A. General Overview

The XL 3000 Modular Digital Pump is a fully programmable, open framed, precision liquid handling instrument designed for OEM applications. It is a stepper motor driven syringe pump. The pump operates from a single 24 volt power supply and is controlled by an external computer or microprocessor. It works as a slave unit automating pipetting, diluting and dispensing functions.

The XL 3000 has a default resolution of 3000 steps. A high resolution mode of 12000 steps is available through a firmware command. For applications requiring even higher resolution a 3000/24000 step XL 3000 is also available.

Up to 15 pumps can be combined in a variety of configurations to meet most liquid handling needs. A variety of syringe sizes are available ranging up to 25 mL. Plunger speeds range from less than 1 second to 10 minutes per stroke providing the user with application flexibility.

The XL 3000 is constructed to provide years of reliable service. Pump diagnostics are contained in the firmware to enhance the serviceability of the pump. The stepper motor controlled valve is easy to install and plumb. RS-485 and RS-232 interface options are also available providing the user with flexibility for current and future applications.

B. Warranty

Cavro Scientific Instruments, Inc., warrants this equipment against defects in workmanship and materials for a period of one year in normal service from the date it is first placed in service or delivered to the customer, whichever occurs first.

No warranty is expressed or implied for:

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

C. Firmware Revision Sheet

Please record the firmware number and revision level shipped with your instrument. In the future, new firmware (EPROMs) may be available to provide either enhanced operation or new capabilities. Please record any EPROM changes in the space provided below. The current version of firmware can also be determined using the <&> command described in Chapter 3.C.7.

Date	Comments	Firmware Revision

A. General

This section provides instructions for unpacking and installing the Cavro XL 3000 Modular Digital Pump. The XL 3000 contains both logic and motor drive electronics on a single board. To ensure that the instrument is installed and will operate properly, it is important to closely follow these instructions.

Note: Liquid should always be run through the syringe and valve. Failure to do so can damage the valve and syringe seal.

The pump should always be installed in an upright position. Failure to do so can cause problems in priming the system.

Organic solvents should not be used with this pump. Please refer to the Chemical Resistance Chart found in Appendix G.

B. Unpacking

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

For example, the following is a list of components which may be contained in a typical XL 3000 two pump evaluation system:

Quantity	Description	Part Number
1	Pump Module with valve, RS-232	724020
1	Pump Module without valve, RS-485	724026
1	1.0 mL Reagent Syringe	1424
1	100 uL Aspirate Syringe	5342
1	Evaluation Power Supply (24V) for 2 pumps (includes cables)	723914

The items in your shipment may vary depending upon the pump configuration ordered. For information regarding syringe and tubing selection and installation, please refer to Chapters 5 and 6.

C. Power

Connect a 24V power supply with a current rating of at least of 850 mA per pump as shown in Figures 3 and 4. Use one cable for each 2 pumps to provide noise immunity.

D. Communication Overview

The XL 3000 communicates through an RS-485 interface directly or alternatively through an RS-232 interface which converts the signal into RS-485. It does not support hardware handshaking. When using the RS-485 interface, up to 15 pumps can be addressed separately from the same source (selectable on SW1). Make sure that the A and B lines are not reversed. Single pump applications require jumpers on JP7 or JP8. The first and the last pump in a chain should have the terminator activated with jumpers on JP7 or JP8. JP8 is in parallel with JP7 and can be used to connect RS-485 communication from pump to pump instead of using edge connector JP1 (see Figures 3 and 4).

Caution: Pumps are shipped with jumpers installed in JP7. Please remove and discard the jumpers if not needed.

Two baud rates, 9600 or 38,400 baud, can be selected from SW2-4 to drive the pump.

Please refer to Figure 2 for an outline drawing of the XL 3000 printed circuit board. The drawing indicates the location of the major components on the board such as JP7 and SW2.

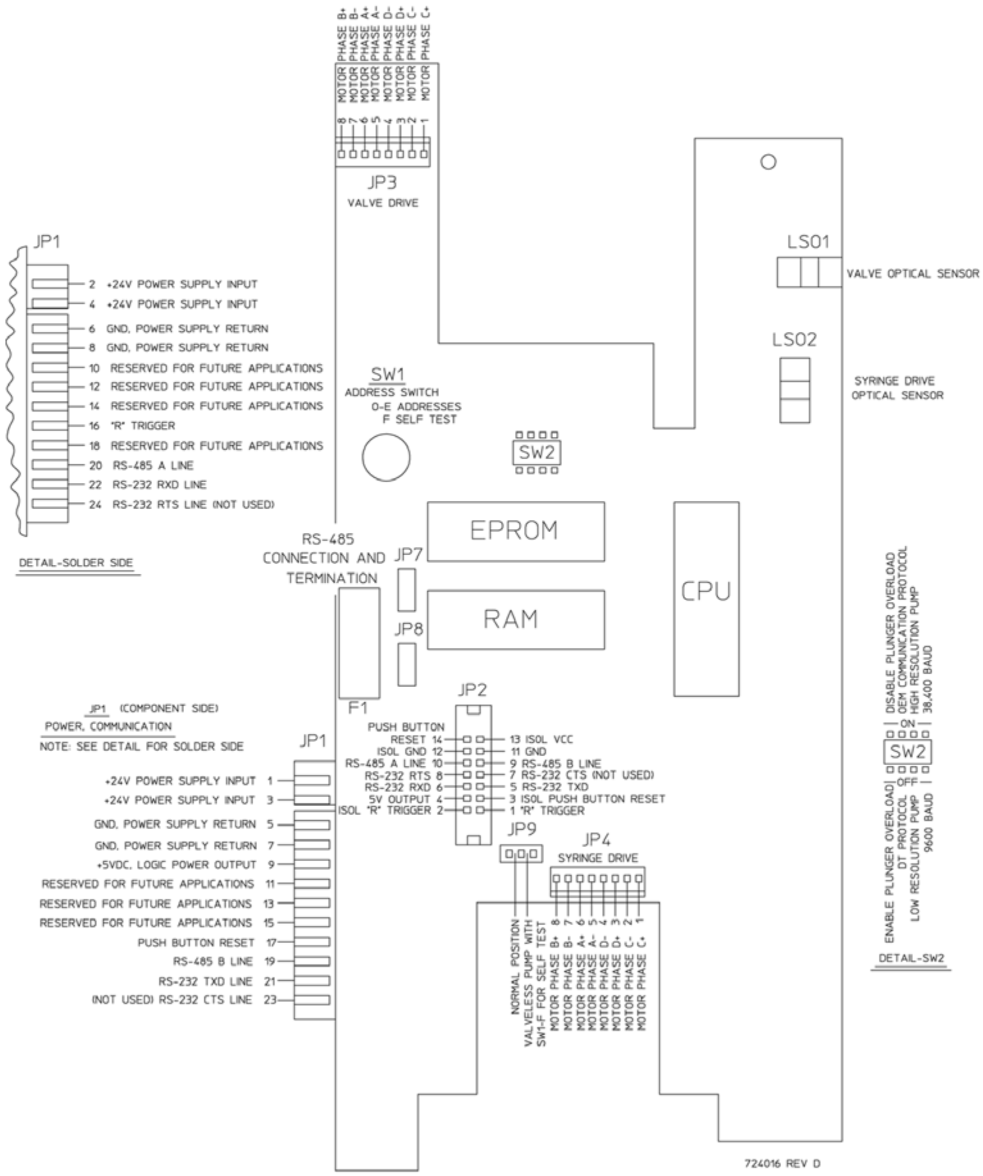
When communicating with the pumps from an RS-232 port, one pump in the chain requires an RS-232 interface board. This board plugs into the pump's mother board at connector JP2. The XL 3000 can be ordered with the RS-232 board with valve or without valve. The RS-232 interface board converts the signal into RS-485. From then on all pumps in the chain communicate through RS-485.

Figures 3 and 4 are cabling illustrations showing multi-pump cabling with RS-232 and with RS-485 respectively. Also shown is the termination scheme for the RS-485. This can be used if the terminators are installed in the system instead of on the pump.

Table 1 contains the pin call-outs for edge connector JP1, and Table 2 provides ordering information for the connector mating with JP1. Please make sure crimps are added to all positions on the mating connector.

Note: When adding or removing additional pumps from the bus, please make sure the pumps are powered down.

Figure 2. XL 3000 Printed Circuit Board



Note:	SW2	Default Positions	
	SW2-1	Plunger Overload	OFF (Factory set. Do not change.)
	SW2-2	Communication Protocol	ON (OEM Protocol)
	SW2-3	Resolution	OFF (Standard Resolution Pump)
			ON (High Resolution Pump)
	SW2-4	Baud Rate	OFF (9600 Baud)

