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Operating Manual

Cavro® XLP 6000 Modular Syringe Pump

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1 Getting Started

Congratulations on your purchase of the Cavro® XLP 6000 Modular Syringe Pump from Tecan Systems.

The XLP 6000 is a fully programmable, open frame, precision liquid handling pump module, designed for applications in the 5 µL to 25 mL range. It is controlled by an external computer or microprocessor and automates pipetting, diluting, and dispensing functions.

This chapter includes these topics:
- Regulatory Considerations
- XLP 6000 Features at-a-Glance
- Unpacking the XLP 6000
- Functional Description of the XLP 6000
- Safety
- Tips for Setting Up the XLP 6000

1.1 Regulatory Considerations

The XLP 6000 is a general laboratory module. Since it not a medical device, it is not subject to FDA regulatory approval. The XLP 6000 uses only recognized components and bears the UL Recognized Component Mark:

The use of UL Recognized components in a product or system allows UL to focus the evaluation of the complete system on its intended end-use, and thus speeds up the evaluation of that product or system. For more information regarding UL certification of Tecan Systems' syringe pumps, please visit the Underwriters Laboratories Inc. website at http://www.ul.com/info/standard.htm. Tecan Systems' customer file number for the recognized component is E164638.

1.1.1 RoHS

The XLP 6000 product line is now RoHS compliant. RoHS compliant modules are built with components that meet the requirements set by the European Union's Directive 2002/95/EC on the Restriction of Hazardous Substances ("RoHS" Directive).

For a complete listing of RoHS compliant modules, see Appendix A.

1.1.2 CE

As a module designed for incorporation into larger systems that require independent testing and certification, the XLP 6000 does not carry its own CE mark.

1.1.3 Radio Interference

The XLP 6000 can radiate radio frequency energy, which may cause interference to radio and television communications. Follow standard good engineering practices relating to radio frequency interference when integrating the XLP 6000 into electronic laboratory systems.

1.2 XLP 6000 Features at-a-Glance

The XLP 6000 is a syringe pump that is designed for OEM precision liquid handling applications. It has the following standard features and functions:

- Syringe sizes ranging from 50 μL to 50mL
- Accuracy $<$ 1.0% at full stroke
- Precision $\leq$ 0.05% at full stroke
- Standard dispense/aspirate resolution of 6,000 increments
- Microstep dispense/aspirate resolution of 48,000 increments
- 3-Port, 4-Port, Y-Block, T-Valve, 3-Port Distribution, 6-Port Distribution, and 9-Port Distribution valves
- RS-232, RS-485 and CAN interface
- Programmable plunger speeds from 1.2 sec/stroke to 160 min/stroke, with ramps and on-the-fly speed changes
- Teflon coated lead screw drive with a quadrature encoder for lost-step detection
- Pump diagnostics, self-test, and error reporting
- Auxiliary inputs and outputs
- Operates using a single 24V DC power supply

1.3 Unpacking the XLP 6000

To unpack the module, follow these steps:

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

1.3.1 ESD Considerations

The XLP 6000 is an electronic device that is sensitive to electrostatic discharge (ESD). Static discharge from clothing or other fixtures can damage these components. To prevent premature failure of pump components, use good ESD practices when handling the XLP 6000**.** These include, but are not limited to:

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

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

1.4 Functional Description of the XLP 6000

The XLP 6000 uses a stepper-motor driven syringe and valve design to aspirate and dispense measured quantities of liquid. Both the syringe and the valve are replaceable. Functional descriptions and illustrations of each major XLP 6000 component are provided in the following sections.

Figure 1-1   *XLP 6000 Modular Syringe Pump*
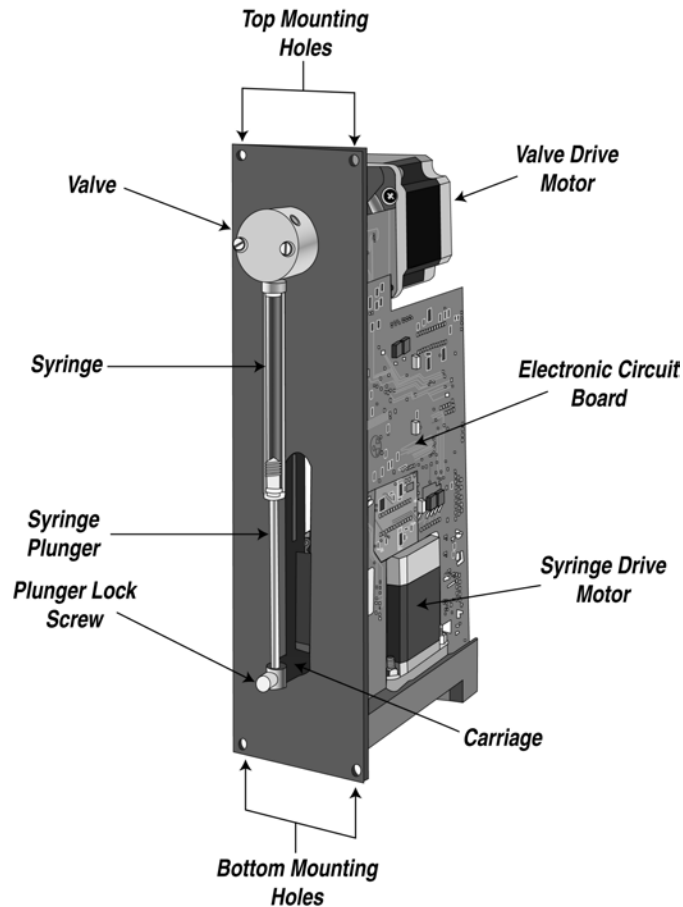
1.4.1   Syringe and Syringe Drive

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

The syringe drive has a 60 mm travel length and resolution of 6,000 increments (48,000 increments in fine-positioning and microstep mode). When power is not applied to the pump, the syringe drive can be removed by releasing the pin assembly.

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

Figure 1-2, 'Syringe Components" shows the components of a typical syringe.

Figure 1-2   *Syringe Components*
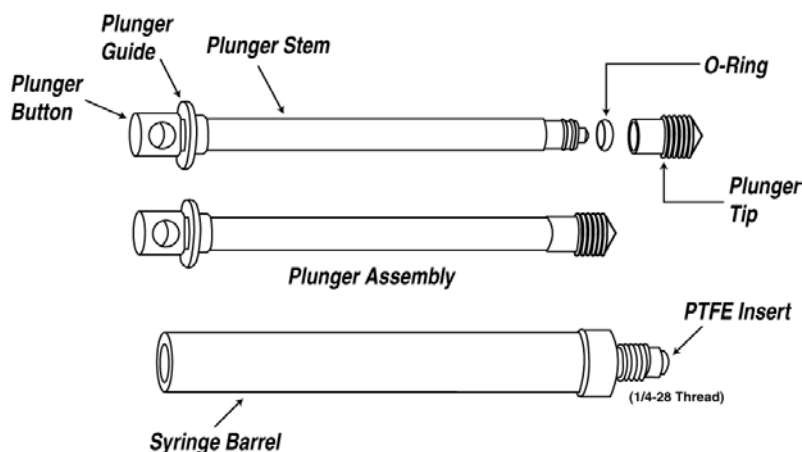
Syringes are available in these sizes: 50 μL, 100 μL, 250 μL, 500 μL, 1.0 mL, 2.5 mL, 5.0 mL, 10 mL, 25 mL and 50 mL.. For ordering information, see Appendix A, "Ordering Information".

