syringe on the left side (as viewed from the front of the pump). The input position will pull fluid into the syringe.

O Move Valve to Output Position

The [O] command moves the valve on the XE 1000 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 to the syringe on the right side (as viewed from the front of the pump). The output position will dispense fluid out of the syringe.

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).

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

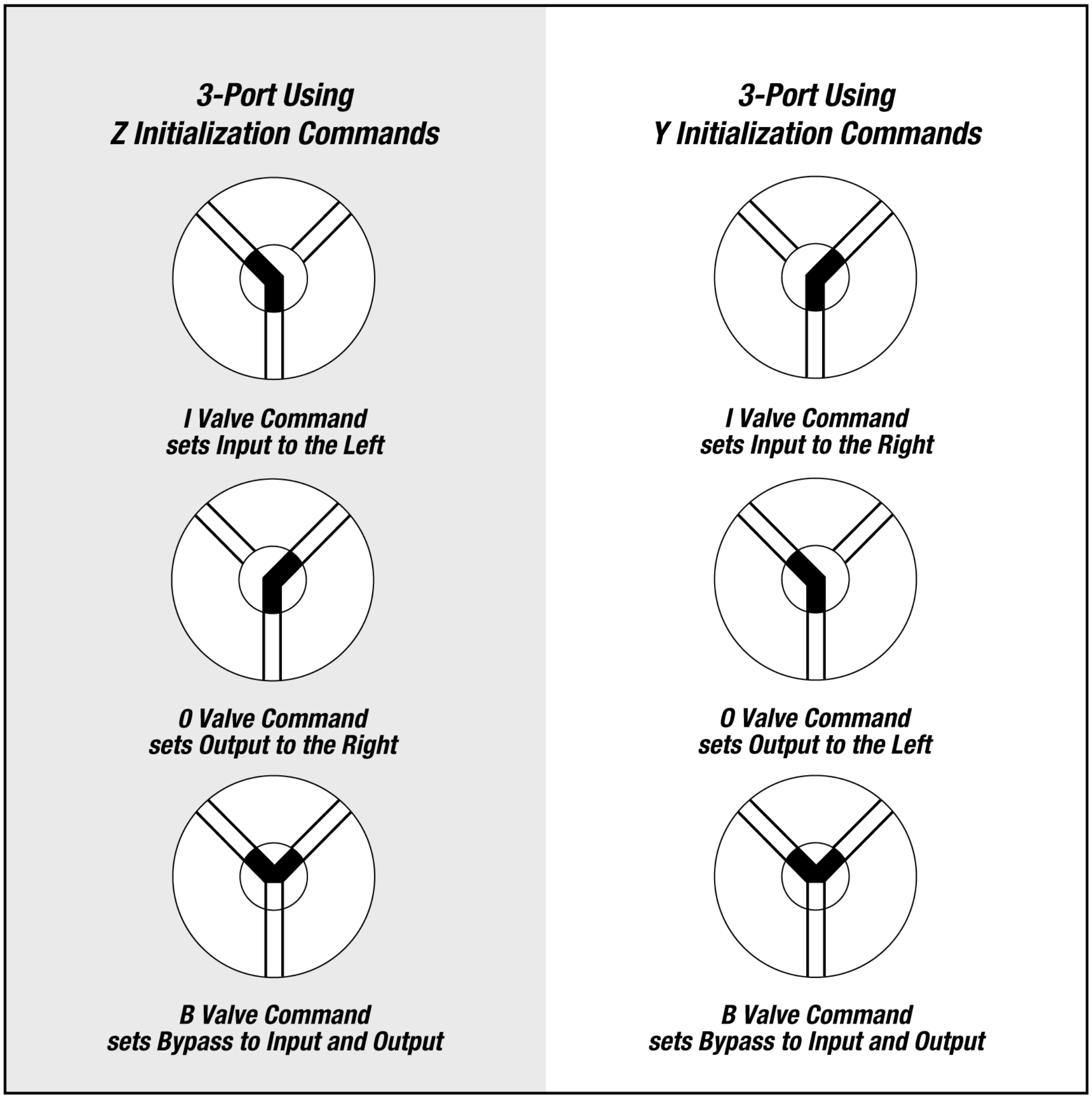


Figure 3-1. Valve Positions (Looking at Front of Pump)

• Plunger Movement Commands

A <N> Absolute Position

The [A] command moves the plunger to the absolute position <n>, where <n> = 0..1000.