Figure 3. Cabling Illustration: RS-232 Multipump Cabling

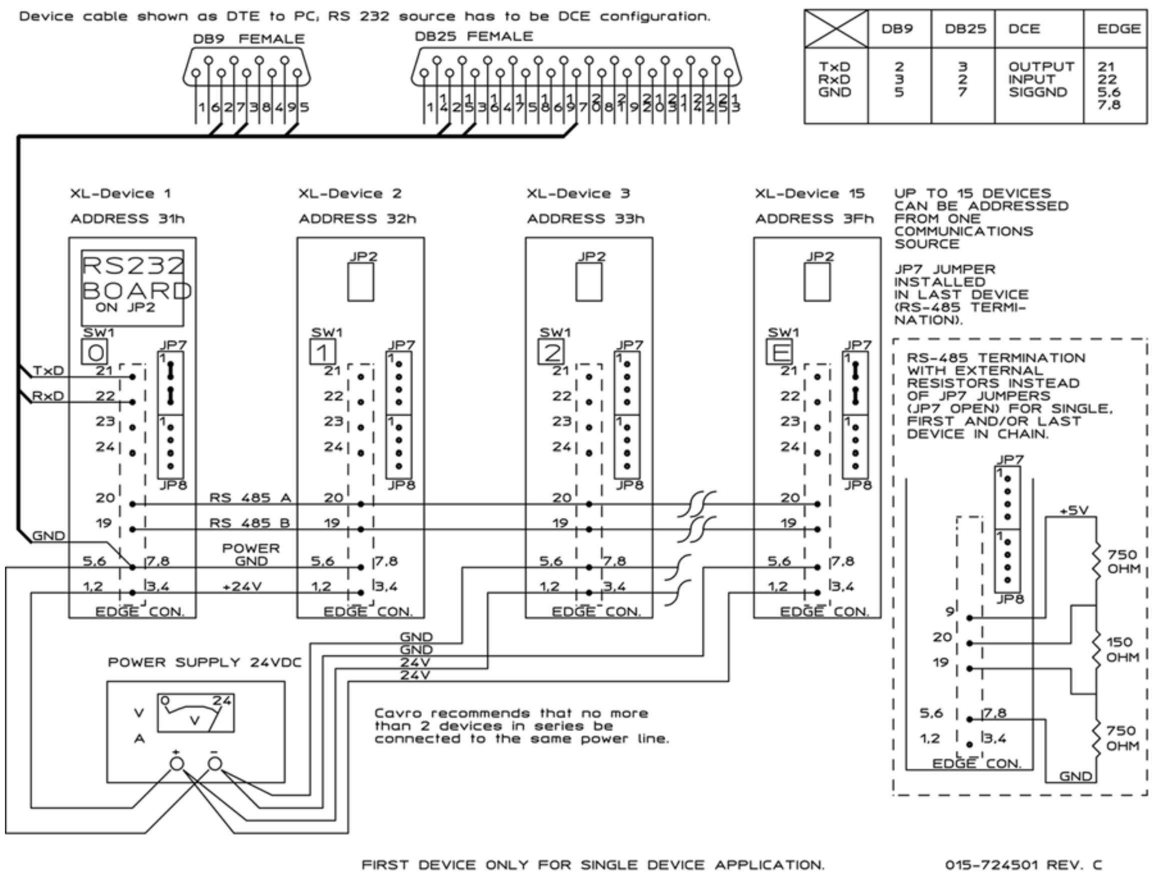


Figure 4. Cabling Illustration: RS-485 Multipump Cabling

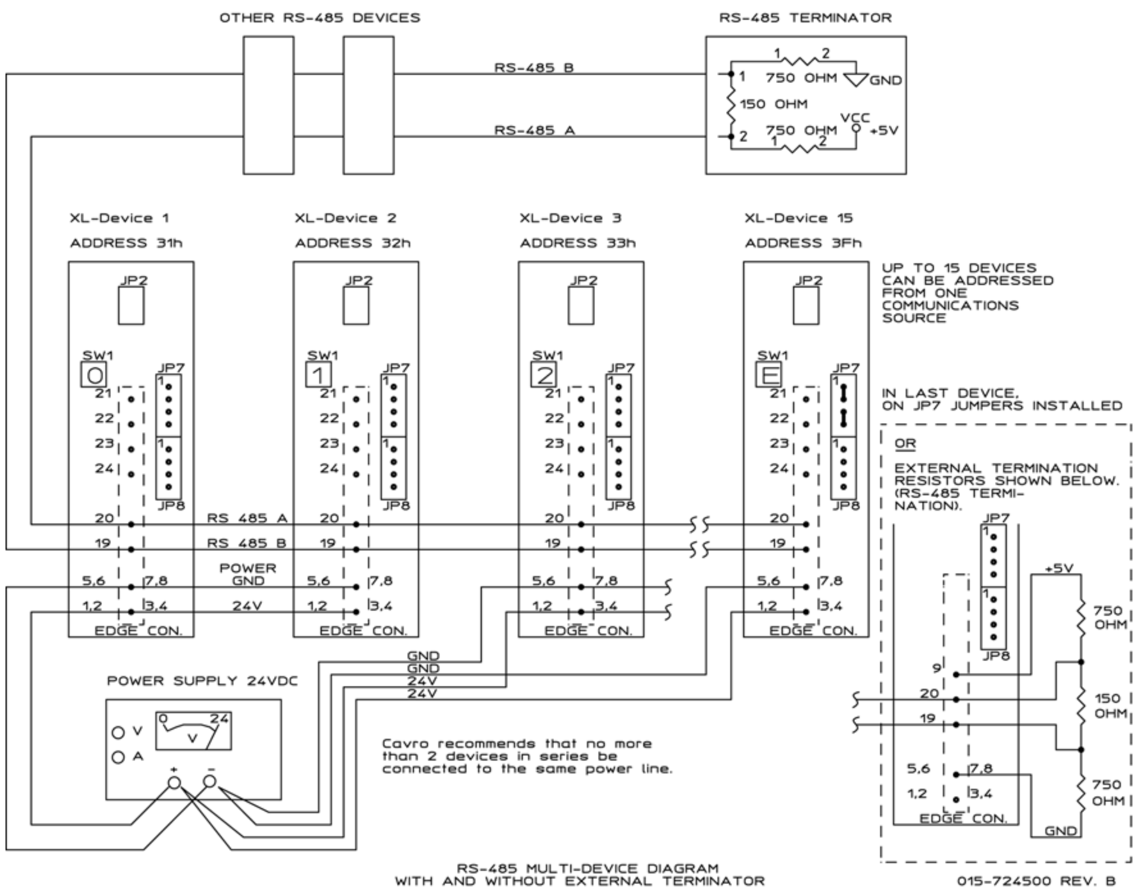


Table 1: Pin Call-Outs for Edge Connector JP1

Pin	Function	Remarks
1	+24 VDC, power supply input	Cavro recommends using
2	+24 VDC, power supply input	all four contacts for the
3	+24 VDC, power supply input	power supply
4	+24 VDC, power supply input	
5	GND, power supply return	Cavro recommends using
6	GND, power supply return	all four contacts for the
7	GND, power supply return	power supply
8	GND, power supply return	
9	+ 5VDC, output	Up to 100 mA output (Refer to Note 3)
10	Reserved for future application	
11	Reserved for future application	
12	Reserved for future application	
13	Isolated push button reset	
14	Reserved for future application	
15	Reserved for future application	
16	"R" Trigger	A switch to GND will execute the command string halted by the "H" command
17	Pushbutton reset	A TTL low signal or a switch to GND will reset the electronics
18	Reserved for future application	
19	RS-485 B line	Do not mix A and B lines
20	RS-485 A line	in multipump applications
21	RS-232 TxD line	Output data
22	RS-232 RxD line	Input data
23	RS-232 CTS line (not used)	
24	RS-232 RTS line	Output ("High" when pump is powered)

Notes:

1. The RS-232 option must be installed in order to use pins 21 to 24.
2. Pin 16 has a software debounce.
3. The power output should be protected from external noise. An L-C filter between the XL 3000 and the external device is recommended.

Table 2: Mating Connectors

The Cavro Series XL 3000 has a card edge connector (24-pin, 0.156"/3.96 mm spacing) to supply power and communication signals.

The connectors can be obtained from:

Mfg	Description	Mfg P/N
For use with a backplane (solder posts):		
AMP	Low Profile Edge Connector	2-530655-3
AMP	Polarizing Key	530687-1
Sullins	Low Profile Dip Solder/ Eyelet Edgecard Connector	EZM12DRXH
Sullins	Polarizing Key	50-PK
EDAC	Card Edge Receptacle	237-024-521-202
EDAC	Polarizing Key	306-240-318
For use with standard cable (crimp contact):		
Molex	Double Sided Edge Connector Housing	
	with mounting flange	09-50-6125
	w/o mounting flange	09-50-5125
Molex	Crimp Contact for AWG 18-24 (24 pcs required)	08-05-0302
Molex	Polarizing Key	15-04-0233
AMP	Twin-Leaf PCB Edge Connector Housing with mounting flange	1-583859-5
AMP	Crimp Contact for AWG 18-22 (24 pcs required)	583649-6
AMP	Keying Contact	583274-1
AMP	Housing with solder contacts (24 pins) and with mounting ears (not keyed)	2-530654-7
AMP	Keying Contact	530687-1
For use with standard cable (solder lug):		
Cinch	Double Sided Edge Connector	50-24A-30
Cinch	Polarizing Key	50-PK-2

E. Pump Addressing/Self Test

Up to 15 devices can be addressed separately from the same source. The address can be selected with switch SW1 in hexadecimal. SW1 position "0" is addressed as device "31h", SW1 position "1" is addressed as "32h" up to SW1 position "E" (address "3Fh"). Each pump in the chain needs to have a different address. The user has the option to address a single pump, 2 pumps, 4 pumps or all 15 pumps depending on the address byte used. For example, the user can initialize all pumps in the chain by using address "5Fh". Then each pump can be operated independently by using addresses "31h" to "3Fh". Please refer to Table 3 for pump addressing options.

When using multiple pump addressing (41h to 5Fh), pumps will not answer back. To find the status, each pump must be <Q>ueried separately.

The pump does not need to be powered down after SW1 has been changed.

SW1 position "F" sets the pump(s) to self-test. The self-test will cause the pump(s) to initialize then cycle continually. If an error condition is present, the pump will stop moving. Typically the self test activates the pump 1000 strokes/hour.

Caution: Liquid should always be run through the syringe and valve. Failure to do so can damage the valve and syringe seal.

Caution: For syringes larger than 5 mL, the valve and syringe should be removed before running the "F" test.

When using a valveless pump in self test, set JP9 to the self test position. Set JP9 back to the normal position for standard operation (see Figure 2).

Table 3: Addressing Options

Address (hex)	Device
01 .. 2F	Reserved
30h	Master Address (Master controller, personal computer etc.)
31 .. 3F	Addresses single device
41 .. 50	Addresses 2 devices at a time
51 .. 5D	Addresses 4 devices at a time
5F	Addresses all diluters in the serial bus
61..70	Reserved for auxiliary devices
7F	Reserved

<table>
<tr><th>Switch Setting</th><th>Single Device</th><th>Dual Device</th><th>Quad Device</th><th>All Devices</th></tr>
<tr><td>0
1</td><td>31 (1)
32 (2)</td><td>41 (A)</td><td rowspan="2">51 (Q)</td><td rowspan="8">5F (-)</td></tr>
<tr><td>2
3</td><td>33 (3)
34 (4)</td><td>43 (C)</td></tr>
<tr><td>4
5</td><td>35 (5)
36 (6)</td><td>45 (E)</td><td rowspan="2">55 (U)</td></tr>
<tr><td>6
7</td><td>37 (7)
38 (8)</td><td>47 (G)</td></tr>
<tr><td>8
9</td><td>39 (9)
3A (:)</td><td>49 (I)</td><td rowspan="2">59 (Y)</td></tr>
<tr><td>A
B</td><td>3B (;)
3C (<)</td><td>4B (K)</td></tr>
<tr><td>C
D</td><td>3D (=)
3E (>)</td><td>4D (M)</td><td rowspan="2">5D (])</td></tr>
<tr><td>E</td><td>3F (?)</td><td>4F (O)</td></tr>
<tr><td>F</td><td colspan="4">Diluter self test</td></tr>
</table>

Notations in hex (ASCII).

Note: Multiple address commands cannot be used to determine device status. Each device must be queried separately. For further details please refer to Chapter 3.C.7.

Caution: For syringes larger than 5 mL, the valve and syringe should be removed before running the diluter self test, switch setting F.

F. SW2 Settings

SW2 contains 4 pump options: Plunger Overload Detection, Communications Protocol, Pump Resolution and Baud Rate. Always power down the pump after changing the SW2 settings.

1. SW2-1: Plunger Overload Detection

   This switch enables or disables plunger overload detection. The standard position for this switch is **off** (plunger overload detection is enabled). If the switch is **on**, plunger overload will not be detected and the pump will not signal an error if it is losing steps. This switch is for factory use. Cavro does not recommend disabling the plunger overload detection.

2. SW2-2: Communications Protocol

   This defines if the pump will use the OEM protocol (SW2-2 is on) or the Data Terminal (DT) protocol (SW2-2 is off). The pump is shipped with SW2-2 to the **on** position, OEM protocol.

3. SW2-3 Resolution

   This is factory set depending on the pump ordered and should not be changed. The switch is turned **off** for the standard resolution pump (3000/12000 steps) and **on** for the high resolution pump (3000/24000 steps).

4. SW2-4: Baud Rate

   Two baud rates are available with the XL 3000. If the switch is **off**, 9600 baud is selected; if it is **on**, 38,400 baud is selected. The pump will be shipped with the baud rate set to 9600.

Please refer to Figure 2 for the location of SW2 on circuit board and a quick reference to SW2 settings.

There are two protocols for communicating with the pump; an OEM protocol and a Data Terminal protocol. They are selected using SW2-2. The Data Terminal protocol can be run via a "dumb" terminal because no sequence numbers or checksums are used. See Appendix J for a guide to writing a communications driver for the XL 3000 for use with the OEM protocol.

A. OEM Protocol (SW2-2 ON)

1. Character Format

Baud Rate :	9600 or 38400 (set using SW2-4)
Data Bits :	8
Parity :	No
Stop Bit :	1
Mode:	Half Duplex

2. Command Block Format Master --> Pump

0	Line Synch. Character (FFh)
1	STX (^B or 02h)
2	Pump Address
3	Sequence Number
4	Data Block (length n)
5 + n	ETX (^C or 03h)
6 + n	Checksum

3. Answer Block Format Pump --> Master

0	Line Synch. Character (FFh)
1	STX (^B or 02h)
2	Master Address (0 or 30h)
3	Status Code
4	Data Block (length n)
4 + n	ETX (^C or 03h)
5 + n	Checksum
6 + n	Line Turn Around Character (FFh)

a. **Line Synchronization Character** (FFh) lets the bus know a command is about to be sent.

b. **STX** (^B or 02h) is the start character which indicates the beginning of a command.

c. **Pump Address** is a hexadecimal number specific for each pump.

d. **Master Address** is the address of the host system. This should always be "30h".

e. **Status and Error Codes** define pump status and signal error conditions. Please refer to Chapter 3, Section C.7., under <Q>uery for an explanation of status and error codes.

f. **Sequence Number** is part of the acknowledgment system between the slave (pump) and master (host). Under normal operation the pump will return an acknowledgement to the host after it has received a valid command. Two types of errors can occur; the host does not understand the pump's acknowledgement or the pump does not understand the host's commands.

If a valid command was received and executed by the slave but the acknowledgement was not received or understood by the host, then the host should repeat the message after a time-out of about 100 ms. Before repeating the command the host must set bit 3 (repeat bit) to 1 and increment the sequence number. The slave will recognize the incremental sequence number and ignore the repeated command. This prevents the pump from executing the same command twice. The master can repeat this process up to 6 times before an error message is generated.

The second mode of failure occurs when the master sends a command but the pump does not understand it due to a checksum error or garbled data block. In this case an acknowledgement is not sent to the master. As in the above situation the master will repeat the message after a time-out of about 100 ms. Before sending the message it will set bit 3 and increment the sequence number. If the message is understood the slave will return an acknowledgement. The master can repeat the message up to 6 times before an error message is generated.

The sequence number cannot equal 0.

Note: If the operator chooses not to use this option, he can set the sequence number to a fixed value of 1 (31h).

g. **Data Block** is the data or commands sent to the pump or host in ASCII.

h. **Checksum** is the last byte of the command. All bytes (excluding line synchronization and checksums) are x'ored to form an 8 bit checksum. This is the last character of the block. The receiver compares the transmitted value to the computed value. If the two values match, then an error free transmission is assumed.

i. **Line Turn Around Character** is sent to ensure that the entire response will be transmitted before the Real Time Executive (RTX) routine turns off the transmitter. On occasion the RTX may turn off the transmitter before the line turn around character has been fully sent.

Sequence Number Byte

```
+--7--+--6--+--5--+--4--+--3--+--2--+--1--+--0--+
   0     0     1     1    REP   SQ2   SQ1   SQ0
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Bits 0-2 or SQ0-SQ2 are sequence numbers. Each time the master repeats a message the sequence number is incremented.

Bit 3 or REP is the repeat command. The first time a message is sent bit 3 = 0. If the command is repeated bit 3 = 1.

Normal or Error Free Byte

```
+--7--+--6--+--5--+--4--+--3--+--2--+--1--+--0--+
   0     0     1     1     0     0     0     1
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Command Repeated Once

```
+--7--+--6--+--5--+--4--+--3--+--2--+--1--+--0--+
   0     0     1     1     1     0     1     0
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Command Repeated Twice

```
+--7--+--6--+--5--+--4--+--3--+--2--+--1--+--0--+
   0     0     1     1     1     0     1     1
+-----+-----+-----+-----+-----+-----+-----+-----+
```

Command Repeated Three Times