Note: Use of a 50 mL syringe requires a modified XLP frame. For more information on the 50 mL option, see Appendix A, "Ordering Information".

Note: To obtain optimal performance and maximum life from any syringe, please follow the syringe cleaning and maintenance procedure included with each Cavro Syringe. Technical Note #1 (PN 730317) contains practical tips for the use and maintenance of Cavro Syringes.

1.4.2   Valve and Valve Drive

XLP 6000 valves are available in one of two configurations: *plug valves* and *face seal valves.*

Plug Valves

The plug valve is made of a PCTFE body and Teflon plug. The plug rotates inside the valve body to connect the syringe port to the various input and output ports. In addition to input and output ports, non-distribution valves also have a bypass position. This position "bypasses" the syringe and connects the input and output ports. The bypass position is often used for flushing fluid lines. 3-port, 4-port, T-valve and 3-port distribution configurations are available in a plug valve design.

Face Seal Valves

The face seal valve is made of a PPS stator and UHMWPE rotor. The rotor is pressed against the stator and rotated to select the various input and output ports.

6-port distribution and 7-port distribution valve configurations are available in a face seal valve design.

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

Figure 1-3   *3-Port Valve Components (Plug Design)*
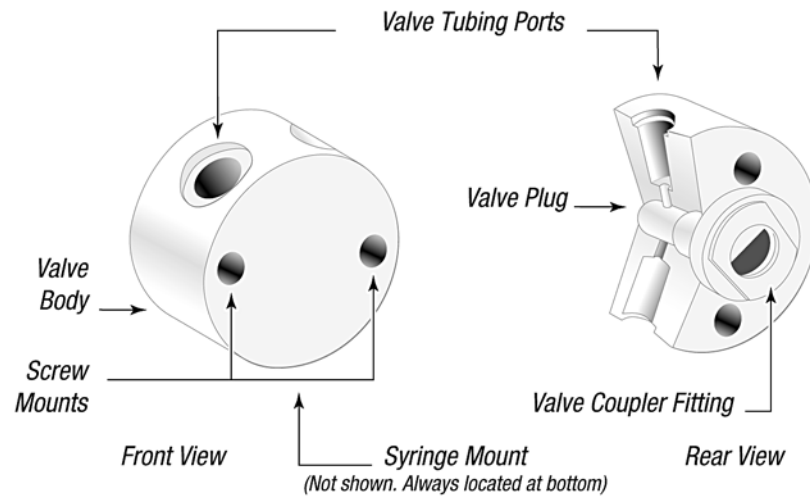
1.4.3   Printed Circuit Assembly

The printed circuit assembly (PCA) holds the microprocessor and circuitry to control the syringe and valve drive. The PCA provides connectors for electrical inputs and outputs as well as a communication address switch. For information on modes of operation, see Chapter 3, "Software Communication".

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

Figure 1-4   *XLP 6000 Printed Circuit Assembly External Connectors*
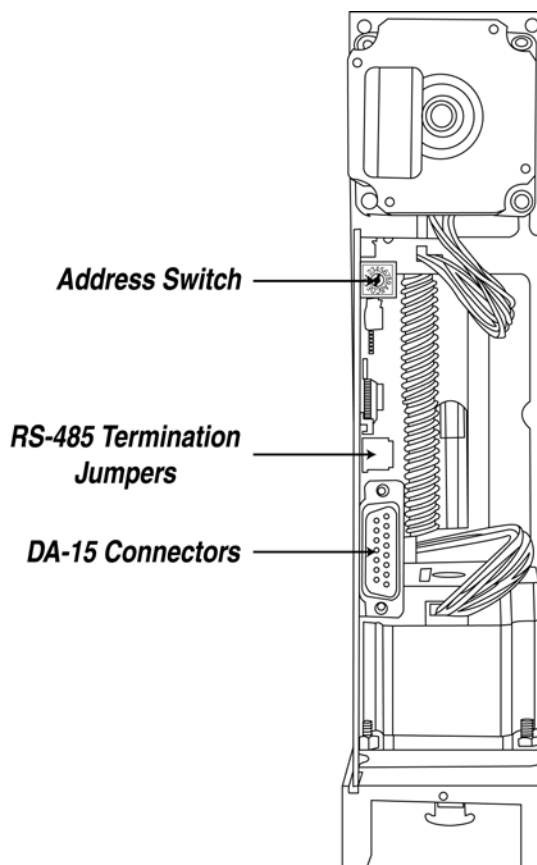
The XLP 6000 PCA has a DA-15 connector to handle power and communications. For more information on the printed circuit assembly inputs/outputs and the address switch, see Chapter 2, "Hardware Setup".

1.4.4   Communication Interfaces

Depending on the pump configuration, the XLP 6000 can communicate singly or in a multi-pump configuration through an RS-232, RS-485, or CAN (Controller Area Network) interface. For RS-232 and RS-485, baud rates of 9600 and 38400 are supported. For CAN, baud rates of 100K,125K, 250K, 500K, and 1M are supported.

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

1.4.5 Multi-Pump Configurations

Up to fifteen (15) XLP 6000 pumps can be connected together in a *multi-pump configuration* (also called "daisy-chaining"). In this configuration each pump is addressed separately from a single terminal via its unique address, which is set using the address switch on the back panel of the pump.

Within a multi-pump configuration, the RS-485 communications bus is required, although the first pump in the chain may receive either RS-232 or RS-485 communications. For CAN communications, neither RS-232 nor RS-485 is required. For more information on setting addresses, see Chapter 2.

1.5 Safety

The Cavro® XLP 6000 Modular Syringe Pump is designed for pipetting and dispensing operations in the 5 µL to 50 mL range. Any other use is considered improper and may result in damage to the pump and/or unreliable test results.

The XLP 6000 is designed to meet recognized technical regulations and is built with state-of-the-art components. Nevertheless, risks to users, property and the environment can arise when the module is used carelessly or improperly. Appropriate warnings in this Operating Manual serve to make the user aware of possible hazards.

1.5.1 Notices and Symbols

Warning Notices Used in this Manual

The triangle warning symbol indicates the possibility of personal injury if the instructions are not followed.

Specific symbols indicate the hazard to which a user is exposed. A few examples follow.

Toxic Substance

Chemical or biological hazards can be associated with the substances used or the samples processed with the XLP 6000. Always be aware of possible hazards associated with these substances.

Explosion and Fire Hazard

Never process explosive or highly flammable liquids with the XLP 6000.

Pinch Point, Mechanical Hazards

Automatically moving parts may cause injuries (crushing, piercing)

Attention

The general "Read This" symbol indicates the possibility of equipment damage, malfunction or incorrect process results, if instructions are not followed.

1.6 Tips for Setting Up the XLP 6000

For complete information on setting up the XLP 6000, see Chapter 2, "Hardware Setup" and "Chapter 3, "Software Communication".

Note: Risk to the user, property, and the environment can arise when he XLP 6000 is used incorrectly. Before performing any work with the pump, first read the manual.

To ensure proper operation, follow these tips:

◆ Always set up and mount the pump in an upright position. Failure to do so can cause problems priming the system.
◆ Always run liquid through the syringe and valve when they are moving. Failure to do so can damage the sealing surfaces.
◆ Before running any organic solvents through the pump, see Appendix D, "Chemical Resistance Chart" for more information on chemical compatibility.
◆ Always power down the instrument when connecting or disconnecting pumps.