For example:

[A300] moves the syringe plunger to position 300.

[A600] moves the syringe plunger to position 600.

> **NOTE** Position 0 is the initialization position.

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..1000.

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 1000.

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..1000.

For example:

The syringe plunger is at position 1000. [D300] will move the plunger up 300 steps to an absolute position of 700.

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

P Prime

The [p] command orders the pump to perform two complete aspiration/dispense cycles of the full syringe volume. One cycle is equivalent to the following command string.

A0IA1000OA0R

> **NOTE** If the plunger is not at the 0 position when the command is first issued, it is moved there before the first complete prime cycle is performed.

• 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..30,000

For example:

[A1000A0G10R] moves the syringe plunger to position 1000 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).

> **NOTE** Both the [g] and [G] commands can only appear once in a string.

Table 3-3 shows the various segments of the command string [IA1000M500OgD100M500G10R].

Table 3-3. Example Program String

Command Segment	Description
I	Turns the valve to the input port.
A1000	Moves the plunger to absolute position 1000.
M500	Delays plunger 500 ms.
O	Turns the valve to the output port.
g	Marks the beginning of a repeat sequence.
D100	Moves the plunger up 100 steps.
M50	Delays plunger 500 ms.
G10	Closes the loop and commands the pump to repeat the commands from the [g] a total of 10 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>]

There is one TTL input available, at JP3-7. It controls execution as follows:

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

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

The status of the TTL input line can be read using [?I]. This command is described in "Report Commands" in this chapter.

T Terminate Command

The [T] command terminates plunger moves in progress ([A], [P], [D], and delays [M]) as well as program strings. It is designed to be an emergency stop.

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

CAUTION! 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 line.

The syntax for this command is:

[J<n>], where <n> = 0..1 (0 is the default)

The XE 1000 provides one TTL output on JP3 (pin 13). It is controlled as follows:

J0 = low (i.e., ground)
J1 = high (i.e., +5VDC)

> **NOTE** On power up the output is set low.

Set Commands

K <n> Backlash Steps

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

[K<n>], where <n> 0..20 (15 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 may flow out the "input" side of the valve during this operation.

S <N> Set Speed

The [S] command sets the plunger speed. This parameter specifies the approximate time required for one full stroke (plunger travel in a single direction). The syntax for this command is:

[S<n>], where <n> = 20..600 (40 is the default)

The speed range is equivalent to 2 – 60 seconds per stroke in 0.1 second increments. For example:

[S20] = 2 seconds/stroke

[S21] = 2.1 seconds/stroke

@ Sets Initialization Gap

The [@] command sets the initialization gap or 0 position of the plunger. The syntax for this command is:

[ZP10@0] (default 0 initialization gap)

Where:

Z initializes the pump

P10 tells the pump to move down 10 steps after initialization

@0 tells the pump to set the plunger move (10 steps) to the 0 position

NOTE A small initialization gap helps preserve the life of the Teflon seal. The gap also increases dead volume. The user needs to determine the initialization gap that works best in the application.

CAUTION! In order to ensure the full 1000 steps of plunger movement, the initialization gap should not exceed 50 steps.

Report Commands

Report commands do not require an [R] command.

NOTE	Report commands are not used in CAN communication. The frame type 6 is provided to retrieve information from the pump. For more information, see Appendix F, "CAN Communication Commands."

? Reports Plunger Position

The [?] command reports the position of the plunger in steps [0..1000].

?S Reports Current Speed Setting

The [?S] command reports the current speed setting in [S] command format: tenths of seconds/stroke [20..600].

?K Reports Number of Backlash Steps

The [?K] command reports the backlash setting.

?I Reports Status of Auxiliary Input (JP3, Pin 7)

0 = low
1 = high

?J Reports Current Output Line Status

The [?J] reports the state of the output line, JP3-13.