```
+--7--+--6--+--5--+--4--+--3--+--2--+--1--+--0--+
   0     0     1     1     1     1     0     0
+-----+-----+-----+-----+-----+-----+-----+-----+
```

The master can repeat the command up to 6 times.

B. Data Terminal (DT) Protocol (SW2-2 OFF)

The DT protocol can easily be used from any terminal or terminal emulator capable of 9600 baud and 8 bits, no parity. See Appendix I for using Microsoft Windows Terminal Emulator.

1. Character Format

Baud Rate:	9600 or 38,400 (set using SW2-4)
Data Bits:	8
Parity:	None
Stop Bit:	1
Mode:	Half Duplex

2. Command Block Format Master --> Pump

1	Start Command Block /(2Fh)
2	Pump Address (31h - 5Fh)
n	Data Block (length n)
n + 1	End Command Block <CR> (0Dh)

3. Answer Block Format Pump --> Master

1	Start Answer Block /(2Fh)
2	Master Address (30h)
3	Status Character
n	Response (if applicable)
n + 1	<ETX> (03h embedded in the answer block)
n + 2	Carriage Return (0Dh)
n + 3	Line Feed (0Ah)
n + 4	Line Turn Around Character (FFh)

a. **Start Command** lets the pumps know a command is being sent.

b. **Pump Address** is a hexadecimal number specific for each pump.

c. **Master Address** is the address of the host system. This should always be "30h" (0 ASCII).

d. **Status and Error Codes** define pump status and signal error conditions. Please refer to Chapter 3, Section C.7 under <Q>uery for an explanation of status and error codes.

e. **Carriage Return** - 0Dh ends a command.

f. **Line Feed -** 0Ah ends a response.

g. **Data Block** is the data or commands sent to the pump or host in ASCII.

h. **Line Turn Around Character** is sent to ensure that the entire response will be transmitted before the Real Time Executive (RTX) routine turns off the transmitter. On occasion the RTX may turn off the transmitter before the line turn around character has been fully sent.

C. Command Set

1. Overview

Single or multiple commands can be sent to the pump. For example a single command such as A3000R moves the plunger to position 3000. Commands can also be combined to form a program string such as IA3000OA0R.This string moves the valve to the input position, moves the plunger to position 3000, turns the valve to the output position and finally returns the plunger to position 0.

The pump contains a command buffer of 256 characters. If a command has been sent without the <R> (execution) command, it is placed into the buffer without being executed. If a new command is sent before the first command is executed, the new command will overwrite the first command.

All commands except control and report commands must be followed by an <R> (execution) command.

Once a command is executed, new commands are not accepted until the sequence has been completed. Exceptions to this rule include interruptible and report commands. These will be discussed later in this section.

Make sure that the numerical value is within the given range.

The syntax for the command set is:

nn	Numerical value
{nn}	Default value programmed into pump's firmware
0..5800	Range of numerical values

Caution: Liquid should always be run through the syringe and valve. Failure to do so may harm the valve and syringe seal.

After a command has been sent, the pump will answer immediately. If an invalid command has been sent in a command string, the pump will immediately report an error. If there was an invalid parameter, the pump will start executing up to the invalid parameter and then stop. With a Q command, the error can be read back to the host computer.

Examples:	A4000R	Will return no error immediately after the command, but when <Q>ueried will then return invalid parameter error.
	A3000A3500R	Will move to position 3000, then it stops, a Q will return error.
	E2000R	Will return an invalid command error immediately, pump is not busy.
	A3000E2000R	Will return an invalid command error immediately, pump is not busy.
	Valve in B A1000R	Will not return error immediately.

2. Initialization Commands

During initialization the plunger is set to position 0, the output position of the valve is assigned to the left or right side (depending on the initialization command) and firmware is reset to its default values.

The plunger moves upward until it contacts the top of the syringe and loses steps. The force at which the plunger presses against the top of the syringe can be controlled by using parameters 0, 1 or 2 after the initialization command. Smaller syringes should use a lower initialization force and larger syringes should use higher initialization force. The high and low resolution pumps use speed 500 for initialization.

Table 4 lists the initialization forces and recommended initialization force/syringe.

Z Initializes plunger drive and sets valve output to the right (when viewed from the front of the pump).

Z or Z0 Initializes at **full** plunger force
Z1 Initializes at about **half** plunger force
Z2 Initializes at about **quarter** plunger force
Z3 Initializes 25 mL syringe

Y Initializes plunger drive and sets valve output to the left (when viewed from the front of the pump).

Y or Y0 Initializes at **full** plunger force
Y1 Initializes at about **half** plunger force
Y2 Initializes at about **quarter** plunger force
Y3 Initializes 25 mL syringe

Note: Z3 and Y3 use a slower initialization speed.

The 25 mL syringe is recommended for use only with the High Resolution XL 3000 Modular Digital Pumps.

W Initializes plunger drive. The W commands are used for pumps without valves.

W or W0 Initializes at **full** plunger force
W1 Initializes at about **half** plunger force
W2 Initializes at about **quarter** plunger force

Z10-Z40 (or Y10-Y40) are initialization speeds which correspond to <S>et Speeds S10-S40 found in Appendix A. These commands can be used to change the standard initialization speeds. Slower initialization speeds may be useful when working with viscous fluids or small ID tubing. These initialization commands are only recommended for High Resolution XL 3000 Pumps. Users must determine the most appropriate commands for their applications.

Note: These commands are only available on Revision E or higher of firmware P/N 724013 for Standard Resolution XL 3000s or all revisions of firmware P/N 724842 for High Resolution XL 3000s. Commands Z4-Z9 (Y4-Y9) are open for future use.

Table 4. Initialization Forces (Typical)

Parameter	Standard. Resolution Pump Force (lbs.)	High Resolution Pump Force (lbs.)
0, 3-40	22.0	40.5
1	9.0	18.0
2	5.0	9.0

Recommended Initialization Force/Syringe

Parameter	Force (lbs.)	For Syringes
0, 3-40	Full	1.0 mL and Larger
1	Half	250 µL, 500 µL
2	Quarter	100 µL and Smaller

3. Plunger Movement Commands

Overview

The XL 3000 can be stopped on half steps or microsteps by using the <N> command which is described later in this Chapter. This determines the resolution of the plunger travel (6 cm). Following are the maximum (max) values for the plunger positions.

Note: When running the pump with fine positioning off, the plunger will still travel in 12000 step increments for slow speeds (<1kHz).

Pump Resolution Model	Positioning Mode	Plunger Resolution (Steps)
Standard	Fine Positioning off	3000
Standard	Fine Positioning on	12000
High	Fine Positioning off	3000
High	Fine Positioning on	24000

A nn <A>bsolute Position nn = 0..max

Moves the plunger to the absolute position nn. For example A300 moves the syringe plunger to position 300. A600 moves the syringe plunger to position 600.

a nn <a>bsolute Position nn = 0..max

Same as <A> command except that the status bit indicates pump is not busy.

P nn Relative <P>ickup nn = 0..max

Moves the plunger in a downward direction to the number of steps commanded. The new absolute position is the previous position + nn. 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.

If the resulting absolute position exceeds the maximum possible position, the pump will not execute the command. An error will not be reported.

p nn Relative <p>ickup nn = 0..max

Same as <P> command except that the status bit indicates the pump is not busy.

D nn Relative <D>ispense nn = 0..max

Moves the plunger upward to the number of steps commanded. The new absolute position is the previous position - nn. For example the syringe plunger is at position 3000. D300 will move the plunger up 300 steps to an absolute position of 2700.

d nn Relative <d>ispense nn = 0..max

Same as <D> command except that the status bit indicates the pump is not busy.

4. Valve Commands

The absolute output position of the valve is dependent on the initialization command <Z> or <Y>.

I **Moves Valve to <I>nput Position**

O **Moves Valve to <O>utput Position**

Note: If a valve command is issued to a valveless pump, the command will be ignored.

The following shows the valve position in relation to the initialization command and valve movement command used.

Valve Port Position	Initialization Command	
	Z	**Y**
Left	I	O
Right	O	I

B **Moves Valve to the <B>ypass or Throughput Position**

Connects the input and output positions bypassing the syringe. The syringe plunger should not be moved when the valve is in this position. If a plunger movement command is sent, an error 11 will occur.

5. Set Commands

Overview

Plunger movement is structured into three speed phases: Ramp Up, Constant or Top Speed, and Ramp Down. The firmware calculates how many steps the plunger must travel during the second phase in order to move the total number of steps commanded during a move. All speeds are in half steps/second. For speeds <1000 Hz, the pump automatically microsteps to reduce the pulsation.

<u>Phase 1: Ramping Up</u>

Plunger movement begins with the start <v>elocity and accelerates with the programmed s<L>ope to the constant or top speed.

<u>Phase 2: Constant or Top Speed</u>

The plunger is moved at the constant or top speed. Plunger speed or <V>elocity can be programmed in Hz (half-steps/second) or in preprogrammed <S>et Speeds. The actual time the plunger travels is dependent on phases 1 and 3. If the plunger move is short, it may never reach top speed.

Phase 3: Ramp Down

The plunger will decelerate based on the programmed s<L>ope. To enhance fluid breakoff two cutoff commands (<C> or <c>) can be used to define the end velocity of the plunger just before it stops.

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

Note: If a set command is not embedded in a program string, an <R> command (execute) should follow the set command.

S nn	**<S>et Speed**	**nn = 0..40**	**{11} Standard**
		nn = 1..40	**{14} High Resolution**

Predefined top speed codes. As nn increases, the plunger speed decreases. Please refer to Appendix A, Set Speeds, for a listing of set speeds, the Hz equivalent and seconds per stroke.

The default speed code is S11 which corresponds to a velocity of 700 Hz.

V nn	**Top <V>elocity**	**nn = 5..5800**	**{701} Standard**
			{893} High Res.

Top speed in Hz (half-steps/second). Please refer to the following section.

Caution: Syringes 5 mL and larger may require slower speeds. Users must determine the appropriate speeds for their applications.

v nn	**Start <v>elocity**	**nn = 50..900**	**{701} Standard**
			{743} High Res.

This is the velocity at which the plunger begins its movement. The plunger will then ramp up (s<L>ope) to the top <V>elocity.

The start <v>elocity should always be less than the top <V>elocity.

c nn	**<c>utoff velocity in Hz**	**nn = 50..900**	**{701} Standard**
			{743} High Res.

This is the velocity at which the plunger ends its movement. The plunger will ramp down (s<L>ope) from the top <V>elocity

L nn	**S<L>ope**	**nn = 1..20**	**{7}**

During the beginning and end of a move, the plunger ramps up and down to speed. The ramp is programmed using the s<L>ope command. It is calculated as nn * 2.5 kHz/sec.

The default s<L>ope is 17.5 kHz/sec. Please refer to Appendix B, Slope Table, for a listing of slopes and corresponding kHz/sec.

K nn	**Bac<K>lash Steps**	**nn = 0..63**	**{24} Standard**
		nn = 0..31	**{24} High Res.**

When the motor reverses direction, the carriage will not move until the backlash due to mechanical play is compensated. During aspiration the plunger moves down additional steps, then back up the additional steps to compensate for the backlash. This ensures the plunger is in the correct position.

N nn	**Fine Positioning Off/On**	**nn = 0 or 1**	**{0}**

If nn = 0 then fine positioning is off, the standard resolution pump uses 3000 increments/full stroke and the high resolution pump uses 3000 increments/stroke. If nn = 1 then fine positioning is on. The standard resolution pump uses 12000 increments/full stroke and the high resolution pump uses 24000 increments/full stroke. Velocities are still programmed in increments/second.

Note: The pump is always travelling in microsteps with slow speeds, but it cannot be halted on microsteps when fine positioning is off.

Changing Speed On The Fly