Caution! *Keep fingers out of the syringe slot while the pump is running. Failure to do so can cause injury.*

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2 Hardware Setup

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

- Power and Electrical Considerations
- Cabling
- Communication Interfaces
- Settings and Options
- Installing Components
- Mounting

2.1 Power and Electrical Considerations

The XLP 6000 requires a 24V DC power supply with a current rating of at least 1.5A, provided through a DA-15 connector. Tecan Systems recommends using one power cable for every two pumps to provide noise immunity, i.e., power should not be daisy-chained to more than two pumps.

2.1.1 Choosing a Power Supply

The 24V DC supply for a single XLP 6000 should meet the following basic requirements:

- Output voltage: 24V nominal $\pm$ 2%
- Well-regulated power supplies are recommended, as operating pumps below 24V will affect performance.
- Current rating of at least 2.0A
- Output voltage ripple: 100mV rms maximum at full load
- Conformance to required safety and EMI/RFI specifications

Current should be limited to 35A or less.

2.1.2 Integrating a Power Supply

When a power supply is used to operate more than one XLP 6000 or other device, it must provide the total peak current for all devices. The power supply and filter capacitance together must satisfy the total peak input current for all devices.

If the pumps are not operating simultaneously then a reduced power supply rating may apply. The minimum power supply rating must be confirmed by measurement.

External equipment with inadequate bypass capacitance or that is inadequately sourced for current can cause overvoltage transients and sags, and can create

unnecessary ripple current in the XLP 6000. This can result in decreased component life. Additionally, it is possible for a regulated power supply to become unstable with certain loads and oscillate if adequate filter capacitance is not present. Some forms of oscillation can cause failures in the XLP 6000. These issues can be avoided by using a properly designed commercial power supply.

Consideration should also be given to the wiring of the XLP 6000 and any additional devices. Wiring should be of sufficient gauge for the current, and as short as possible. Unless otherwise required by safety requirements, the power supply lines to the XLP 6000 should be 20AWG or heavier. Multiple XLP 6000s can be daisy-chained, provided that the wire size and the power supply are adequate for the total current. In the example of the six XLP 6000 pumps above, use 18AWG wire if the units are daisy-chained. It is best if each pair is twisted or dressed together from the device to the supply. For more information on multi-pump cabling, see Section 2.2, Cabling.

To control power to the XLP 6000, switch power to the power supply. Do not use a relay or switch contacts between the 24V supply and the XLP 6000 (i.e., do not switch DC input to the pump).

2.1.3 Switching Power Supplies

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

Note: The XLP 6000 idle current is less than 10% of the full running current.

For example, in a system with multiple XLP 6000 pumps, a 24V 5-amp switcher with a minimum load less that 500mA may not provide sufficient current when the XLP 6000 motors are idle and all other devices are in a low current state. If the XLP 6000 is the only load on the 24V supply, a switcher should have a minimum load specification of 50mA or less. An appropriate external power resistor can be used to ensure that the minimum load is met.

2.2 Cabling

A single cable supplies both power and communications to each XLP 6000. A unique address identifies each pump module. For more information, see "Address Switch Settings" later in this chapter. See also Chapter 3, "Software Communication"."

Power requirements are described in Section 2.1, Power and Electrical Considerations.

Table 2-1   *DA-15 Connector Pin Assignments*

Pin	Function	Remarks
1	24V DC	
2	RS-232 TxD line	Output data
3	RS-232 RxD line	Input data
4	Reserved	
5	CAN high signal line	
6	CAN low signal line	
7	Auxiliary input #1	TTL level
8	Auxiliary input #2	TTL level
9	Ground	Power and logic
10	Ground	Power and logic
11	RS-485 A line	Data +
12	RS-485 B line	Data -
13	Auxiliary output #1	TTL level
14	Auxiliary output #2	TTL level
15	Auxiliary output #3	TTL level

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

Figure 2-1   *DA-15 Connector Pins*
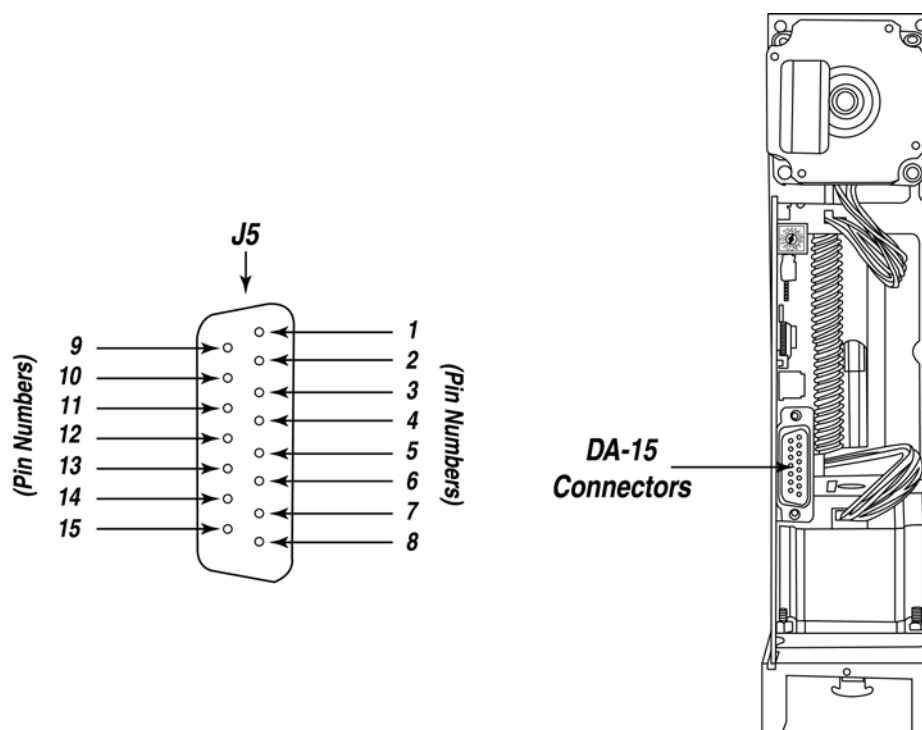
2.3   Communication Interfaces

The computer or controller communicates with the XLP 6000 through an RS-232 interface, RS-485 interface, or CAN (Controller Area Network) interface.The XLP 6000 automatically detects the communication interface.

Examples of cabling connections are shown in Figure 2-2, Figure 2-3, and Figure 2-4 on the following pages.

2.3.1   RS-232/RS-485 Interface

The RS-232 interface automatically converts the protocol to RS-485 for the benefit of any other devices which may be connected to the XLP 6000's RS-485 communication bus (this constitutes the so-called "multi-drop" device configuration).

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

When using a multi-drop arrangement, up to 15 pumps can be addressed by the controller on the same communications bus. Take special care to ensure that the RS-485 A and B lines are not reversed. Refer to the cabling illustrations on the following pages. These illustrations show the multi-pump cabling for RS-232, RS-485, and CAN connections, respectively. Also shown is the external termination scheme for the RS-485 chain.