0 = low
1 = high

F Reports 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.

& Reports Firmware Version

The [&] command returns the XE 1000 firmware revision code.

Reports Command or Command String in Buffer

The [#] command reports the actual command or command string in the buffer.

Error Codes and Pump 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 best 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.

Error Codes

Error codes describe problem conditions that may be detected in the XE 1000 (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 3-4. 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.
7 (07h)	Device Not Initialized. This error occurs when the pump is not initialized or has lost its positional information, i.e., a stall occurs, but a move command has been issued. 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. 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 string 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 the command string contains more than 32 characters. 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.

CAUTION!	All errors reported by the pump should be captured by the user software and the physical cause corrected before continuing operation. Failure to do so may result in damage to the pump or adversely affect pump performance, and void the warranty.

Table 3-5. 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 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.
[A1000A1500R]	Moves to position 1000, then stops. A [Q] command returns an error.
[E2000R]	Returns an invalid command error immediately. The pump status is “Not Busy.”
[A1000E2000R]	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 XE 1000 for Your Application

The XE 1000 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 XE 1000 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 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 XE 1000 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, flow path restrictions 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 generally 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")
Inside diameter of the fluid path orifice.

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 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.

volume conversion
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 XE 1000 pump with 1 mL syringe, move the plunger as follows:

$$\#\text{ of steps} = \frac{1000\text{ steps} \times 100\ \mu\text{L}}{1000\ \mu\text{L}} = 100\text{ steps}$$

• Optimizing XE 1000 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 XE 1000 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 XE

1000 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.

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)
500 µL	0.5	15
1 mL	1.0	30
2.5 mL	2.5	75
5 mL	5.0	150

NOTE Flowrate numbers do not include refill time.

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 XE 1000 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., 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
500 µL, 1 mL, 2.5 mL	5133	4609
	720595	5729
	720597	721370
5 mL	4333	720592
	720595	721370

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 XE 1000 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 by sending the command [Z10R] (initializes at reduced speed). Repeat with decreasing initialization speed (increase "Z_" value) until the pump successfully initializes.

7 Prime the syringe.

a) Send the command [IA1000OA0R] 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 that the tube fittings and syringe are screwed in tightly.

c) Re-prime.

Possible errors:

Error 9 (plunger overload). See step 8.

8 Check aspirate/dispense.

Send the command [IA1000OA0R] to aspirate a full syringe stroke (1000 steps) from input and dispense it to output. Successful execution will move the syringe plunger to position "1000" 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 back pressure 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 [S100IA1000OA0R]. Repeat with decreasing plunger speed (increase "S_" value) until the pump aspirates and dispenses successfully.

9 Set speeds.

As a general rule aspiration should be slow (to avoid cavitation) and dispense fast (to promote breakoff). Since both cavitation and breakoff will affect accuracy and precision, it is important to optimize aspiration and dispense speeds. Using the default speed (4 seconds/stroke) send the command [IA1000R]. If cavitation is an issue, decrease the aspiration speed (increase "S_" value) until there is no cavitation.

Send the command [OA0R] to determine the optimum dispense plunger speed. Increase or decrease the "S_" value to avoid overloads and to obtain good breakoff.

10 Check breakoff.

Along with rapid dispense speeds, 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. Increasing the dispense speed will usually improve the inertial air gap. Another option is to try a larger syringe.

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 can 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):

* [S40IA1000OS400A0R] - will leave a drop on the tip

* [S40IA1000OS100A0R] - no drop will be left

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 smaller syringes.

Set backlash compensation.

The XE 1000 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 XE 1000:

- ❑ 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 XE 1000 with caution. Using organic solvents may reduce tubing, valve and syringe life.

5 Maintenance

Although required maintenance may vary with your application, the following procedures are recommended for optimal performance and maximum life of the XE 1000.

Perform maintenance tasks in these intervals:

- daily
- weekly
- periodically

Daily Maintenance

To ensure proper operation of the XE 1000, 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. Failure to do so can result in crystallization of reagents. Crystals can damage the syringe seal and valve plug resulting in leakage.