Speed changes can be made while the syringe plunger is moving. This is referred to as changing speed on the fly. Speeds can be decreased or increased between 5-1000 Hz (approximately 3 seconds/stroke-10 minutes/stroke). The top <V>elocity or<S>et speed is followed by an upper or lower case plunger movement command. The move command string is executed. A <V> command is sent while the plunger is moving to change the speed on the fly. When upper case move commands are used for speed changes on the fly, the status bit will reflect busy during the move. When lower case move commands are used for speed changes on the fly, the status bit will reflect ready.

For example the command V100A3000R is sent causing the pump to move to position 3000. While the syringe plunger is moving, V200R is sent to the pump causing the plunger to change velocity or "change speed on the fly."

Ramps are not included in changing speed on the fly; therefore large speed changes are not recommended.

Note: The <S>et speed or top <V>elocity cannot exceed the start <v>elocity in the initial program string.

6. Control Commands

R Executes Command or Program String

This 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 command in the buffer. Repeatedly sending on <R> will not repeat the program string.

X Executes the Last Command or Program String

This command repeats the last executed command or program string.

G nn Repeat Command Sequence nn = 0..30000

This command repeats a command or program string nn times. If nn = 0 the sequence will be repeated endlessly unless a <T>erminate command is issued.

An example of the <G> command is: A3000A0G10R. In this example the syringe plunger moves to position 3000 then back to position 0. This sequence is repeated 10 times.

g Marks the Start of a Repeat Sequence

The <g> command is used in conjunction with the <G> command. Instead of repeating a whole command sequence, the <g> command marks the beginning of a loop. Both the <g> and <G> commands can be used to nest up to 10 loops.

An example of using both commands is: A0gP50gP100D100G10G5R

A0 moves the plunger to position 0
<g> marks the start of the first loop
P50 moves the plunger down 50 steps
<g> marks the start of the second loop
P100 moves the plunger down 100 steps
D100 moves the plunger up 100 steps
G10 repeats the second loop 10 times
G5 repeats the first loop 5 times
R executes the command string

In this example the plunger moves to position 0. The first loop is started with the plunger moving down 50 steps. It then moves down and up an additional 100 steps. The up and down sequence is the second loop and is repeated 10 times. This also ends the first time through the first loop. The first loop is then repeated a second time. The plunger moves down 50 steps, then goes into the second loop which is the up and down sequence. This continues until the first loop is repeated 5 times ending the program string.

M nn **Delay in <M>illiseconds** **nn = 5..30000**

Delays execution of a command in milliseconds. This command is usually used to allow time for liquid in the syringe and tubing to stop oscillating, thereby enhancing precision.

H **<H>alts Command Execution**

The <H>alt command is used within a program string. Execution of the string will stop at the H. To resume execution an <R> command must be sent.

T **<T>erminate Command**

Terminates plunger moves in progress (<A>, <a>, <P>, <p>, <D> and <d>) and delays (M). The <T>erminate command will terminate both a single command and program string. If a program string is terminated before completion, the <R> (execution) command will resume the program string. If the command was terminated due to a problem or error, the operator can reinitialize the pump or send a new command to the pump.

Note: The <T>erminate Command will not work on valve move commands.

7. Report Commands

Report commands do not require an <R> (execution) command.

In some cases the pump will report a velocity that is different from the programmed command. The following table contains executed and reported commands.

Q **<Q>uery, Status and Error Bytes**

This reports error codes and pump status (ready or busy). Status codes reflect status from the previously sent command. Bits 0-3 indicate error codes and bit 5 indicates status. Please refer to Appendix D for a list of error definitions.

Note: If a command is sent to the XL 3000 while it is executing a command, the new command is ignored and a command overflow error is returned.

Status Bit 5:	X = 1	Pump is ready to accept new commands
	X = 0	Pump is busy and will only accept report and terminate commands

Upper case move commands (<A>, <P> and <D>) will return a busy signal. Lower case move commands (<a>, <p> and <d>) will return a ready signal.

Note: The <Q>uery command is the only valid method of obtaining status.

Multiple address commands cannot be used to obtain pump status. Each pump must be addressed separately.

Status Byte 7 6 5 4 3 2 1 0	Hex # if Bit 5 = 0	or 1	Dec # if Bit 5 = 0	or 1	Error Code 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

? Reports <A>bsolute Plunger Position [0..max]

?1 Reports Start <v>elocity [50..900]

?2 Reports Top <V>elocity [5..5800]

?3 Reports <c>utoff Velocity [50..900]

Note: Velocities reported back may not reflect the exact programmed value due to rounding within the firmware.

F Reports Buffer Status [0,1]

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 command is loaded into the buffer and the pump status becomes 1. An <R> will then execute this command.

& Reports Firmware Version

$ Reports Lost Valve Steps [0..255]

This reports the number of lost valve steps between 0 and 255. The valve will automatically correct its position up to 400 microsteps (quarter turn). Beyond this point a valve overload error (10) will be returned. This command provides an indication of future valve problems. If the valve is continually losing more and more steps, it should be replaced.

Note: Correction is up to 400 microsteps, readback up to 255.

% Reports Number of Valve Movements [0..255]

This command reports the number of valve moves since the last % command. Each % command resets the counter.

***		Reports Voltage**

The 24V supply voltage in the pump is fed to an analog input on the microprocessor. Voltage can be reported with this command. The number is rounded to the next lowest digit (for example, 23.9 is rounded to 23). Voltage is measured after power up.

The volume aspirated or dispensed for a given pump motion is dependent on the syringe size. To determine the appropriate number of steps the following formula should be used.

$$\text{Number of steps} = \frac{\text{Plunger Resolution (in steps) x Desired Volume (uL)}}{\text{Syringe Size (uL)}}$$

For example:

Pump Resolution (in steps)	=	3000 Steps (Default Resolution)
Desired Volume	=	100 uL
Syringe Size	=	1000 uL

$$\frac{3000 \times 100}{1000} = 300 \text{ Steps}$$

This means to aspirate or dispense a volume of 100 uL the XL 3000 would be commanded to move 300 steps. Depending upon the valve position and the command used, 100 uL of fluid would be either aspirated or dispensed.

Note: Plunger resolution (fine positioning on/off) is set by the user. The default resolution is 3000 steps. However, the pump can be microstepped. If the plunger is microstepped, the pump resolution equals 12000 steps for the standard resolution pump or 24000 steps for the high resolution pump.

Many factors come into play when aspirating and dispensing fluids. These include the pump mechanics, tubing selection, aspirate and dispense speeds and air gaps. Each can affect accuracy and precision in different ways. Following please find a general description of some of these different factors.

A. Backlash

The Cavro XL 3000 Modular Digital Pump uses a stepper motor to drive a precision lead screw. There is a mechanical tolerance between the motor shaft and the carriage which houses the lead screw. This tolerance is referred to as backlash. When the motor reverses direction, the carriage will not move until the backlash is compensated. Even though the lead screw is preloaded, the backlash cannot be completely eliminated.

In order to minimize the effects of backlash Cavro incorporates "backlash compensation" into the firmware. This means that during aspiration the plunger moves down a few additional steps further than required, then reverses direction and moves back up a few additional steps. This ensures the plunger will move to the correct position.

B. Tubing Selection

Cavro supplies a wide variety of Teflon tubing to meet most applications. Following please find general guidelines for choosing tubing and recommendations for specific syringes.

Tubing comes in two categories: aspirate/dispense tubing and reagent tubing. Aspirate/dispense tubing is used to aspirate sample and dispense sample plus reagent. Reagent tubing is used to fill the syringe with reagent.

As a general rule, smaller syringes use smaller ID tubing and larger syringes use larger ID tubing. Another factor to consider when choosing tubing is the tip of the aspirate/dispense tube. A thermal drawn tip or tapered tip is most commonly used. This tubing provides good breakoff and excellent accuracy and precision for most applications. A necked down tip is also available. This is generally used when aspirating very small volumes of sample, i.e. 1-5 uL. Lastly, a blunt cut tip is available for those applications using large volumes.

Following please find descriptions of our most commonly used tubing and a chart of general tubing recommendations for different syringes.

Tubing Description

P/N	Description	Material	Length	ID	Tip
4609	Reagent Tube	FEP	12"	1/32	Angled blunt cut
5729	Reagent Tube	TFE	20"	1/32	Blunt cut
721370	Reagent Tube	TFE	27"	1/16	Angled blunt cut
720592	Reagent Tube	TFE	60"	1/16	Angled blunt cut
4333	Aspirate/Dispense Tube	TFE	30"	1/16	Necked
4410	Aspirate/Dispense Tube	FEP	40"	1/32	Thermal drawn
5133	Aspirate/Dispense Tube	FEP	29"	1/32	Thermal drawn
5402	Aspirate/Dispense Coiled Tube	FEP	64"	1/32	Thermal drawn
5723	Aspirate/Dispense Tube	FEP	29"	1/32	Necked
720595	Aspirate/Dispense Tube	TFE	60"	1/16	Necked
720597	Aspirate/Dispense Tube	FEP	60"	1/32	Thermal drawn

Tubing Recommendations

Syringe Size	Aspirate/Dispense Tubing Part Number	Reagent Tubing Part Number
Reagent Syringes		
0.50 mL, 1.0 mL, and 2.5 mL	5133 720595 720597	4609 5729 721370
5.0 mL, 10.0 mL, and 25.0 mL	4333 720595	720592 721370
Aspirate Syringes		
50 µL, 100 µL and 250 µL	5133 5723	*
500 µL	4333 4410	*
1.0 mL	4333 4410 5402	*

*Interconnect tubing, P/N 6865, is generally used in conjunction with two pumps equipped with an aspirate and reagent syringe.

Please refer to the spare parts list for additional available tubing. Custom tubing is also available upon request.

These are only guidelines for choosing tubing. Each laboratory should perform its own testing to ensure it has the proper tubing to match its applications.

C. Speed Selection

The XL 3000 provides the user with a wide variety of plunger speeds. These speeds range from 0.8 seconds per stroke to 10 minutes per stroke (standard pump). The syringe stepper motor drive cannot instantaneously bring the plunger to the full speed; therefore, it "ramps-up." At the end of the move the plunger decelerates or "ramps-down." The XL 3000 firmware allows the user to change the s<L>ope and <c>cutoff to enhance fluid breakoff.

The choice of speeds can affect both accuracy and precision. As a general rule aspiration should be slow and dispense fast. Rapid aspiration speeds can cause the air gap to break up resulting in a significant dilution effect or can introduce bubbles into the system. Faster dispense speeds generally result in better breakoff at the tip.

A number of other variables must be considered when determining aspirate and dispense rates. Larger syringes generally require slower rates. Tubing diameter also affects the syringe speed. The viscosity of the fluid should also be considered. Higher viscosity fluids require slower rates. Since there are numerous pipetting applications for this instrument, it is important to experimentally determine the appropriate rates for each application.

D. Air Gaps

There are two types of air gaps in liquid handling systems; inertial air gaps and programmed air gaps.

Inertial air gaps are mechanically generated. They generally occur on larger reagent syringes, 500 uL and larger. Inertial air gaps enhance the breakoff of liquid from the tip of the tubing. For example, if an application uses a 250 uL reagent syringe but has poor breakoff, then a 500 uL syringe may improve fluid breakoff.

In some instances it may be possible to improve fluid breakoff. Fluid breakoff is important so that no drops are left on the tip after dispensing. This is especially a concern when using slow speeds because drops will usually adhere to the tip. In order to accomplish improved fluid breakoff, the last 5 steps should be at a much faster velocity than the rest of the program string. This should accelerate the fluid enough to prevent any drops from adhering to the tip.