2.3.2 CAN Interface

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

Caution! *Always power off pumps before connecting to or disconnecting from the bus.*

RS-232 Cabling

Figure 2-2   *RS-232 Multi-Pump Cabling*
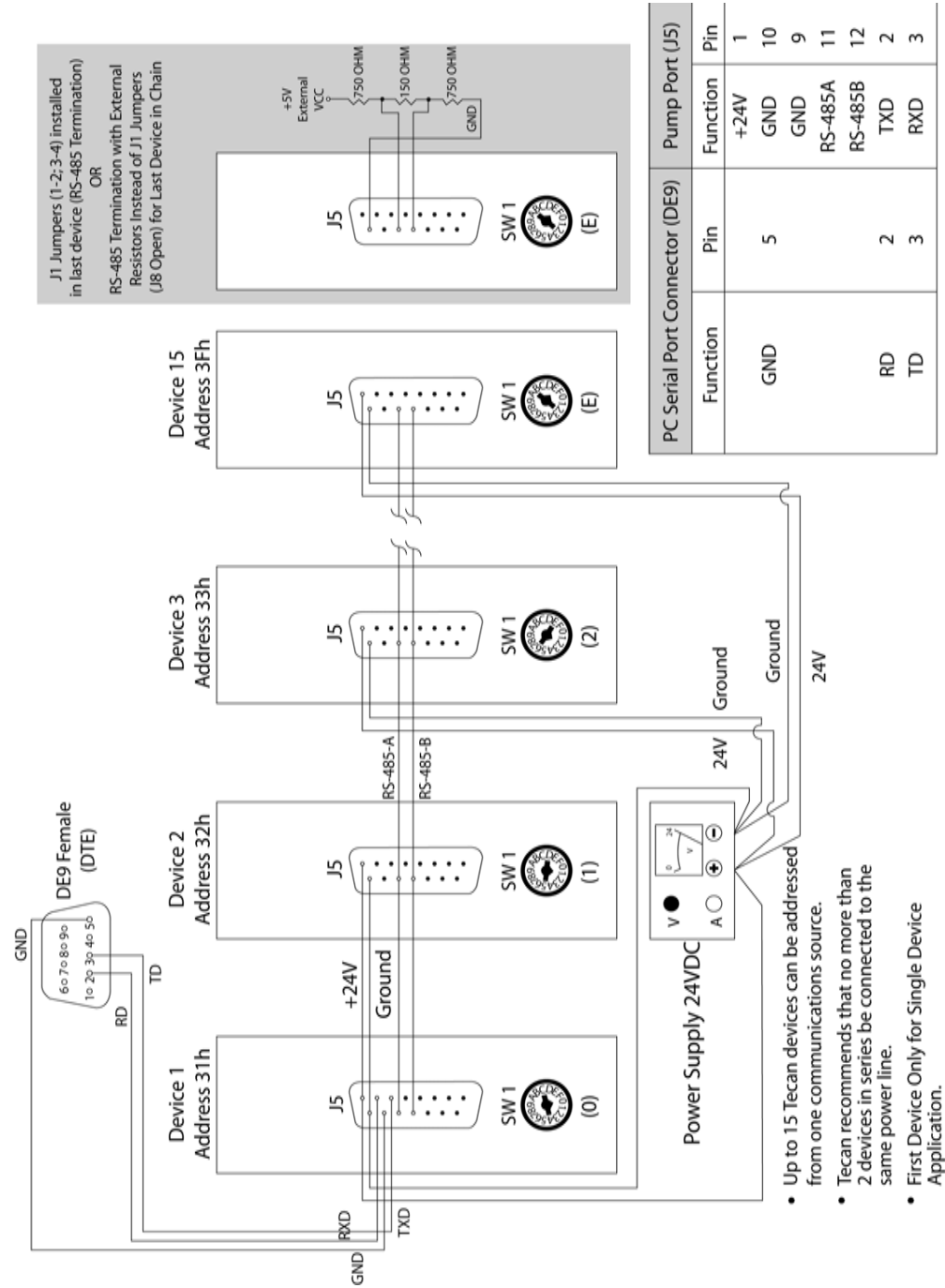
RS-485 Cabling

Figure 2-3 *RS-485 Multi-Pump Cabling*

CAN Cabling

Figure 2-4   *CAN Multi-Pump Cabling*
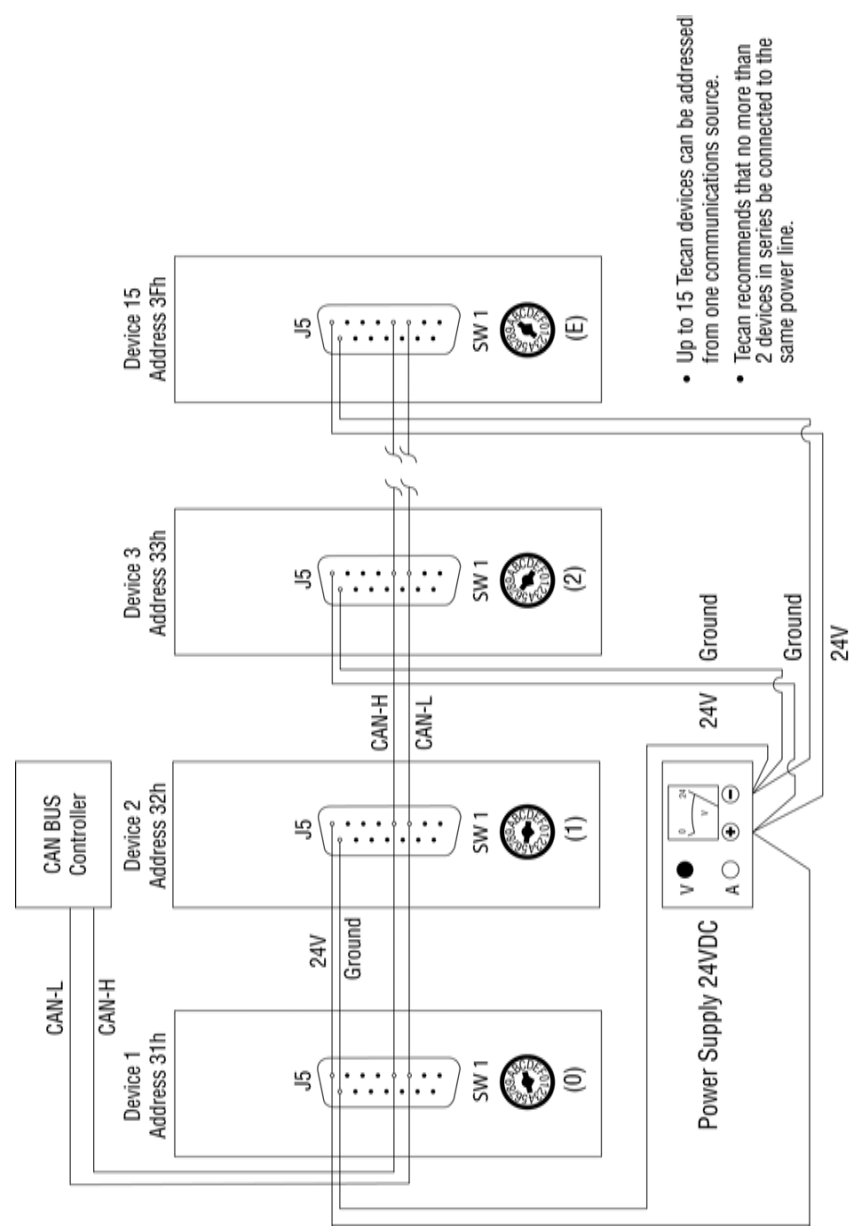
2.4 Settings and Options

2.4.1 Configuration Commands

The XLP 6000 firmware allows the user to configure the pump for different modes of operation. The U commands (see Chapter 3, "Software Communication") are used to write the configuration information to the non-volatile memory and control the following options:

- **Valve type:** The pump can be configured to operate with different valve options (3-port, 4-port, T-valve, Y Block, 3-port distribution, 6-port distribution, and 9-port distribution).
- **Baud rate:** RS-232/RS-485 communication is possible at 9600 baud (default) and 38400 baud. CAN communication is possible at 100K baud (default), 125K baud, 250K baud, 500K baud, and 1M baud rates.
- **Non-Volatile Memory Auto Mode:** Allows the pump to run command strings out of the non-volatile memory.