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

Weekly Maintenance

The fluid path of the XE 1000 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.
>
> flo-kleen can be purchased through Ciba Corning Gilford Systems.
>
> 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 XE 1000 on a regular basis.

Cavro recommends checking both accuracy and precision gravimetrically, using a calibrated 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

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

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

where:

d = density of $H_2 0$ @ 25°C = 0.99707

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

n = number of replicates

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 Lower the plunger drive by sending the [A1000R] command. If power is not applied, the carriage can be manually lowered by firmly pushing down on the carriage assembly.

3 Unscrew the syringe from the valve.

4 To install the syringe, do the following:

a Place the self-aligning ball on the bottom of the plunger into the carriage.

b Pull the syringe up and screw it into the valve, finger tight. Using pliers on the syringe 1/4-28 fitting, turn the syringe an additional quarter turn.

c Screw the syringe plunger into place.

5 Re-initialize the pump.

NOTE Make sure the syringe is securely screwed into the valve.

Replacing the Syringe Seals

> **NOTE** See Chapter 2, “Hardware Setup,” for an illustration of the syringe components.

To replace the 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 5-1.

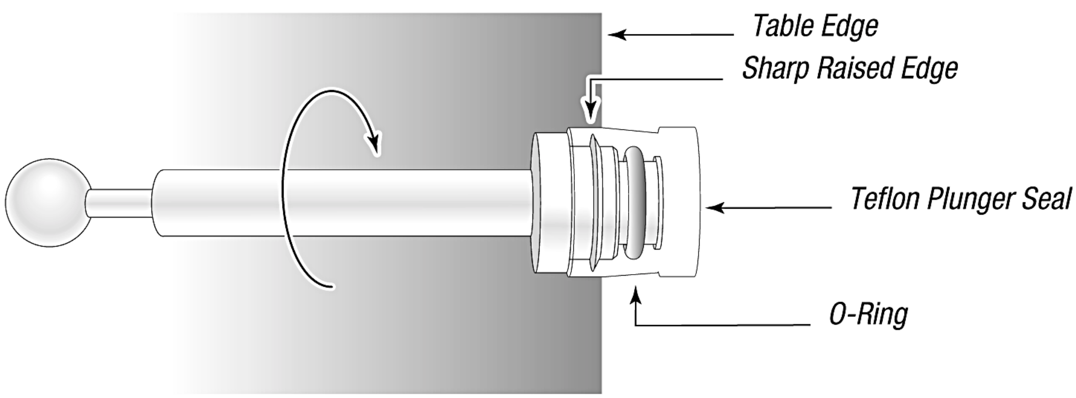


Figure 5-1. Syringe Seal Assembly

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.

Replacing the XE 1000 Valve

To replace the XE 1000 valve, follow these steps:

1. Remove the fluid from the pump.
2. Initialize the pump using the [ZR] command so that the motor shaft is in the correct position.
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. Install the valve by placing it in the front panel so the screw holes line up. The valve coupler fitting should be in the correct position.
6. Replace the valve screws. Tighten ¼ to ½ turn after the screws contact the valve body.