Example: On a standard resolution pump using a 2.5 mL reagent syringe, P/N 5133, dispense tubing and deionized water with a surfactant added, the following program string will demonstrate this:

S24IA3000OA0R	will leave a drop on the tip
S24IA3000OA5S1A0R	no drop will be left
V100IA3000OA0R	will leave a drop on the tip
V100IA3000OA5V5500A0R	no drop will be left

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

Note: It may be impossible to get good fluid breakoff under any circumstances with syringes smaller than 500 uL or with some fluids.

In order to prevent premature mixing between sample and reagent or between multiple samples or multiple reagents, we recommend aspirating a small amount of air before aspirating sample. The volume of the air gap is programmable. Due to the wetting of the tubing walls, there is always a small dilution effect. As the sample volume increases, a larger air gap is needed to reduce the dilution effect.

E. Syringe Selection

Generally, smaller syringes will maximize accuracy and precision; however, numerous other factors are also involved in determining the appropriate syringe size. These factors include the smallest and largest volumes pipetted, accuracy requirements, speed and breakoff.

If the application requires multiple aspirations or multiple dispenses, then a larger syringe will allow more aliquots. Breakoff must also be considered. Larger syringes provide better breakoff than smaller ones. In addition, the speed which the fluid must be aspirated or dispensed and the viscosity of the fluid all play a part in the syringe selection.

Chapter 6 Maintenance

To obtain optimum performance and maximum life from the Cavro XL 3000 Modular Digital Pump it is important that the recommended cleaning and maintenance instructions are followed.

A. Routine Maintenance

1. Daily Maintenance

    a. Flush the pump(s) out thoroughly with distilled or deionized water after each use.

    b. The pump(s) should be primed with distilled or deionized water when not in use.

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

    d. Inspect the pump(s) for leaks, and correct any problems immediately.

    e. Wipe up all spills on and around the XL 3000 immediately.

2. Weekly Maintenance

    Thoroughly clean the fluid path using one of the procedures outlined below.

    a. Weak Detergent:

        (1) Prime the pump(s) with a weak detergent solution (e.g., 2% solution of CONTRAD® or flo-kleen*).

        Note: CONTRAD® is a registered trademark of Decon Laboratories, Inc., Malvern, PA. CONTRAD® can be purchased through Curtin Matheson Scientific, Inc. Order P/N 117-655 for 500 mL size.

        *flo-kleen can be purchased through Ciba Corning Gilford Systems. Order P/N 402342 for 400 mL size.

        (2) The detergent should sit in the pumps with the syringe plungers fully lowered for 30 minutes.

        (3) After the 30 minute period, remove the reagent tubing from the detergent and cycle all the fluid from the syringes and tubing into a waste container.

        (4) Prime the instrument a minimum of 10 cycles with distilled or deionized water. Leave the fluid pathways filled for storage.

b. Weak Acid and Base in Sequence:

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

(2) Flush the pump(s) with distilled or deionized water.

(3) Prime the pump(s) with 0.1 N HCl and allow the solution to sit in the unit 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(s) a minimum of 10 cycles with distilled or deionized water.

c. 10% Bleach:

(1) Make a solution of 10% bleach, by adding 1 part of commercial bleach to 9 parts of water.

(2) Prime the pump(s) with the 10% bleach, and allow the solution to sit in the pump(s) 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 pumps a minimum of 10 cycles with distilled or deionized water.

3. Periodic Maintenance

a. Tubing Replacement

It is important that all tubing be kept clean and free of crimps. Tubing that has become dirty, blocked or crimped can result in poor accuracy and precision, loss of air gap, or syringe stalls. Replace the tubing if necessary. Frequency of replacement will be dependent on duty cycle, reagents and maintenance.

b. Seal Replacement

The syringe seals will need to be replaced periodically. How often will depend on the duty cycle of the XL 3000 pumps, the types of fluids being run through the system, the size of the syringe, and how well the instrument is maintained.

If a syringe seal becomes worn, and is not replaced, the following problems may occur:

* Poor precision and accuracy.
* Variable or moving air gap.
* Fluid leaks from the bottom of the syringe.
* The tip of the plunger breaks through the seal and scratches the inside of the barrel. If this happens the entire syringe will need to be replaced.

c. Lead Screw and Lead Screw Encoder

If the pump is used in a dusty environment, the lead screw encoder can be cleaned periodically with air. The lead screw should be lubricated:

1) If the pump is making a "screeching" noise.
2) If the syringe is stalling frequently.

Only Cavro lubricant, P/N 5984, should be used for lubricating the lead screw.

Note: Lubrication is usually only needed after 1,000,000 syringe strokes. If the unit appears to need lubrication more frequently, suspect another problem.

B. Component Replacement

1. To replace the Dispense or Reagent Tubing

   a. To remove the tubing, use a 5/16" wrench and gently loosen the fittings. Unthread the fittings using your fingers and remove the tubing.

   b. To install new tubing, insert the fitting into the valve and tighten it finger tight. Using a 5/16" wrench, turn the fitting another 1/4 to 1/2 turn.

2. To install or replace the Interconnect Tubing (for 2 or more pumps)

   a. To remove the tubing, use a 5/16" wrench and gently loosen the fitting that attaches the interconnect to the aspirate syringe. Using your fingers, remove the tubing from the aspirate syringe.

   b. Gently loosen the interconnect fitting from the valve with the wrench, then remove it using your fingers.

   c. To install the new tubing, attach it to the valve first, and then to the aspirate syringe. Finger tighten the fittings, then give them another 1/4 to 1/2 turn with a 5/16" wrench.

   Note: To prevent breakage when tightening the fitting, support the plastic cross-flow manifold on the aspirate syringe.

3. To install or replace the Reagent Syringe

   a. Lower the syringe or plunger shaft (if no syringe is installed) approximately 1500 steps.

   b. Remove the plunger pin at the base of the syringe plunger.

   c. If you are replacing a syringe, carefully unscrew the syringe barrel from the luer lock fitting (about 1 1/2 turns) while pulling downward slightly. Then slide the syringe plunger from the plunger shaft.

   d. To install a syringe, place the plunger over the plunger shaft. Line up the barrel with the luer lock fitting. Screw the barrel onto the fitting while pushing upward slightly.

      Caution: You must assist the luer lock threads by pushing upward. Otherwise they may become stripped.

   e. Replace the plunger screw at the base of the syringe plunger.

4. To install or replace the Aspirate Syringe

   a. Lower the syringe or plunger shaft (if no syringe is installed) approximately 1500 steps.

   b. Remove the plunger pin at the base of the syringe or plunger shaft.

   c. If you are removing a syringe, loosen the black knurled knob at the top of the aspirate syringe. Carefully slide the syringe away from the pump and remove the tubing.

   d. To install a new syringe, attach the tubing. Line up the syringe plunger with the plunger shaft and the top of the crossflow manifold with the guide on the front of the pump. Carefully slide the syringe back into position to avoid breaking the syringe or bending the plunger. Screw the black knurled knob finger tight

      Caution: Do not over tighten the knurled knob. This can result in a broken syringe.

   e. Replace the plunger pin at the base of the syringe plunger.

5. Reagent Syringe Seal Replacement

   This procedure applies to all reagent syringes except the 5.0 mL, 10.0 mL and 25.0 mL syringes. Following please find replacement procedures for these syringes.

a. Remove the reagent syringe from the pump following the above procedure.

b. Remove the syringe plunger.

c. 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.

Caution: 0.5 mL, 1.0 mL and 2.5 mL syringes have "O"- rings beneath the seal. Do not cut the "O"-ring. Replace the "O"-ring if it is damaged.

d. Wet the "O"-ring (if present) and plunger tip with distilled or deionized water.

e. 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.

f. Wet the seal and replace the plunger, then replace the syringe.

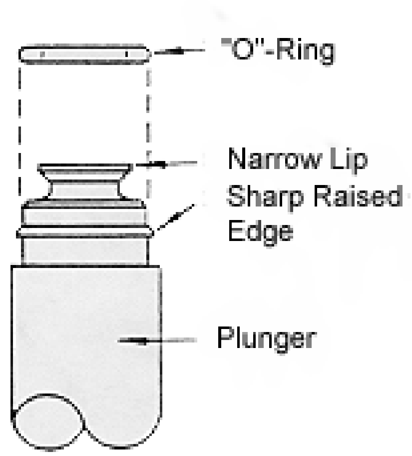
6. Reagent Syringe Seal Replacement for 5.0 mL and 10.0 mL Syringes

a. Remove the reagent syringe from the pump.

b. Remove the syringe plunger.

c. Remove the seal from the plunger tip using a pair of pliers and gripping the seal approximately one third of the way down. Refer to Figure 9.

Figure 5. Plunger and "O"-Ring Configuration



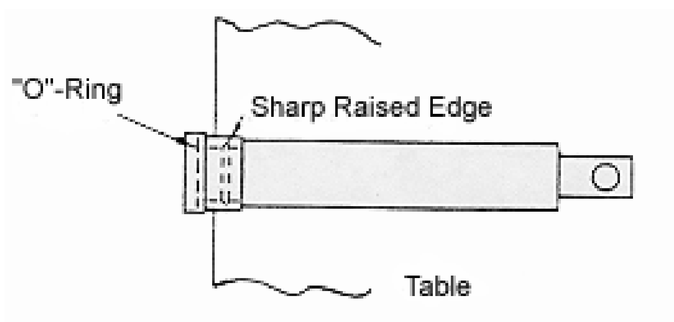
Caution: 5.0 mL, 10.0 mL and 25.0 mL syringes have "O"-rings beneath the seal. Be careful not to damage the "O"-ring. If it is necessary to replace the "O"-ring, simply slip the new "O"-ring over the narrow lip on the plunger. It may be necessary to use needle nose pliers to assist in removing the "O"-ring from the 10.0 mL and 25.0 mL plunger.

d. Wet the plunger tip and the "O"-ring with distilled or deionized water.

e. 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.

f. Lay the plunger on a flat table top. Position the plunger so that the seal (from the "O"-ring up) hangs over the edge. Please refer to Figure 10. Slowly roll the plunger along the table edge, pressing firmly on the portion of the seal below the "O"-ring. Rotate the plunger three complete turns. This is necessary for the sharp, raised edge of the plunger to bite into the seal for a secure fit.

Figure 6. Seal Installation



g. Wet the seal and replace the plunger in the barrel.

h. Replace the syringe.

7. 25.0 mL Reagent Syringe Seal

If the 25.0 mL syringe seal leaks, please replace it with plunger and seal assembly, P/N 724599.

8. Aspirate Syringe Seal Replacement

a. Remove the aspirate syringe from the pump.

b. Slice off the old seal from the plunger using a razor.

Note: The 1.0 mL aspirate syringe has an "O"-ring beneath the seal. Caution should be taken not to cut the "O"-ring when removing the seal. Replace the "O"-ring if damaged. Please refer to Figure 9 for an illustration of the plunger and "O"-ring.

c. Place the seal on a flat surface with open end facing up. Press the plunger tip firmly into the hole until it snaps into position.

d. Wet the seal, replace the plunger, and the syringe.

Caution: Do not exert excessive pressure on small seals. They are easily flattened.

9. 3-Port Valve Replacement

   a. Power down the pump.

   b. Remove the aspirate tubing, reagent tubing and syringe.

   c. Remove the valve by loosening the two screws on the valve.

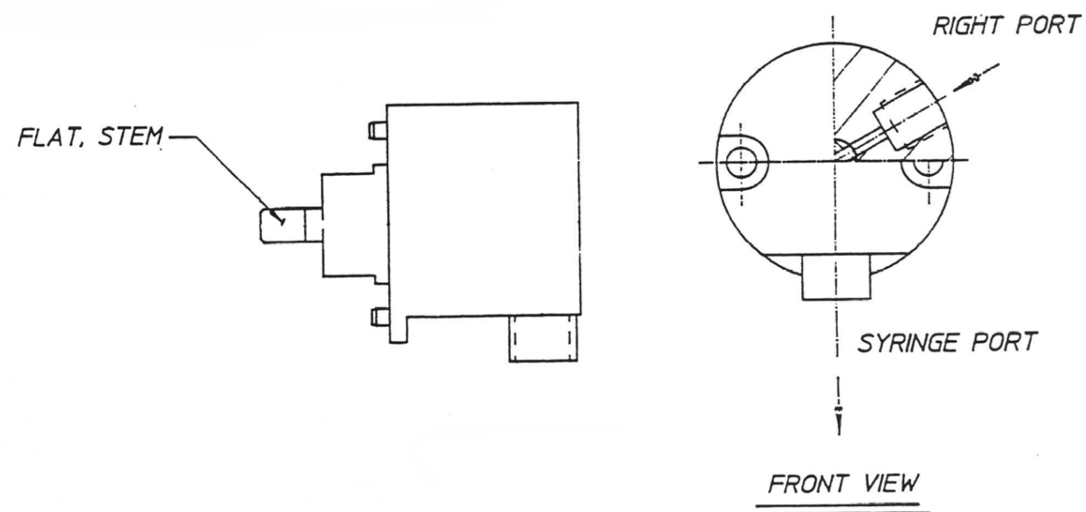
   d. Install the new valve by aligning the "D" coupler on the valve stem with the "D" hole in the encoder.

   e. Rotate the valve body so that the luer fitting is oriented toward the bottom of the pump.

   f. Gently push the valve in place ensuring the locating pins on the frame side of the valve body fit in the holes on the XL 3000 frame and replace the screws.

   g. Power up the pump and reinitialize.

Figure 7. Cavro 3-Port Valve



10. EPROM Replacement Instructions

    a. Power down the pump.

    b. Turn the pump so that the component side of the PC board is facing you. The EPROM is located in position U6 towards the left of the board. The EPROM will have a label with a Cavro part number.

    c. Remove the EPROM. This can be done by using an EPROM puller. The

EPROM puller should be placed so that the ends are gripping both the top and bottom of the EPROM. Rock gently while pulling straight out from the board to remove EPROM.

d. To install the new EPROM, line the EPROM up so that the **NOTCHED END IS TO THE LEFT**. Make sure all metal pins are aligned with the holes on the receptacle. Once the pins are seated in the holes, press the EPROM firmly into place. If the two rows of pins on the EPROM are too far apart to match the holes on the receptacle, gently press the side of a complete row of pins against a table top to push the row slightly towards the center.

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

e. Power up the pump and reinitialize.

11. Circuit Board Replacements

   a. Turn the pump so that the solder side of the circuit board faces you.

   b. Remove the two screws holding the circuit board.

   c. Turn the pump around. Remove the valve motor screw holding the circuit board bracket.

   d. Gently move the circuit board away from the pump.