2.4.2 Address Switch Settings

The address switch (see Figure 2-5, "Address Switch") is located near the top of the XLP 6000 electronic circuit board. It is used to give each XLP 6000 in a multi-pump configuration a unique or specific address, allowing the user to direct commands to specific pumps. The address switch has sixteen positions (numbered 0 through F). Fifteen positions (addresses 0 through E) are valid pump addresses.

Figure 2-5   *Address Switch*
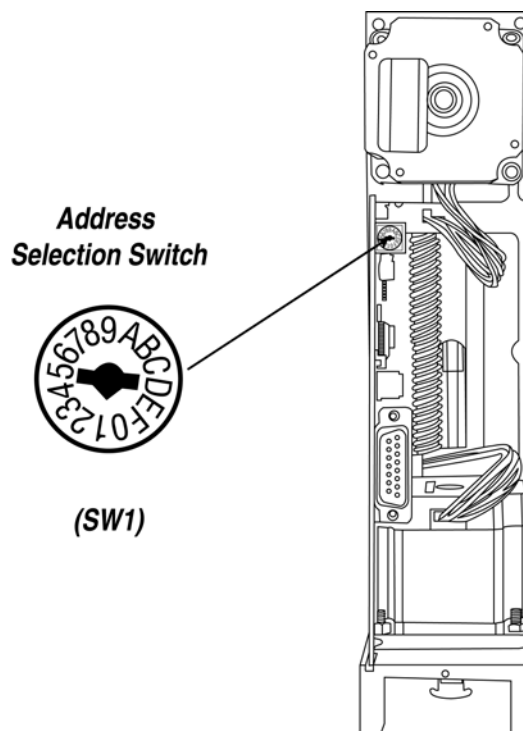
To set the address switch:

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

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

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

2.4.3   Self-Test

The "F" address switch position is used to activate the XLP 6000 self-test. Self-test causes the XLP 6000 to initialize, then cycle repeatedly through a series of plunger movements. The self-test cycles through speed codes 0 to 14. If an error condition occurs, the pump stops moving.

To run the self-test, set the address switch to position "F." Then supply power to the pump.

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

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2.4.4 J5 Inputs/Outputs

The XLP 6000 provides two auxiliary inputs and three auxiliary outputs that can be accessed through the DA-15 connector, J5. They provide TTL level signals. The outputs are controlled by the [J] command.

The auxiliary inputs are located on J5, pins 7 and 8. They can be read back using report commands ?13 and ?14. Additionally, the inputs can be used to externally trigger a command sequence using the [H] command. The commands are described in Chapter 3, "Software Communication".

The auxiliary outputs are located on J5, pins 13, 14, and 15.

2.5 Installing Components

2.5.1 Installing the XLP 6000 Valve

To install the XLP 6000 valve, follow these steps:

1 Remove as much fluid as possible from the system by cycling the pump and using air as the system fluid.

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

3 Issue an [A6000R] command to move the plunger to the bottom of travel.

4 Remove the syringe and tubing.

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

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

7 Replace the valve screws but do not tighten completely.

8 Install the syringe and pull the syringe plunger until it is aligned with the carriage. Align the valve using the plunger as a guide, and tighten from 1/4 to 1/2 turn after the screws contact the valve body.

9 Pull the syringe plunger all the way into the carriage and secure by tightening the plunger lock screw.

Caution! *Be sure to reconfigure the pump firmware when changing valve types. Failure to do so may damage the valve. See Section 3.3.2, Pump Configuration Commands, for instructions on reconfiguring the pump.*

![TECAN logo]

Caution! *Chemical or biological hazards may be associated with the substances used or the samples processed with the XLP 6000. **Always be aware of possible hazards when fluids are exposed (i.e., when replacing valves and syringes).** Use suitable guards and/or personal protection when handling chemicals and biological substances.*

Figure 2-6 *XLP 6000 Valve Installation (3-Port Valve Shown)*
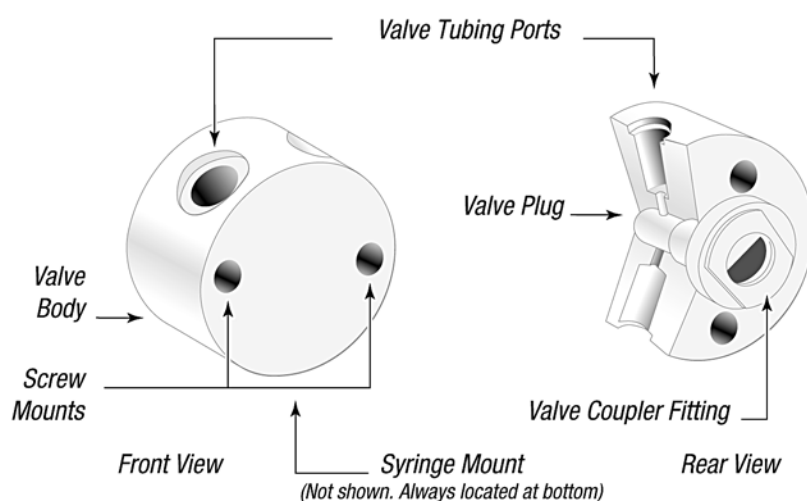
2.5.2 Installing a Syringe

To install a syringe, follow these steps:

1 Remove the plunger lock screw.

2 Install the syringe as shown in Figure 2-7, following these steps:

a. Screw the syringe into the valve.

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

c. Align the plunger button through hole to the carriage mounting hole.

d. Slide the plunger lock screw through the plunger button and fasten to the carriage.

Note: Make sure the plunger lock screw is securely tightened and the plunger button is free to move on the plunger lock screw.

Figure 2-7   *Syringe Installation*
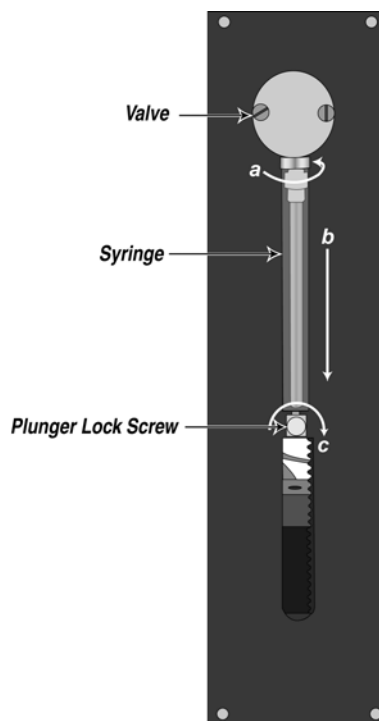
2.6   Mounting

The XLP 6000 contains four mounting holes on the front plate of the frame.

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

To facilitate mounting, see Figure 2-8, "XLP 6000 Outline Drawing" for critical dimensions and location of the mounting holes.