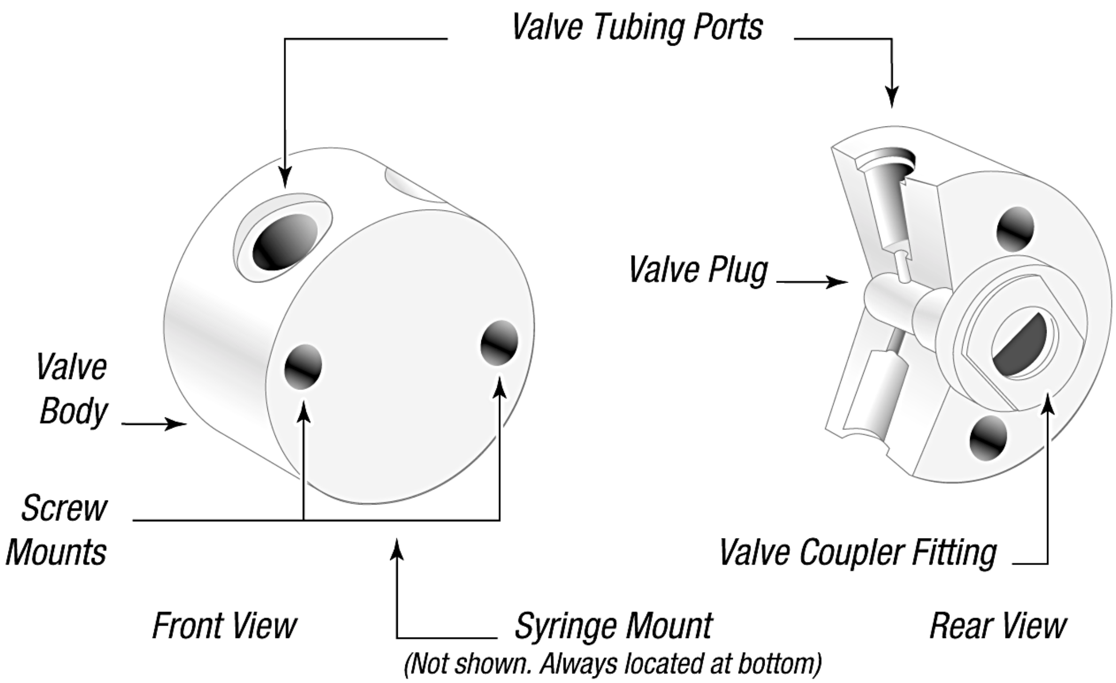


Figure 5-2. XE 1000 Valve Replacement (3-Port Valve Shown)

On-Site Replacements

CAUTION! Use good ESD practices when replacing XE PCBs or EPROMs.

Replacing the Printed Circuit Board (PCB)

To replace the printed circuit board, follow these steps:

1. Power off the pump.
2. Remove the three screws holding the PCB to the standoffs.
3. Note the cable connection locations and unplug the cable from the board.
4. Plug the cables into the new board.
5. Install the new board and screw it into place.
6. Power on and reinitialize the pump.

Replacing the EPROM

To replace the EPROM, follow these steps:

1. Power down the pump.
2. Remove the old EPROM by using a PROM puller. The EPROM is located in position U2 on the printed circuit board. (See Chapter 2, “Hardware Setup.”)

> **CAUTION!** Care should be taken when removing the EPROM. Prying it out may damage adjacent components.

3. 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.
4. 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.

5. Power on and reinitialize the pump.

6 Technical Service

For information or questions regarding ordering or operating the XE 1000, 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 internet	http://www.cavro.com

The 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 the XE 1000, other Cavro liquid handling components, and spare parts for the XE 1000.

Pump Description

Table A-1. XE 1000 Pump Configuration

Description	Part Number	Communication Protocol	Valve	Fittings
XE 1000 with 3-port valve, 1/4-28", RS232	730045	RS 232/485	3-Port	¼-28"
XE 1000 with 3-port valve, 1/4-28", CAN	730044	CAN/RS485	3-Port	¼-28”
XE 1000 with 3-port valve, M6, RS232	731288	RS 232/485	3-Port	M6
XE 1000 with 3-port valve, M6, CAN	731293	CAN/RS485	3-Port	M6

XE 1000 Spare Parts

The following spare parts are available:

- Syringes
- Syringe Seals
- Syringe “O”-Rings
- Valve
- Printed circuit board
- Tubing
- Pump Evaluation Accessories
- Miscellaneous Parts

Syringes

Table A-2. Syringes

Part Number	Description
730070	Syringe, 50 µL. Black
730071	Syringe, 100 µL. Black
731069	Syringe, 250 µL.
728661	Syringe, 500 µL
728662	Syringe, 1.0 mL
728663	Syringe, 2.5 mL
728664	Syringe, 5.0 mL

- ## Syringe Seals

Table A-3. Seals

Part Number	Description
730365	Plunger, 50µL. Seal
730366	Plunger, 100µL. Seal
730130	Seal, 500 µL (4/pkg)
730131	Seal, 1.0 mL (4/pkg)
730132	Seal, 2.5 mL (4/pkg)
730133	Seal, 5.0 mL (4/pkg)

- ## Syringe “O”-Rings

Table A-4. “O”-Rings

Part Number	Description
	Please use the complte seal package with the included O-ring.