   e. Transfer the circuit board bracket to the new circuit board.

   f. Drop the new circuit board into place. Please make sure that the lead screw and valve encoder do not touch the opto switches on the circuit board.

   g. Install the screws (one motor screw and two solder side).

C. Quality Control

As with all pipetting devices, the accuracy and precision of the XL 3000 should be checked on a regular basis. Cavro recommends checking both accuracy and precision gravimetrically, using an analytical balance with the capability to measure to 0.1 mg. Gravimetric measurements should be corrected for the specific gravity of water at the ambient temperature.

The accuracy and precision of the aspirate syringe can be determined by measuring the weight of fluid aspirated.

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

To determine precision, a minimum of 20 replicates should be run. The Mean, Standard Deviation and % C.V. can then be calculated. The calculations to determine accuracy must take into account the specific gravity of water which is effected by 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 (i.e. Fluorad® at a 0.01% concentration).

A. Dimensions

Height	10.00 in (25.4 cm)
Width	2.56 in (6.5 cm)
Depth	5.61 in (14.2 cm) from valve to board connector
Weight	4.5 lbs. (2.0 kg)

B. Power Requirements

	Supply Voltage	Current
Peak	24 VDC $\pm$10%	850 mA
Holding	24 VDC $\pm$10%	200 mA

C. Resolution

Standard Pump	3,000/12,000 steps
High Resolution Pump	3,000/24,000 steps

D. Plunger Drive

Principle	Stepper motor driven lead screw with optical feedback
Travel	60 mm

E. Plunger Speeds

0.8 Second-10 min/stroke for standard resolution pump
1.5 Seconds-20 min/stroke for high resolution pump
(Speed ranges vary depending on the syringe size and tubing.)

F. Syringes

Sizes	Aspirate: 50 uL - 1.0 mL
	Reagent: 500 uL - 25 mL
Material	Barrel: Borosilicate Glass
	Plunger: Stainless Steel
	Seal: Virgin Teflon

G. Imprecision

0.05% CV within run at full stroke

H. Inaccuracy

<1% at full stroke

I. Valve /Valve Drive

3 positions	Input, Output, Bypass
Angle	120 degrees
Turn time	250 ms
Drive	Stepper motor with optical encoder positioning feedback
Materials	Plug: Virgin Teflon Body: Kel-F
Standard Fitting	1/4-28" tubing fitting, luer fitting for syringe

J. Interface

Type	RS-232 or RS-485
Baud Rate	9600 or 38,400
Format	Data Bits: 8 Parity: No Stop Bit: 1 Half Duplex
Addressing	Up to 15 pumps can be addressed individually
Communications	Data terminal and OEM protocol (with error recognition)

K. Fluid Contact

Glass, Kel-F, Teflon

L. Firmware

Programmable Ramps
Programmable Cutoff Velocity
Programmable Backlash Compensation
Programmable Plunger Speeds
Programmable Delays
Programmable Loops
Change the Speed on the Fly
Terminate Moves, Delays
Diagnostics
Absolute or Relative Positions

M. Environmental

Temperature	
Operating (mechanism)	59°F (15°C) to 104°F (40°C)
Humidity	
Operating (mechanism)	20-95%RH at 104°F (40°C)

Figure 8. Outline Drawing of XL 3000

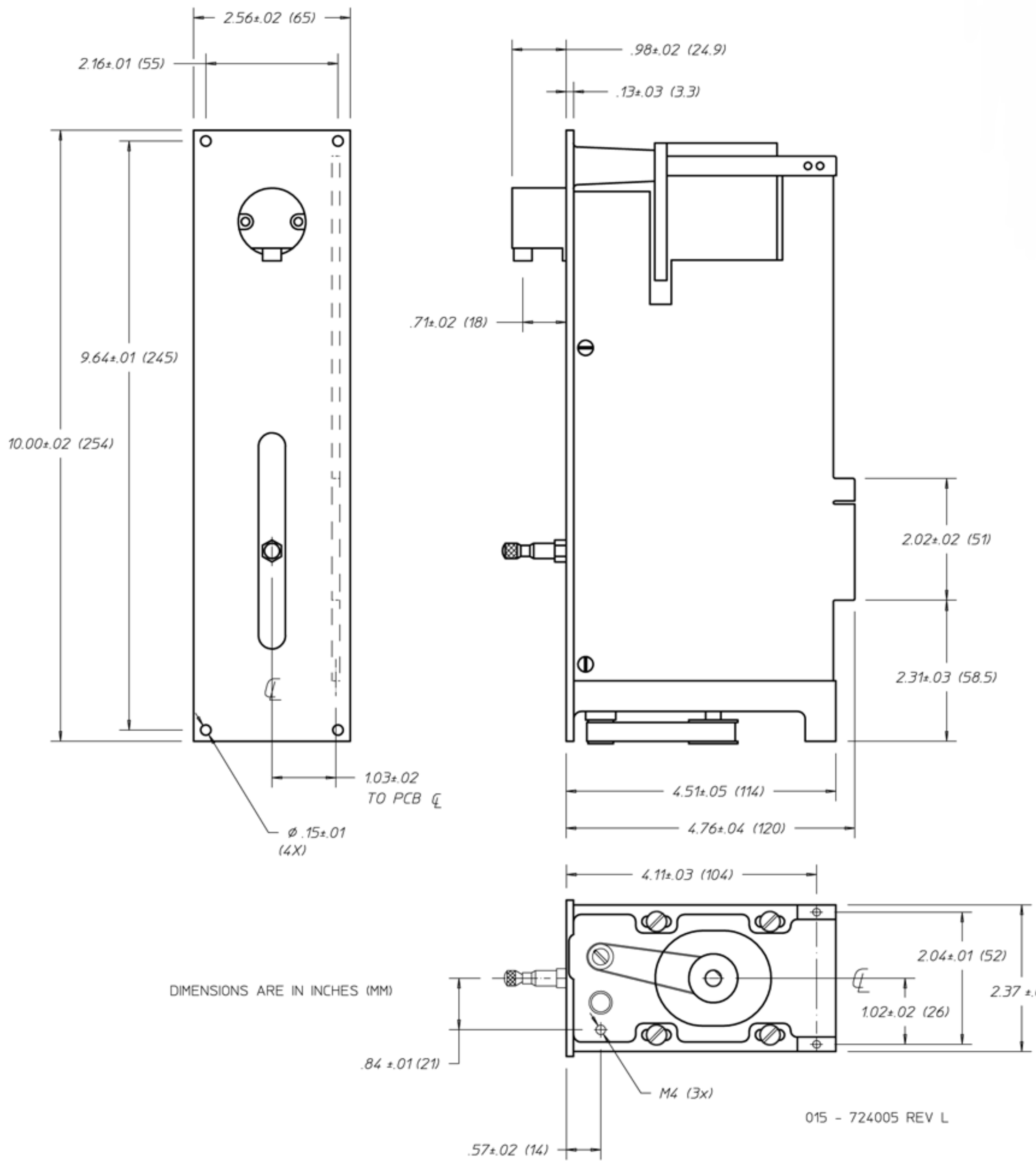


Figure 9. XL 3000 Standard Resolution Pump Typical Plunger Force Curve (Dynamic Force)

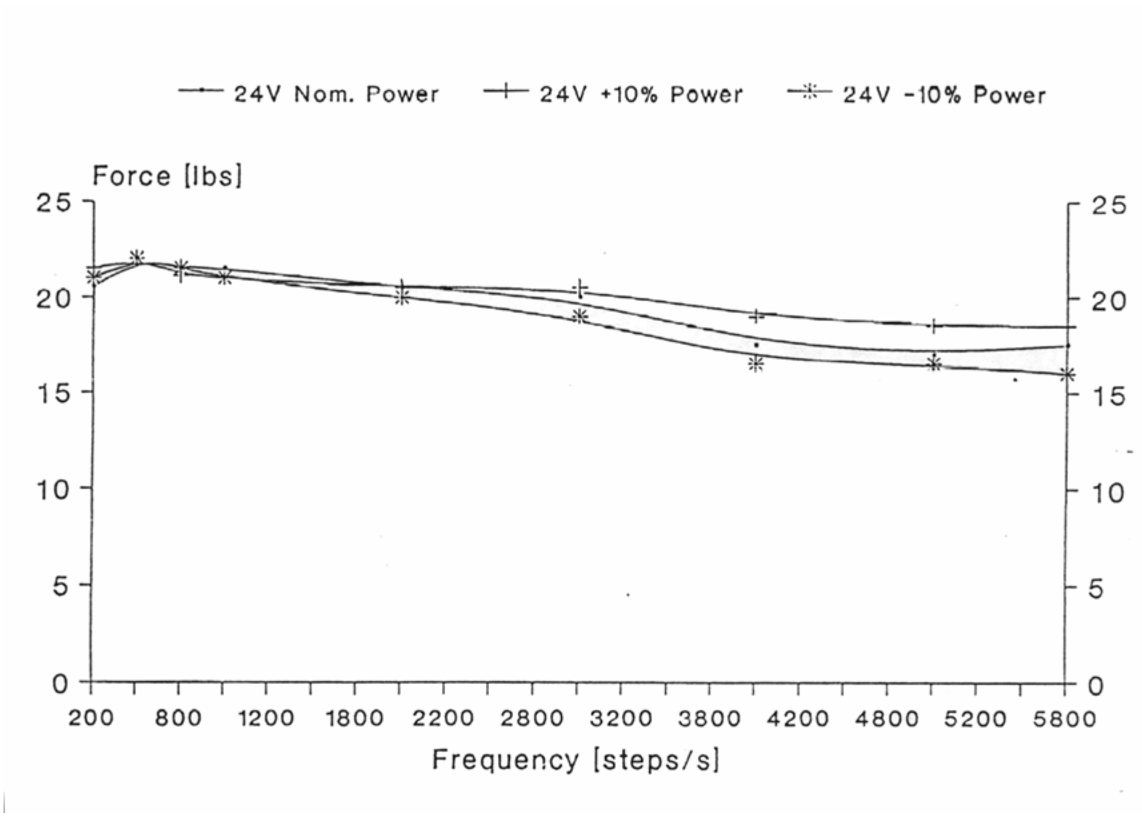
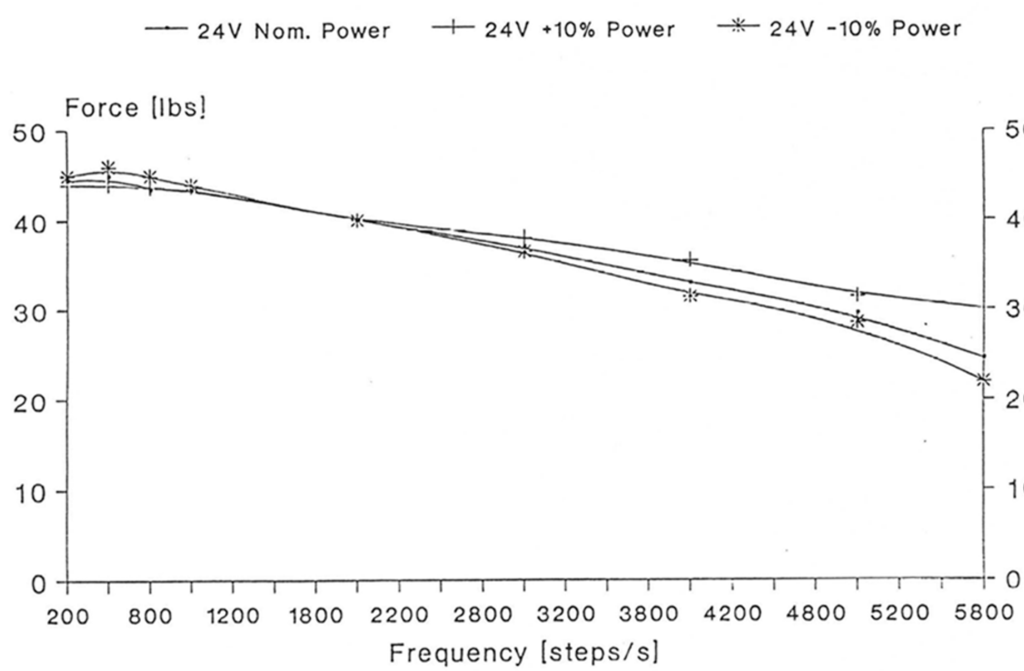


Figure 10. XL 3000 High Resolution Pump Typical Plunger Force Curve (Dynamic Force)



PROBLEM	PROBABLE CAUSE	REMEDY
No air gap, or moving air gap; instrument will not draw in reagent; no fluid being dispensed.(**HINT**: To check if the hydraulic system is tight, check the air gap size as the dispense tubing is lifted overhead and below the knee. The air gap should not change size.)	Fittings not tight.	Make certain all fittings are tight.
	Valve fitting threads damaged.	Replace valve.
	Reagent syringe not tight in the valve luer.	Make sure that the reagent syringe is tight within the valve luer.
	Tubing kinked, blocked or has holes in it.	Check the tubing, and replace if necessary.
	Aspirate syringe manifold is broken (cracked).	Replace aspirate syringe.
Reagent being dispensed back through the reagent tubing into reagent vessel.	Valve motor not functioning properly.	Check to see if the encoder changes position with each valve movement. Also listen for a valve movement.
	Encoder manually moved.	Power pump down and reinitialize pump.
	Incorrect valve movement command.	Please refer to Chapter 3.C.2 and 4.
	Damaged valve.	Replace valve.
. Air gap breaks up when aspirating sample.	Incorrect tubing size.	Check to see if tubing is correct. See tubing recommendations, Chapter 5.B.
	The tip of the dispense tubing is frayed.	Trim a small section off the tip of the tubing by making a square cut with a razor blade.
	The dispense tubing is dirty.	Clean or replace tubing.
	Sample aspiration is too fast.	Reduce speed.
Bubbles in the reagent syringe.	Fittings not tight.	Make certain all fittings are tight.

PROBLEM	PROBABLE CAUSE	REMEDY
	Reagent syringe not tightened onto the valve.	Make sure the reagent syringe is tightened onto the valve.
	Syringe is dirty.	Clean syringe; replace if necessary.
	Valve fittings damaged.	Replace valve.
Fluid leaking from bottom of syringe.	Worn seals.	Replace seals.
	Reagent too cold.	Allow reagent to warm to room temperature.
Syringes are not aspirating or dispensing the programmed volumes.	Incorrect number of steps programmed for syringe size.	Review programming, making sure correct number of steps are programmed.
The instrument will not power up	Loose power connections.	Check pump connections.
	Improper or inoperable power supply.	Check power supply for proper output.
	1 amp fuse on PCB blown.	Check fuse; replace fuse if necessary.
Syringe stall.	Blockage in tubing or valve.	Inspect all tubing, visually inspect valve.
	Syringe not properly installed.	Check to make sure syringe is properly installed.
	Dispense rates too fast for syringe size.	Reduce dispense rate.
	Valve not turning.	Call Cavro Technical Service
	Continual plunger overload error.	Call Cavro Technical Service

PROBLEM	PROBABLE CAUSE	REMEDY
No communication with the pump.	Pump may be busy waiting for an <R> (execute command) or an error may have occurred.	Check pump status
	Pump incorrectly addressed.	Change pump address.
	Voltage dropped to an unacceptable level.	Check voltages to the pump.
Poor accuracy and precision.	Seal worn.	Replace seal.
	Tubing crimped, dirty or frayed.	Replace tubing.
	Improper selection of syringe and/or tubing.	Refer to Chapter 5.

Chapter 9 — Cavro Services

A. Customer and Technical Services

For information or questions regarding the ordering or operation of the XL 3000 Modular Digital Pump, please call Cavro Customer or Technical Services at:

(800) 231-0711

Or outside the continental United States, call:

(408) 953-3100

The fax number is:

(408) 953-3107

The mailing address is:

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

B. Ordering Information

Cavro's XL 3000 Modular Digital Pump can be ordered through our Customer Service Department using the following part numbers:

Part Number	Description
Standard Resolution Pump (3000/12000 steps)	
724020	XL 3000 with valve, RS-232
724086	XL 3000 with 4-port valve, 1/4-28 fitting, RS-232
724140	XL 3000 with 4-port valve, M6 fitting, RS-232
724022	XL 3000 without valve, RS-232
724024	XL 3000 with valve, RS-485
724136	XL 3000 with 4-port valve, 1/4-28 fitting, RS-485
724142	XL 3000 with 4-port valve, M6 fitting, RS-485
724026	XL 3000 without valve, RS-485
High Resolution Pump (3000/24000 steps)	
723903	XL 3000 with valve, RS-232
723928	XL 3000 without valve, RS-232
723905	XL 3000 with valve, RS-485
723930	XL 3000 without valve, RS-485

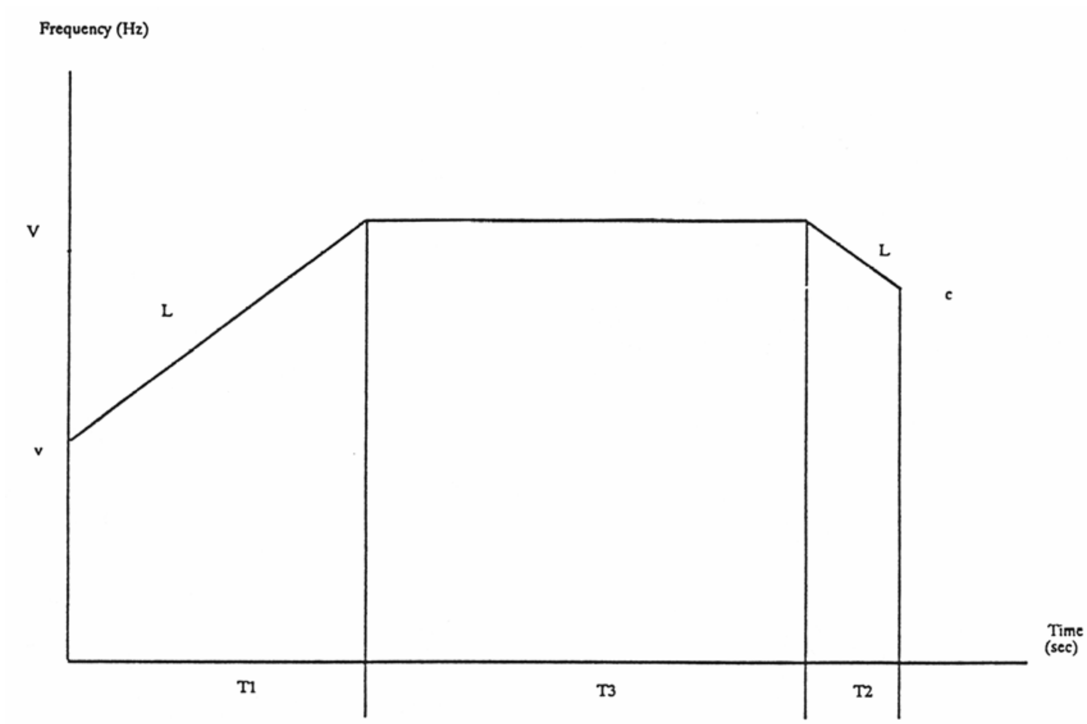
- To obtain maximum pump performance, change the syringe seals and tubing regularly.
- Do not cycle the pumps without fluid. This will greatly reduce syringe, seal and valve life.
- Screeching noises and frequent syringe stalls are indications that the pump needs lubrication. Use Cavro Lubrication Kit, P/N 5984. Do not use substitute lubricants. They may have adverse effects on the pump. Please refer to Cavro's Syringe Drive Lubrication Procedure, P/N 009-6133B, for lubricating instructions.
- If the pump is in a dusty environment, the lead screw encoder should be cleaned periodically with air.
- Flush the pump daily with distilled or deionized water. Flush the pump weekly with a 10% solution of bleach, a weak detergent or a weak acid and base.
- If bubbles remain in the syringe after priming, clean the syringe with alcohol. Also check to ensure the fittings are tight and the syringe is tight within the Teflon fitting.
- Wipe up all spills immediately.
- Cold fluids run through the pump may cause leakage due to the shrinking of the Teflon parts. This occurs at approximately 16°C (61°F).
- To reduce the amount of carryover a ratio of three parts reagent to one part sample is recommended.
- The pump should always be installed in an upright position. Failure to do so can result in priming problems.
- Do not use organic solvents with the XL 3000.

Speed Code	Standard Res. Pump Freq (Hz)	High Res. Pump Freq (Hz)	Seconds/Stroke
0	3000	N/A	1.2
1	2800	5600	1.2
2	2500	5000	1.3
3	2200	4400	1.4
4	1900	3800	1.6
5	1600	3200	1.9
6	1300	2600	2.2
7	1100	2200	2.6
8	1000	2000	2.9
9	900	1800	3.3
10	800	1600	3.7
11	700	1400	4.3
12	600	1200	5.0
13	500	1000	6.0
14	400	800	7.5
15	300	600	10.0
16	200	400	15.0
17	100	200	30.0
18	95	190	31.0
19	90	180	33.0
20	85	170	35.5
21	80	160	37.5
22	75	150	40.0
23	70	140	43.0
24	65	130	46.0
25	60	120	50.0
26	55	110	55.0
27	50	100	60.0
28	45	90	67.0
29	40	80	75.0
30	35	70	86.0
31	30	60	100.0
32	25	50	120.0
33	20	40	150.0
34	15	30	200.0
35	10	20	300.0
36	9	18	333.3
37	8	16	375.0
38	7	14	428.6
39	6	12	500.0
40	5	10	600.0

The frequency data refers to half-steps/second. All times are approximate and will vary with different ramp speeds and cutoffs. Please refer to Appendix C for calculations.

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

To find the exact time required to move a given amount of steps, please use the following formula. The Cavro program, Pumper, will also calculate this. Please contact Cavro for a copy of the program.



L = Slope (kHz/sec)
SU = Steps in the up ramp
SD = Steps in the down ramp
v = Start velocity
V = End velocity
C = Cutoff velocity (Hz)
S = Total number of steps

$$SU = \frac{1}{2} * \frac{V^2 - v^2}{L}$$

$$T1 = \frac{V - v}{L}$$

$$SD = \frac{1}{2} * \frac{V^2 - c^2}{L}$$

$$T2 = \frac{V - c}{L}$$

$$T3 = \frac{S - SU - SD}{V}$$

Total time = T1 + T2 + T3

For Example:

L = 17.5 (KHz/sec or 17500 Hz/sec)
V = 3000 Hz
v = 100 Hz
c = 400 Hz
s = 3000 steps

$$SU = \frac{1}{2} * \frac{(3000)^2 - (100)^2}{17500} = 256.9 = 257$$

$$T1 = \frac{3000 - 100}{17500} = 0.166 = 0.17$$

$$SD = \frac{1}{2} * \frac{(3000)^2 - (400)^2}{17500} = 252.6 = 253$$

$$T2 = \frac{3000 - 400}{17500} = 0.149 = 0.15$$

$$T3 = \frac{3000 - 257 - 253}{3000} = 0.83$$

Total Time = 0.17 + 0.15 + 0.83 = 1.15 seconds

This formula is only valid if S > SU + SD

0 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.

2 (02h) Invalid Command

This error occurs when an incorrect command is issued. Correct the command and operation will continue normally.

3 (03h) Invalid Operand

This error occurs when an invalid parameter (nn) 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. To clear the error initialize the pump.

9 (09h) Plunger Overload

This error occurs when the syringe plunger loses steps. **The pump must be reinitialized before normal operation can resume.**

10 (0Ah) Valve Overload

This error occurs when the valve drive loses too many steps. Continual valve overload errors are an indication the valve should be replaced. **The pump must be reinitialized before normal operation can resume.**

11 (0Bh) Plunger Move Not Allowed

When the valve is in the <B>ypass or throughput position, plunger movement commands are not allowed.

15 (0Fh) Command Overflow

The buffer contains too many characters. Commands in the buffer must be executed before more commands can be sent.

Appendix E *Command Summary*

Initialization Commands

Z nn	Initializes plunger drive and sets the valve to the right or output position
Y nn	Initializes plunger drive and sets the valve to the left or output position
W nn	Initializes plunger drive. This command is used for pumps without valves

nn = 0, 3-40 = full plunger force
1 = half plunger force
2 = quarter plunger force

Note: nn = 3 uses a slower initialization speed
nn = 10-40 corresponds to <S>et Speeds S10-S40

Plunger Movement Commands

			Status Bit Reports
A nn	<A>bsolute Position	nn = 0..max	Busy
a nn	<a>bsolute Position	nn = 0..max	Ready
P nn	Relative <P>ickup	nn = 0..max	Busy
p nn	Relative <p>ickup	nn = 0..max	Ready
D nn	Relative <D>ispense	nn = 0..max	Busy
d nn	Relative <d>ispense	nn = 0..max	Ready

Note: For N = 0 Max = 3000
For N = 1 Max = 12000 (standard resolution pump)
Max = 24000 (high resolution pump)

Valve Commands

I	Moves Valve to <I>nput Position
O	Moves Valve to <O>utput Position