Figure 2-8   *XLP 6000 Outline Drawing*
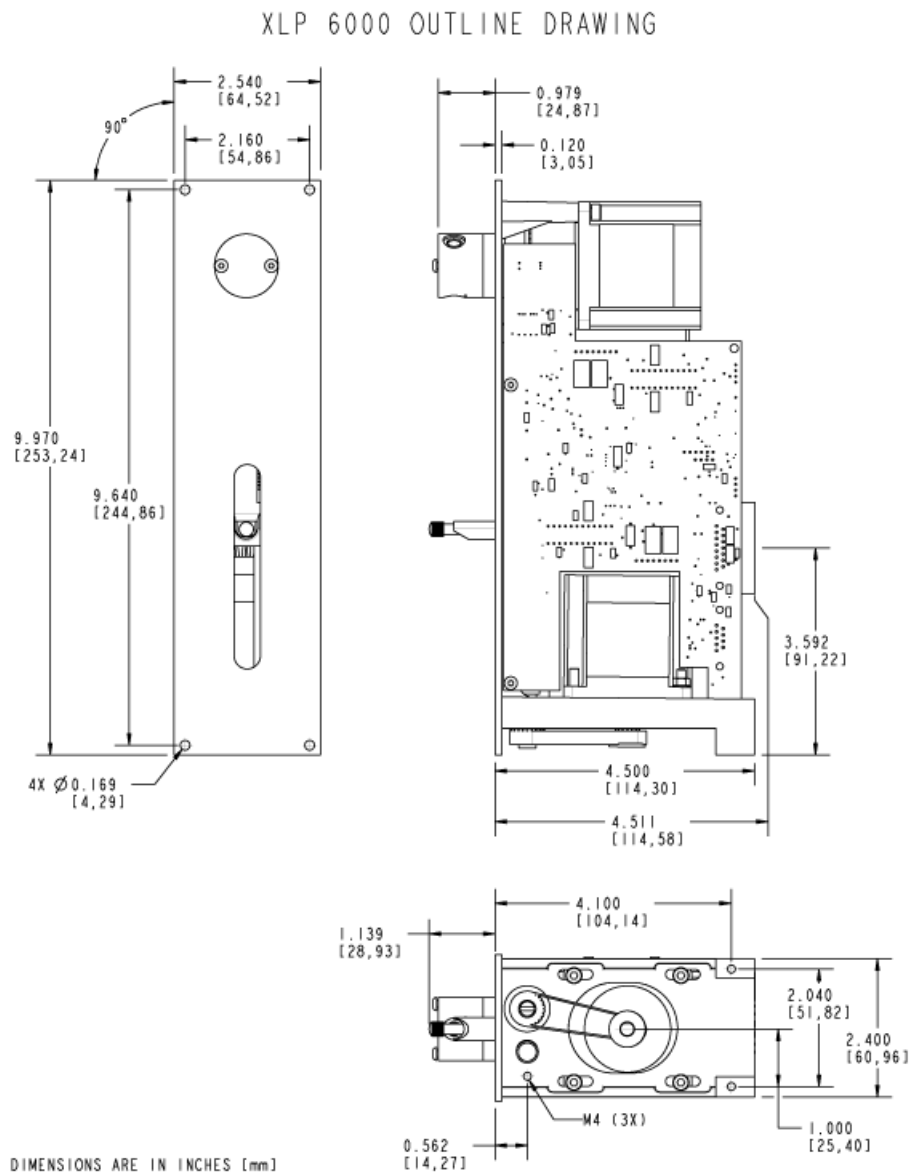
3 Software Communication

This chapter describes how to communicate with the XLP 6000: through an RS-232, RS-485, or CAN (Controller Area Network) interface.

This chapter includes these topics:
- XLP 6000 Addressing Scheme
- Communication Protocols
- Using the XLP 6000 Command Set
- Initialization
- Operating Commands
- Error Codes and Pump Status

3.1 XLP 6000 Addressing Scheme

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

Table 3-1 *Hexadecimal Addressing Scheme*

Address (hex)		
RS-232/RS-485	**CAN**	**Device**
30	0	Master Address (master controller, personal computer, etc.)
31..3F	1..F	Addresses single device
41..4F	N/A	Addresses two devices at a time (dual device)
51..5D	N/A	Addresses four devices at a time (quad device)
5F	N/A	Addresses all devices on the bus

For example, an XLP 6000 with address switch set to 0 is addressed as device "31h" in the RS-232 or RS-485 communication protocol, hardware address 1 is addressed as device "32h," and so on.

Table 3-2, Address Switch Settings in Hex (ASCII), shows the different address switch settings for each of these configurations.

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

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

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

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

Note: *Multiple address commands cannot be used to determine device status or to request reports. Each device must be queried separately to gather status or generate a report.*

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3.2 Communication Protocols

Three communication protocols are available:
- OEM communications protocol
- Data Terminal (DT) protocol
- CAN protocol

The XLP 6000 firmware automatically detects the communication protocol.

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

Note: Tecan Systems recommends using the OEM protocol for RS-232 and RS-485 interfaces. It provides increased error checking through the use of checksums and sequence numbers.

Once the XLP 6000 detects either the OEM or DT protocol, it will ignore the other protocol until the next power cycle.

3.2.1 OEM Communication Protocol

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

Table 3-3   OEM Protocol

Parameter	Setting
Character Format	
Baud rate	9600 or 38400
Data bits	8
Parity	None
Stop bit	1
Command Block **(see "OEM Protocol Command Block Characters" for details)**	
1	STX (^B or 02h)
2	Pump address
3	Sequence number
3+n	Data block (length n)

4+n	ETX (^C or 03h)
5+n	Checksum
Answer Block **(see "OEM Protocol Answer Block Characters" for details)**	
1	STX (^B or 02h)
2	Master address (0 or 30h)
3	Status code
3+n	Data block (length n)
4+n	ETX (^C or 03h)
5+n	Checksum

OEM Protocol Command Block Characters

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

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

STX (^B or 02h)

The STX character indicates the beginning of a command

Pump Address

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

Sequence Number/Repeat Flag

The sequence number is a single byte that conveys both a sequence number (legal values: 0 to 7) and a bit-flag indicating that the command block is being repeated due to a communications breakdown. The sequence number is used as an identity stamp for each command block. Since it is only necessary that every message carry a different sequence number from the previous message (except when repeated), the sequence number may be toggled between two different values (e.g., "1" and "2") as each command block is constructed. During normal communication exchanges, the sequence number is ignored. If, however, the repeat flag is set, the pump compares the sequence number with that of the previously received command block to determine if the command should be executed or merely acknowledged without executing.

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

The following two scenarios clarify this error detection mechanism.

Scenario 1.

1 The computer sends a command block stamped with sequence #1 to the pump.

2 The pump receives the command, sends an acknowledgement to the PC, and executes it.

3 Transmission of the acknowledgement message is imperfect; the PC does not receive it.

4 The PC waits 100 ms for the acknowledgement, then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.

5 The pump receives the transmission, identified as such by the repeat bit.

6 The pump checks the sequence number against that of the previously received command block. Noting a match, the pump sends an acknowledgement to the PC, but it does not execute the command (since it has already been executed).

7 The PC receives the acknowledgement and continues with normal communications.

8 The next command block is stamped with sequence #2 to indicate a new command.

Scenario 2.

1 The computer sends a command block stamped with sequence #1 to the pump.

2 The pump never receives the command due to a communication error and thus does not send an acknowledgement to the PC.

3 The PC waits 100 ms for the acknowledgement, then retransmits the command block with the sequence number left at 1 and the repeat bit set to indicate a retransmission.