- ## Valve

Table A-5. Valve

Part Number	Description
729370	Valve, 3-Port (1/4-28" fitting)

Printed Circuit Board

Table A-6. Printed Circuit Board

Part Number	Description
730148	PCB, RS-232/RS-485
730149	PCB, CAN/RS-485

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

EPROM

Table A-7. EPROM

Part Number	Description
728317	EPROM, XE

Tubing

Table A-8. Tubing

Part Number	Description	Material	Length (Inches)	ID	Tube Ends
1067	Reagent tube	TFE	16"	.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
723114	Aspirate/Dispense tube	FEP	6"	0.079	1/4-28" to M6
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"

Part Number	Description	Material	Length (Inches)	ID	Tube Ends
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	Card-edge to DB-15 adapter. (Order two adapters per power supply).

• Miscellaneous Parts

Table A-10. 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"
729428	Manual, Operator's, XE 1000
728694	Packaging
725772	Connector, XE mating (DB15-female)
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.

XP 3000 Modular Digital Pump

The XP 3000 is a small, lightweight pump module that stands 5" tall and weighs only 2.5 pounds. With a full range of commands, the XP automates pipetting, diluting and dispensing providing excellent accuracy and precision over a wide range of speeds using a variety of syringe sizes. It uses a rack and pinion drive and encoders to detect lost steps on both the syringe and valve drives. The pump communicates through RS-232, RS-485, or CAN and operates from a single 24VDC power supply.

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 24VDC 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.

- ## 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 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 24VDC 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 Peri 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 Peri Pump uses a single 24VDC power supply and contains a buffered output port which can be used to drive an additional relay or solenoid.

- ## 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 level (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 XE 1000 plunger force curve for reference only. Forces were determined by hanging weights from the carriage and pulling them up at various speeds. The plunger speed in seconds/stroke is shown on the X-axis and plunger force is shown on the Y-axis. These data represent an average of four pumps.