B	Moves Valve to <B>ypass Position

Set Commands

S nn	<S>et Speed	nn = 0..40	{11}
V nn	Top <V>elocity	nn = 5..5800	{701}
v nn	Start <v>elocity	nn = 50..900	{701}
C nn	<C>utoff Steps	nn = 0..25	{0}
c nn	<c>utoff Steps	nn = 50..900	{701}
L nn	S<L>ope	nn = 1..20	{7}
K nn	Bac<K>lash	nn = 0..63	{24}
N nn	Fine Positioning	nn = 0 or 1	{0}

Control Commands

R	Executes Command or Command String	
X	Repeats Last Command String	
G nn	Repeats Command Sequence	nn = 0..30000
g	Marks Start of a Repeat Sequence	
M nn	Delay in <M>illiseconds	nn = 5..30000
H	<H>alts Command Execution	
T	<T>erminates Command	

Report Commands

Q Query, Status and Error Bytes

Status Byte 7 6 5 4 3 2 1 0	**Hex # if Bit 5 = 0**	**or 1**	**Dec # if Bit 5 = 0**	**or 1**	**Error Code 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

?	Reports <A>bsolute Plunger Position
?1	Reports Start <V>elocity
?2	Reports Top <V>elocity
?3	Reports <c>utoff Velocity
F	Reports Buffer Status
&	Reports Firmware Version
$	Reports Lost Valve Steps
%	Reports Number of Valve Movements
*****	Reports Voltage

Dec	Hex	Character or Function
0	00	none
1	01	Control A
2	02	Control B
3	03	Control C
4	04	Control D
5	05	Control E
6	06	Control F
7	07	Control G
8	08	Control H
9	09	HT
10	0A	LF
11	0B	VT
12	0C	FF
13	0D	Carriage Return
14	0E	SO
15	0F	S1
16	10	none
17	11	DC1
18	12	DC2
19	13	DC3
20	14	DC4
21	15	none
22	16	none
23	17	none
24	18	CAN
25	19	none
26	1A	none
27	1B	ESC
28	1C	none
29	1D	none
30	1E	none
31	1F	none
32	20	b/(space)
33	21	! (Roman)
34	22	"
35	23	#
36	24	$
37	25	%
38	26	&
39	27	' (apostrophe)
40	28	(
41	29	)
42	2A	*
43	2B	+
44	2C	, (comma)
45	2D	- (en dash)
46	2E	. (period)
47	2F	/
48	30	0
49	31	1
50	32	2
51	33	3
52	34	4
53	35	5
54	36	6
55	37	7
56	38	8
57	39	9
58	3A	:
59	3B	;
60	3C	<
61	3D	=
62	3E	>
63	3F	?
64	40	@
65	41	A
66	42	B
67	43	C
68	44	D
69	45	E
70	46	F
71	47	G
72	48	H
73	49	I
74	4A	J
75	4B	K
76	4C	L
77	4D	M
78	4E	N
79	4F	O
80	50	P
81	51	Q

Dec	Hex	Character or Function
82	52	R
83	53	S
84	54	T
85	55	U
86	56	V
87	57	W
88	58	X
89	59	Y
90	5A	Z
91	5B	[
92	5C	\ (backslash)
93	5D	]
94	5E	^ (control)
95	5F	- (em dash)
96	60	` (tick)
97	61	a
98	62	b
99	63	c
100	64	d
101	65	e
102	66	f
103	67	g
104	68	h

Dec	Hex	Character or Function
105	69	i
106	6A	j
107	6B	k
108	6C	l
109	6D	m
110	6E	n
111	6F	o
112	70	p
113	71	q
114	72	r
115	73	s
116	74	t
117	75	u
118	76	v
119	77	w
120	78	x
121	79	y
122	7A	z
123	7B	{ (left brace)
124	7C	| (vertical bar)
125	7D	} (right brace)
126	7E	~ (tilde)
127	7F	DEL

Appendix G — *Chemical Resistance Chart*

- No Data Available
0 - No effect - excellent
1 - Minor effect - good
2 - Moderate effect - fair
3 - Severe effect - not recommended

Plastic Materials used in Cavro Pumps

Polysulfone: Cross Flow Manifold Assembly in the aspirate syringe
Teflon® (PTFE, TFE, FEP): Tubing, Valve Plug, Seal
Kel F®: Valve Body
Polypropylene: Fittings for Tubing

Solvent	***Polysulfone***	***Teflon***	***Kel F***	***Polypropylene***
Acetaldehyde	-	0	0	0
Acetates	-	-	0	0
Acetic Acid	0	0	0	0
Acetic Anhydride	-	-	0	-
Acetone	3	0	0	0
Acetyl Bromide	-	0	-	
Ammonia	0	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	3	0	3	*
Benzyl Alcohol	-	0	0	0
Boric Acid	-	0	0	0
Bromine	-	0	0	*
Butyl Alcohol	2	0	0	1
Butyl Acetate	3	0	-	*
Carbon Sulfide	-	0	-	*
Carbon Tetrachloride	0	0	1	3
Chloracetic Acid	-	0	0	-
Chlorine	-	0	1	3
Chlorobenzene	3	-	-	3
Chloroform	3	0	-	3
Chromic Acid	3	0	0	-

Solvent	Polysulfone	Teflon	Kel F	Polypropylene
Cresol	-	0	-	*
Cyclohexane	0	0	-	3
Ethers	-	0	-	**
Ethyl Acetate	3	0	-	0
Ethyl Alcohol	0	0	-	0
Ethyl Chromide	-	0	1	3
Formaldehyde	0	0	0	0
Formic Acid	-	0	0	0
Freon	2	0	2	0
Gasoline	2	0	0	3
Glycerin	0	0	0	0
Hydrochloric Acid	0	0	0	0
Hydrochloric Acid (conc)	0	0	0	0
Hydrofluoric Acid	2	0	0	*
Hydrogen Peroxide	-	0	0	0
Hydrogen Peroxide (conc)	-	0	0	0
Hydrogen Sulfide	-	0	0	0
Kerosene	2	0	0	0
Methyl Ethyl Ketone (MEK)	3	0	-	0
Methyl Alcohol	0	0	-	0
Methylene Chloride	3	0	0	3
Naptha	0	0	1	0
Nitric Acid	0	0	0	0
Nitric Acid	3	0	0	-
Nitrobenzene	-	0	-	**
Phenol	-	0	-	0
Pyridine	3	0	-	-
Silver Nitrate	-	0	-	0
Soap Solutions	-	0	-	0
Stearic Acid	-	0	-	*
Sulfuric Acid	0	0	0	0
Sulfuric Acid (conc)	3	0	0	-
Sulfurous Acid	-	0	0	0
Tannic Acid	-	0	0	0
Tanning Extracts	-	-	-	-
Tartaric Acid	-	0	-	-
Toluene	3	0	1	**
Triclorethylene	3	0	3	3
Turpentine	2	0	0	**
Water	0	0	0	0
Xylene	3	0	4	*

* Polypropylene - Satisfactory to 22° C (72° F)
** Polypropylene - Satisfactory to 49° C (120° F)

Part Number	Description
Reagent Syringes	
1426	Syringe, Reag, 500 uL
1424	Syringe, Reag, 1.0 mL
1423	Syringe, Reag, 2.5 mL
6742	Syringe, Reag, 5.0 mL
6741	Syringe, Reag, 10.0 mL
724597	Syringe, Reag, 25.0 mL
Reagent Seals	
1469	Seal, Reag, 500 uL
1473	Seal, Asp/Reag, 1.0 mL
1477	Seal, Reag, 2.5 mL
6740	Seal, 5.0 mL (w/O-ring)
6739	Seal, Reag, 10.0 mL (w/O-Ring)
Reagent Plungers w/Seals	
1466	Plunger, Reag, 500 uL
1470	Plunger, Reag, 1.0 mL
1474	Plunger, Reag, 2.5 mL
6623	Plunger, Reag, 5.0 mL (w/O-Ring)
6630	Plunger, Reag, 10.0 mL (w/O-Ring)
724599	Plunger, Reag, 25.0 mL
Reagent Barrels	
1467	Barrel, Reag, 500 uL
1471	Barrel, Reag, 1.0 mL
1475	Barrel, Reag, 2.5 mL
6620	Barrel, Reag, 5.0 mL
6627	Barrel, Reag, 10.0 mL
O-Rings	
720396	O-Ring, Reag, 500 uL
9321	O-Ring, Asp/Reag, 1.0 mL
8480	O-Ring, Reag, 2.5 mL
6633	O-Ring, Reag, 5.0 mL
6634	O-Ring, Reag, 10.0 mL

Part Number	Description
Aspirate Syringes	
5341	Syringe, Asp, 50 uL
5342	Syringe, Asp, 100 uL
5343	Syringe, Asp, 250 uL
5344	Syringe, Asp, 500 uL
5345	Syringe, Asp, 1.0 mL
Aspirate Seals	
1456	Seal, Asp, 50 uL
1385	Seal, Asp, 100 uL
1382	Seal, Asp, 250 uL
3374	Seal, Asp, 500 uL
1473	Seal, Asp/Reag, 1.0 mL
Aspirate Plungers w/Seals	
1453	Plunger, Asp, 50 uL
1387	Plunger, Asp, 100 uL
1380	Plunger, Asp, 250 uL
3371	Plunger, Asp, 500 uL
1470	Plunger, Asp, 1.0 mL
Aspirate Barrels	
721600	Barrel, Asp, 50 uL
721597	Barrel, Asp, 100 uL
721599	Barrel, Asp, 250 uL
721601	Barrel, Asp, 500 uL
721598	Barrel, Asp, 1.0 mL
Valves	
724751	Valve, 3-Port (1/4-28 fittings & luer)
724753	Valve, 4-Port (1/4-28 fittings & luer)
724754	Valve, 4-Port (M6 fittings & luer)
724755	Valve Plate
724165	Knob, Knurled Thumb
724166	Support Manifold

Part Number	Description
Tubing w/Fittings	
6865	Interconnect
5402	Tube, Asp, 1/32, coil, 1.0 mL
4333	Tube, Asp/Disp, 1/16, 30"
720595	Tube, Asp/Disp, 1/16, 60"
5723	Tube, Asp/Disp, 1/32, 29" necked
5133	Tube, Asp/Disp, 1/32, 29"
4410	Tube, Asp/Disp, 1/32, 40"
720597	Tube, Asp/Disp, 1/32, 60"
1067	Tube, Reag, 1/16, 16"
721370	Tube, Reag, 1/16, 27"
720592	Tube, Reag, 1/16, 60"
4609	Tube, Reag, 1/32, 12"
5729	Tube, Reag, 1/32, 20"
Printed Circuit Board	
724746	Printed Circuit Board
724013	EPROM, Standard Resolution XL 3000
724748	RS-232 Board
724094	EPROM, 4-Port Valve
724842	EPROM, High Resolution XL 3000
Fuses	
724756	Fuse, 1 amp
Manuals	
724043	Manual, Operator's, XL 3000

Part Number	Description
Pumper (Interface Software Program)	
723992	Pumper Software Package (Includes Pumper Instructions, 3-1/2" and 5-1/4" Diskette)
Power Supplies	
723914	Power Supply, 24V (120V) Evaluation, (2 Pumps)
723942	Power Supply, 24V (220V) Evaluation, (2 Pumps)
Miscellaneous	
1590	Fitting, Tube, 1/16(2/pkg)
1589	Fitting, Tube, 1/8(2/pkg)
5984	Lubrication Kit, Carriage
724757	Wrench, 5/16"& 9/64"
724758	Screw, Plunger
724696	Connector, Edge with Key

Appendix I DT Protocol for Microsoft Windows

The Data Terminal protocol can easily be used with the Microsoft Windows software program via the Windows terminal accessory. To communicate with the XL 3000 follow these steps.

1. Connect your XL 3000 to COM1 of your PC (refer to Figure 3).
2. From the Microsoft Program Manager window, select Terminal from the accessory group window.
3. Select the Settings menu, then click on communications.
4. Select a baud rate 9600, 8 data bits, 1 stop bit, no parity, COM1 connector, and no flow control.
5. Click OK.
6. Set the pump address switch SW1 to 0, and the pump options switch positions SW2 1-4 to off.
7. Power up the pump.
8. Type /1ZR<CR>. The pump should initialize.
9. To run the pump refer to the commands listed in Chapter 3, Communications Protocol.

Appendix J Guide to Writing a Communications Driver

This guide is meant to help you write your own communications driver for the XL 3000. Following is an example of a communications driver. Please thoroughly read Chapter 1, Introduction to XL 3000, and Chapter 3, Communication Protocol, before proceeding.

A. Summary of Basic XL 3000 Pump Communications

1. Character Format

Interface:	RS-232 or RS-485
Baud Rate:	9600 or 38400
Data Bits:	8
Parity:	No
Stop Bit:	1
Mode:	Half Duplex
Communication:	OEM or Data Terminal protocols

The XL 3000 communicates directly through an RS-485 interface or through an RS-232 interface which converts the signal to RS-485. The interface format is listed above.

Two baud rates are available: 9600 or 38,400. These are selectable using switch SW2-4 located on the main PC board (refer to Figure 2, XL 3000 Printed Circuit Board, found in the Operator's Manual).

The XL 3000 has two communications options: an OEM Protocol or a Data Terminal Protocol. These options are selectable using SW2-2 on the main PC board. The Data Terminal Protocol is provided as a quick means to run the pump via a dumb terminal. It has no sequence numbers or error checking. Therefore, we recommend using the OEM Protocol within a system and have written this guide for its use. Switch SW2-2 should be set to the ON position for the OEM protocol.

2. Pump Command Block Format (Master -->Pump)

The pump commands are contained in a data block consisting of seven parts:

0	Line Synch. Character (FFh)
1	STX (^B or 02h)
2	Pump Address
3	Sequence Number
4	Data Block (length n)
5+n	ETX (^C or 03h)
6+n	Checksum

a. The **Line Synchronization Character (FFh)** lets the bus know that a command is about to be sent.

b. The **ASCII STX (02h)** indicates the beginning of a command.

c. The destination **Pump Address (31h to 5Dh)** is a hexadecimal number specific for the pump for which the command was meant.

d. The **Sequence Number** is part of the acknowledgment system between the slave (pump) and the master (host). It is used for advanced error recovery (31h, ie ASCII character "1").

e. The **Data Block** contains the characters that make up the command. For example, "ZR" in the data block is an initialize command.

f. The **ETX (03h)** signals the end of transmission.

g. The final character is sent as a **Checksum.** This is done by exclusive or'ing (XOR) the characters in the command block from the STX to the ETX.

An example of the initialize command sent to Pump-1 in hexadecimal format is: FF0231315A520309h.

3. Answer Block Format (Pump --> Master)

The pump response is contained in a data block similar to the command block.

0	Line Synch. Character (FFh)
1	STX (^B or 02h)
2	Master Address (0 or 30h)
3	Status Code
4	Data Block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum
6+n	Line Turn Around Character (FFh)

a. The **Line Synchronization Character (FFh)** lets the bus know that a command is about to be sent.

b. The **STX** indicates the beginning of a command.

c. The **Master Address** is the address of the host system. It is always 30h (ASCII 0).

d. The **Status Code** contains pump error codes, if errors have occurred, and defines the pump status ready/busy bit. If the four least significant bits of the status byte are 0 then there is no error. Otherwise they contain the error code. See Appendix D, Error Code Definitions, for definitions of error codes.

e. The **Data Block** contains the characters that make up the command. If the answer block contains data, such as a response to a "?" command, then the data block holds the ASCII characters of the response. For example, if the pump is at location 567 and you ask for the pump position with the "?", then the data block would have the three characters 567.

f. The **ETX (03h)** lets you know that the data block is complete. If there is no data block, the ETX will follow the status code.

g. The **Checksum** from the pump is calculated in the same way as the command block. Everything from the STX to the ETX is exclusive or'ed together. Data integrity can be verified by XORing the characters for the answer block and comparing it to the checksum.

h. The **Line Turn Around Character** ensures that the entire response will be transmitted before the Real Time Executive (RTX) routine turns off the transmitter.

B. Communications Driver Example

The following is an example of a communications driver taken from a Cavro program written in Turbo Pascal. It accepts two parameters, the pump address and the command string. After it sends the synchronization character, the STX, and the pump address, it sends the command string one character at a time. When the string is sent, the ETX is output, followed by the checksum which has been calculated character by character. At the end of the routine it waits until all characters are received by the host before proceeding.

Communications Program Example