4 The pump receives the retransmission, identified as such by the repeat bit.

5 The pump checks the sequence number against that of the previously received command block. Noting a mismatch, the pump recognizes this as a new command block and sends an acknowledgement to the PC. It then executes the command.

6 The PC receives the acknowledgement and continues with normal communications.

7 The next command block is stamped with sequence #2 to indicate a new command.

The sequence number/repeat byte is constructed as follows:

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

REP

0 for non-repeated / 1 for repeated

SQ0 – SQ2

Sequence value, as follows:

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

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

Data Block (length n)

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

ETX

The ETX character indicates the end of a command string.

Checksum

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

OEM Protocol Answer Block Characters

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

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

Master Address

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

Status and Error Codes

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

3.2.2 Data Terminal (DT) Protocol

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

Table 3-4   *DT Protocol*

Character Format	
Parameter	**Setting**
Baud rate	9600 or 38400
Data bits	8
Parity	None
Stop bit	1
Command Block (see "DT Protocol Command Block Characters" for details)	
1	Start command (ASCII "/" or 2Fh)
2	Pump address
2+n	Data block (length n)
3+n	Carriage Return ([CR] or 0Dh)
Answer Block (see "DT Protocol Answer Block Characters" for details)	
1	Start answer (ASCII "/" or 2Fh)
2	Master address (ASCII "0" or 30h)
3	Status character

3+n	Data block (if applicable)
4+n	ETX (03h)
5+n	Carriage return (0Dh)
6+n	Line feed (0Ah)

DT Protocol Command Block Characters

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

Start Block

The start character indicates the beginning of a message block.

Pump Address

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

Data Block (length n)

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

End Block

The end character indicates the end of a message block.

DT Protocol Answer Block Characters

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

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

Master Address

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

Status Character

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

Data Block

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

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

This character terminates the reply block.

3.2.3 Using DT Protocol with Microsoft Windows

The XLP 6000 can be controlled in DT protocol mode directly from the Microsoft Windows terminal accessory.

To communicate with the XLP 6000 using Windows 3.x, follow these steps:

1 Connect the XLP 6000 to a communications port of the PC (for example, COM1).

2 From the Microsoft Program Manager window, select **Terminal** from the Accessories group window.

3 Select the **Settings** menu, and choose **Communications**.

4 Select a baud rate of 9600, 8 data bits, 1 stop bit, no parity, communications port connector, and no flow control.

5 Click **OK**.

6 Set the pump address switch to 0.

7 Power on the pump.

8 Type /1ZR<CR> to initialize the pump.

9 To run the pump, see the commands listed in "Using the XLP 6000 Command Set" in this chapter.

To communicate with the XLP 6000 using Windows 95/98/NT/2000/XP, follow these steps:

1 To connect the XLP 6000 to a communications port on the PC, first select the **Start Programs/Accessories/Communications Hyperterminal** menu and choose **Run**.

2 In the Run dialog box, type **Hyperterm.exe**. The Connection Description dialog box appears.

3 Enter a name for the connection and select an icon, then click **OK**. The Phone Number dialog box appears.

4 Select the following in the fields provided:

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

Click **OK**. The COM Properties dialog box appears.

5 Select the following in the fields provided:

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

---

6 Click **OK**.

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

8 Select the **Settings** tab, and enter or select these options:
  – Function, arrow, and Control keys act as:
    • Select "Terminal keys"
  – Emulation:
    • Select "Autodetect"
    • Enter "500" in Backscroll buffer lines
  – Click the **ASCII Setup** button. The ASCII Setup dialog box appears.

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

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

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

12 The communication protocol is detected automatically.

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

   To run the pump, see the commands listed in "Using the XLP 6000 Command Set" in this chapter.

3.2.4 CAN Interface Communications

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

Note: All Tecan XLP 6000 systems use CAN controller chips compatible with Phillips Semiconductor CAN bus specification, version 2.0.

When using the CAN interface, termination resistors (120 ohm) are necessary at both ends of the bus. The pump does not provide CAN termination resistors.

CAN Messages

CAN messages consist of *frames*. Each frame has an 11-bit Message Identifier (MID) and a 4-bit length identifier. The bits:
 • Indicate to which device on the bus the message is directed
 • Identify the message type
 • Show the direction of the message (to or from the master device)

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

CAN Message Construction

Each message frame begins with the Message ID (MID). The data block (up to 8 bytes in length) follows the MID and length information. The MID makes up three nibbles that are transmitted first in a message frame. The bits are grouped as shown in Figure 3-1, 'CAN Message Structure".

Figure 3-1   *CAN Message Structure*
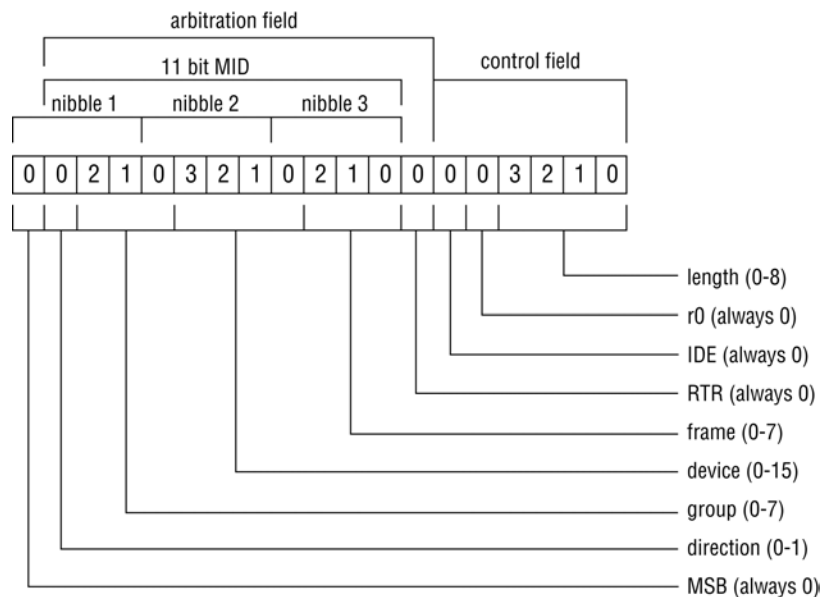
Direction

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

Note: Peer-to-peer messaging is not supported.

Group

This is the group number (0 - 7). Each type device on the CAN bus has a group assignment. The XLP 6000 is assigned to group 2. The group number "1" is reserved for the boot request procedure.

Device

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

Frame

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

RTR

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

IDE

This will always be set to 0 for standard format frames.

r0

Reserved bit, set to 0.

Length

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

CAN Frame Types

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

"On-the-Fly" Commands (V and T), Type 0

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

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

Action Frames, Type 1

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

Common Commands, Type 2

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

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

Multi-Frame Start Message, Type 3

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

Multi-Frame Data, Type 4

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

Note: There is no type 5 frame.