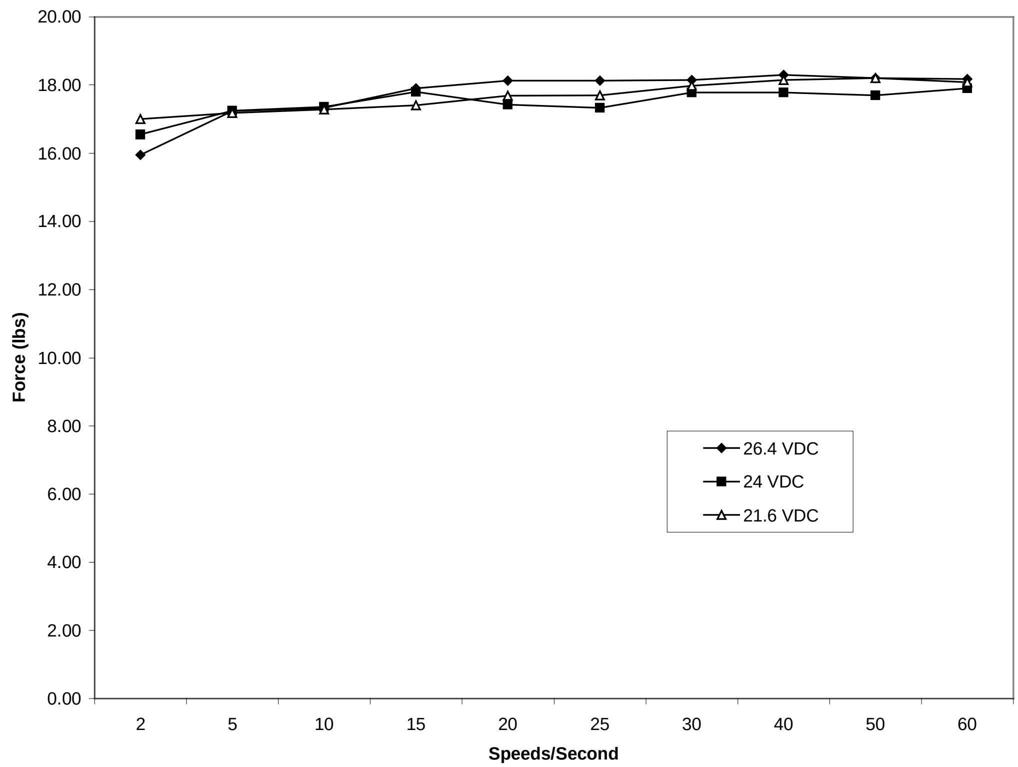


Figure B-1. Plunger Force Curve

• Holding Current

The current on the XE 1000 Pump decreases when the pump is in a holding position. For applications that use viscous solutions or involve backpressure due to smaller ID tubing, the holding current may need to be increased. This can be accomplished by putting a jumper in JP2-2. Figure B-2 shows a force curve of the standard holding current (no jumpers in JP2-2). These data are based on an average of four pumps.

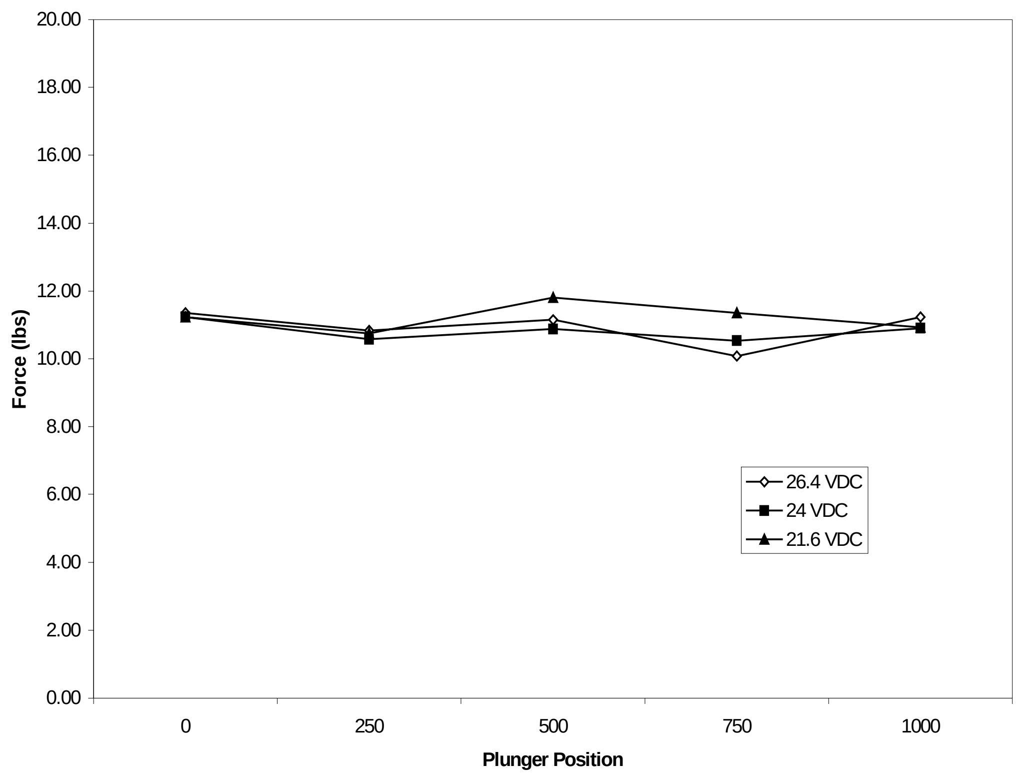


Figure B-2. Holding Current Curve

CAVRO.