```
{**************************************************************}
{Send XLComm this is the communications routine for the XL3000 }
{**************************************************************}
procedure SendXLComm(pump:byte;strng:string);

var
   TheFile      :  Text;
   PortNo       :  byte;
   ModemReg     :  byte;
   LStat,MStat  :  byte;
   ErrorCode    :  word;
   OutQSize     :  word;
   Statp        :  word;
   Tries,Start  :  word;
   Current      :  word;
   count        :  integer;
   count_out    :  integer;
   code         :  integer;
   sum          :  integer;
   sequence     :  integer;
   Address      :  ingeger;
   SumCh        :  Char;
   Xpump        :  string;
   countstr     :  string;
   respond      :  string;
   messagechr   :  string;
   inmessage    :  string;
   ErrorChar    :  char;
   RespChar     :  Char;

const
   STX          =  02;
   ETX          =  03;
   SYNC         =  $FF;

begin
   if keypressed then
   begin
     Key_Was_Pressed  := true;
     _FlushKey;
   end;
   count_out  := 0;
     Com_Flush_Rx;
     Com_Flush_Tx;

         case Pump of
           1:  cpump  := #49;   {set the pump character}
           2:  cpump  := #50;
           3:  cpump  := #51;
           4:  cpump  := #52;
           5:  cpump  := #53;
           6:  cpump  := #54;
           7:  cpump  := #55;
           8:  cpump  := #56;
           9:  cpump  := #57;
```

```
            10:  cpump  := #58;
            11:  cpump  := #59;
            12:  cpump  := #60;
            13:  cpump  := #61;
            14:  cpump  := #62;
            15:  cpump  := #63;
            end;
if Protocol = 1 then    {Protocol 1 is OEM}
begin
   DisplayCommand (pump,strng);                      {displays command on screen}
   PortNo              := 1;                         {pumps should be on port 1}
   sequence            := $31;                       {default to sequence number 1}
   Sum                 := 0;                         {reset checksum}
   ModemReg            := Port[$3FC];                {Get the modem register}
   ModemReg            := ModemReg or ( RTS BIT);    {Set the RTS bit}
   INLINE($FA);                                      {Disable interupts}
   PORT[$3FC]          := ModemReg;                  {Set the modem register}
   INLINE($FB);                                      {Enable interupts}
   DELAY(10);                                        {wait for the line to change}
   Com_Tx(#$ff,$80);                                 {send sync Character}
   Inc(Count_Out);
   Sum                 := sum xor (STX);             {XOR to Checksum}
   Com_Tx(#02,$80);                                  {send STX Character}
   Inc(Count_Out);
   AscHex(cpump);                                    {convert to hex}
   Sum                 := sum xor (messagenum);      {XOR to checksum}
   Com_Tx(Cpump,$80);                                {send Pump address}
   Inc(Count_Out);
   Sum                 := sum xor (sequence);        {XOR to checksum}
   Com_Tx(chr(sequence),$80);                        {send sequence Character}
   Inc(Count_Out);
   for count := to length(strng) do                  {set up loop for length of string}
       begin
           aschex(strng[count]);                     {conver to hex}
           sum         := sum xor messagenum;        {XOR to checksum}
           Com_Tx(strng[count]$80);                  {send the character}
           Inc(Count_Out);
       end;                                          {till all sent}
       sum             :=  sum xor (ETX);            {XOR ETX}
       Com_Tx(chr(ETX),$80);                         {send End of Transmition}
       Inc(Count_Out);
       Com_Tx(chr(sum),$80);                         {send the checksum}
       Inc(Count_Out);
       repeat
           delay(10);                                {wait for all characters}
       until (Com_Tx_Empty);                         {to be sent }
   delay(10);
   ModemReg     := Port[$3FC];                   {Get the modem register}
   ModemReg     := ModemReg  AND NOT (_RTS_BIT);  {reset RTS bit}
   ONLINE($FA);                                  {Disable interupts}
   PORT[$3FC]   := ModemReg;                     {set the modem register}
   INLINE($FB);                                  {Enable interupts}
end;
```

The standard resolution XL 3000 Modular Digital Pump may be purchased with a 4-port valve using part numbers:

724086	XL 3000 with 4-port valve, RS-232
724136	XL 3000 with 4-port valve, RS-485

These units operate just like the standard XL 3000 except they have an additional valve command, <E>xtra position.

Initialization

The Z or Z0, Z1 and Z2 commands initialize the pump so that the input is on the left and output on the right.

The Y or Y0, Y1 and Y2 commands initialize the pump so that the input is on the right and the output is on the left.

Note: During initialization the valve turns through the open <B>ypass and <E>xtra positions. This allows some air into the system. For this reason the system must be thoroughly primed after any initializations.

Valve Commands

Using Z Initialization Commands

I turns to input position
O turns to output position
B turns to bypass position
E turns to extra position

Using Y Initialization Commands

I turns to input position
O turns to output position
B turns to bypass position
E turns to extra position

A 1 after a valve command will turn the valve in a clockwise direction (i.e. O1); a 2 will turn the valve in a counterclockwise direction (i.e. I2). A 0 or no number after the valve command will turn the valve in the default direction (clockwise) or the shortest distance to the valve position.

4-Port Valve Replacement

1. Power down the pump.

2. Remove the syringe and tubing.

3. Remove the valve and plate by unscrewing the 2 flat head screws. Save the screws. The spacer should remain screwed onto the front panel of the pump.

4. Install the new valve and valve plate by aligning the "D" coupler on the valve stem with the "D" hole in the encoder.

5. Use the 2 flathead screws to install the valve assembly

6. Power up the pump, reinitialize and prime the pump.

4-Port Valve Specifications

Tube Fittings	1/4-28 with luer fittings (P/N 724085) or M6 fitting with luer fitting (P/N 724139)
Housing	Chrome Plated Brass
Valve Seat	Kel-F
Valve Plug	Teflon
Turning Time	Approximately 250 msec between ports
Valve Positions	4 positions at 90 degrees: Input, Output, Bypass, Extra
Life Expectancy	>1 million moves

Figure 11: XL 3000 4-Port Valve Configuration