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

Decimal	Hexadecimal	Character or Function	Decimal	Hexadecimal	Character or Function
37	25	%	102	66	f
38	26	&	103	67	g
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 XE 1000 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 XE 1000 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 XE 1000:

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 -XE 1000 Physical Specifications

Table E-1. XE 1000 Physical Specifications

Dimensions	Height	5.0 in (127 mm)
	Width	2.5 in (64 mm)
	Depth	4.0 in (102 mm) from front panel to connector
	Weight	2.0 lbs (0.9 kg)
Resolution		1000 increments
Plunger Drive	Principle	Direct rack and pinion drive with encoder and home flag
	Travel	30 mm
	Plunger Speed	Variable from 2-60 secs/stroke
Syringes	Sizes	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
	Accuracy	<1% at full stroke
Valve Drive	Turn time	≈330 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
	Valve Angle	120°
	Valve Positions	Input, Output, Bypass
	Fluid Contact	Kel-F, Teflon
Power Requirements	Voltage	24VDC ± 10%
	Current	500 mA (peak)

Interface	Type	RS-232, RS-485 or CAN
	Baud Rate	9600 (RS-232 and RS-485) 100K (CAN)
	Format	Data Bits: 8
		Parity: No
		Stop Bit: 1
Communications	Addressing	Up to 15 pumps can be addressed individually
	Software Communications	Data terminal and OEM protocol (with error recognition) for RS-232/RS-485 hardware protocol/CAN for CAN hardware protocol
Firmware		Programmable Delays
		Programmable Backlash Compensation
		Programmable Plunger Speeds
		Programmable Loops
		Terminate Moves
		Diagnostics
		Absolute or Relative Positions
Inputs		One TTL level input
Outputs		One TTL level output
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	Frame type = 1
Plunger Movement	A, P, D,	Valid	Frame type = 1
Valve	I, O, B	Valid	Frame type = 1
Set	S, K, J	Valid	Frame type = 1
Control	G, g, M, H	Valid	Frame type = 1
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)
Report	?	Invalid	Frame type = 6 Command = "0" (ASCII)
Report	?S	Invalid	Frame type = 6 Command = "6" (ASCII)
Report	?J	Invalid	Frame type = 6 Command = "8" (ASCII)
Report	?K	Invalid	Frame type = 6 Command = "12" (ASCII)
Report	?I	Invalid	Frame type = 6 Command = "13" (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)
Report	#	Unknown	None

G - Command Quick Reference

• Initialization Commands

Command	Value	Description
Z <n>	<n> = 2-20 = seconds	Initializes the plunger drive and sets the valve input at left port and output at right port
Y <n>	<n> = 2-20 = seconds	Initializes the plunger drive and sets the valve input at right port and output at left port

Valve Commands

Command	Description
I	Moves valve to input position
O	Moves valve to output position
B	Moves valve to bypass position

Plunger Movement Commands/Status Bit Reports

Command	Value	Description
A <n>	<n> = 0..1000 steps	[A]bsolute Position
P <n>	<n> = 0..1000 steps	Relative [P]ickup
D <n>	<n> = 0..1000 steps	Relative [D]ispense
p		Prime

Set Commands

Command	Value	Description	Default Setting
S <n>	<n> = 20..600 in 1/10 sec	Set speed	(40)
K <n>	<n> = 0..20 steps	Backlash	(15)
@		Set initialization gap	

Control Commands

Command	Value	Description
R		Executes command or command string
X		Repeats last command string
G <n>	<n> = 0..30,000	Repeats command sequence
g		Marks start of a repeat sequence
M <n>	<n> = 5..30,000	Delay in milliseconds
H <n>	<n> = 0..1	Halts command execution
T		Terminate command
J <n>	<n> = 0..1	Sets state of output line

Report Commands

Command	Description
Q	Query, Status and Error Bytes
?	Reports absolute plunger position
?S	Reports plunger speed
?K	Reports number of backlash steps
?J	Reports status of output
?I	Reports status of input
F	Reports buffer status
&	Reports firmware version
#	Reports commands in buffer

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	
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 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	TTL level
8	Address 0	
9	Ground	Power and logic
10	Ground	Power and logic
11	RS-485 A line	
12	RS-485 B line	
13	Auxiliary output	TTL level
14	Address 2	
15	Address 1	

Index

T

V

X