Report/Answer Commands, Type 6

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

Command	Description
0	Report calculated plunger position in increments (standard/fine positioning)
1	Report start speed in increments per second
2	Report top speed in increments per second
3	Report cutoff speed in increments per second

6	Report current valve position
10	Report buffer status
13	Report status of input #1
14	Report status of input #2
15	Report the number of pump initializations
16	Report the number of plunger movements
17	Report the number of valve movements
18	Report the number of valve movements since last report
20	Report checksum
23	Report firmware version
24	Report zero gap increments
29	Report current status

When the pump responds to a query, the first two bytes of the data block are the status bytes. The first byte contains an error code (same error codes used with the RS-232 and RS-485 protocols) added to Ox20h. The second byte contains the value Ox60h and is not used. The remaining six bytes are for the response in ASCII. If the pump is only reporting current status, the message is only two bytes long. If the reply consists of more than six bytes, multi-frame messages are used.

CAN Data Block

The data block tells the pump what to do. Pump commands are sent in ASCII just like in RS-232 or RS-485. For command strings that are more than eight bytes in length, multi-frame messages are used. This permits long program strings to be sent as with the other communications interfaces (remember that the XLP 6000 buffer size is 255 characters).

Handling of Pump Boot Requests

When the pump is first powered up or receives a system reset command (frame type 2, command 0), the pump notifies the host of this condition by sending a boot request message at 100 millisecond intervals until it receives a proper response. The group number is 1 for the boot request message. The frame type is 2 when the pump sends messages to the host, and the frame type must be 0 when the host replies to the boot request.

Example 1. The pump is set to address 0

Pump sends:

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

Host acknowledges:

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

Host acknowledges the boot request with:

			Note:
Dir = 0	Host to slave		Boot MID is the same for all nodes
Group = 1	Boot request response group		
Device = 0	Always 0 in boot response		
Frame = 0	Boot request response frame		
RTR = 0	Always 0		
Length = 2	Two data bytes in return message		

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

Example 2. The pump is set to address 6

Pump sends:

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

Host acknowledges:

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

Host acknowledges the boot request with:

Dir = 0	Host to slave	**Note**:
Group = 1	Boot request response group	Boot MID is the same for all nodes
Device = 0	Always 0 in boot response	
Frame = 0	Boot request response frame	
RTR = 0	Always 0	
Length = 2	Two data bytes in return message	

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

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

Note: The slave ID does not have to be the same as the node ID. The pump can be assigned any number between 0 and 0x7F (127) for the slave ID.

CAN Host and Pump Exchanges

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

<MID><DLC><Answer>

<MID>

11-bit message identifier. The direction bit is 1. The group number and the frame type are the same as received. Device ID is the slave message ID assigned by the host.

<DLC>

4-bit data length code

<Answer>

Data bytes block. The first byte of the data block is always the status byte, which is an error code (same error codes used with the RS232 and RS485 protocols) added to Ox20h. The second byte is always Ox60h. The remaining bytes contain the response in ASCII format. If the reply consists of more than six bytes, the multi-frame messages are used.

Note: Only one command of a given frame type can be in progress at any one time; e.g., after issuing a command to a slave pump with frame type = 1, the master must wait for the answer with frame type = 1 before issuing the next command with frame type = 1. If the user insists on sending the command, a command overload status results.

Several commands with different frame types can be in progress at the same time; e.g., an action command and a query command.

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

Action Command

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

Host sends:

0	XXXXXXX	001	0	0010	ZR
Dir	Slave ID	Frame Type	RTR	DLC	Data bytes

Pump acknowledges:

1	XXXXXXX	001	0	0000	
Dir	Slave ID	Frame Type	RTR	DLC	

After executing the command, pump reports status:

1	XXXXXXX	001	0	0010	<20h><60h>
Dir	Slave ID	Frame Type	RTR	DLC	Data bytes

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

Multi-Frame Command

The host commands [Z2S5gIA3000OgHD300G10G5R] to a pump, and the pump is set to address 0.

Host sends:

0	XXXXXXX	011	0	1000	Z2S5gA3
Dir	Slave ID	Frame type	RTR	DLC	Data bytes
0	XXXXXXX	100	0	1000	000OgHD30
Dir	Slave ID	Frame type	RTR	DLC	Data bytes
0	XXXXXXX	001	0	1000	00G10G5R
Dir	Slave ID	Frame type	RTR	DLC	Data bytes

Pump acknowledges:

1	XXXXXXX	001	0	0000	
Dir	Slave ID	Frame type	RTR	DLC	

After executing the command, pump reports status:

1	XXXXXXX	001	0	0010	<20h><60h>
Dir	Slave ID	Frame type	RTR	DLC	Data bytes

Note: For multi-frame commands, the pump only acknowledges the last frame.

Common Command

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

Host sends:

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

Pump does not acknowledge common commands.
Pump does not report status after common commands.

Query Command

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

Host sends:

0	XXXXXXX	110	0	0010	29
Dir	Slave ID	Frame Type	RTR	DLC	Data bytes

Pump reports:

1	XXXXXXX	110	0	0010	<20h><60h>
Dir	Slave ID	Frame Type	RTR	DLC	

Note: For query commands, no acknowledge frame is needed.

Report Command

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

Host sends:

0	XXXXXXX	110	0	0010	23
Dir	Slave ID	Frame Type	RTR	DLC	Data bytes

Pump reports:

1	XXXXXXX	011	0	1000	<20h><60h><XLP60>
Dir	Slave ID	Frame Type	RTR	DLC	
1	XXXXXXX	100	0	0111	00 - Vx.x. x<20h>x/200x (frame type 4) <20h>734604<20h> (frame type 4) Rev <20h>X (frame type 6)
Dir	Slave ID	Frame Type	RTR	DLC	Data bytes

Note: For a multi-frame reply, the start frame is type 3, the middle frame is type 4, and the last frame is type 6.

3.3 Using the XLP 6000 Command Set

The XLP 6000 features a robust command set which allows a wide range of parameters to be defined by the user. Many of the commands have default values; however, the default values may not provide the optimal settings for your application. Take a moment to familiarize yourself with each command in order to obtain the best performance for your application.

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

When problems are detected, the XLP 6000 sends an error code. The error codes are described in "Error Codes" at the end of this chapter.

Note: *Some commands are invalid in the CAN interface. For a list of these commands, see Appendix F, "CAN Communication Commands".*

3.3.1 Command Execution Guidelines

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

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

  For example:
    - A single command such as [A6000R] moves the plunger to position 6000.
    - A *multi-command string* such as [IA6000OA0R] moves the valve to the input position, moves the plunger to position 6000, turns the valve to the output position, and finally returns the plunger to position 0.
- The pump's command buffer holds a maximum of 255 characters. If a command is sent without the [R] (Execution) command, it is placed into the buffer without being executed. If a second command is sent before the first command is executed, the second command overwrites the first command (i.e., the first command string is erased).
- Once a command is executed, new commands are not accepted until the sequence is completed. Exceptions to this rule include interruptible (see "T Terminate Command" in this chapter) and Report commands.
- When a command is sent, the pump answers immediately. If an invalid command has been sent in a command string, the pump reports an error immediately. If there was an invalid parameter in the command, the pump will execute up to the invalid parameter, then stop. In the case of a [Q] (Query) command, the error is read back to the host computer.
- Always run liquid through the syringe and valve when issuing a Move command. Failure to do so may damage the valve and syringe seal.
- Keep fingers out of the syringe slot while the pump is running. Failure to do so can result in injury.

Command Syntax and Notes

The syntax for each command in the command set is:

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

Note:

- *Multiple values of <n> in a single command must be separated by commas*
- *Square brackets, [ ], are used to distinguish commands and should not be sent as part of the command strings.*
- *Commands are case-sensitive.*
- *Response time from the transmission of the checksum byte to transmission of the start character is less than 5 msec.*

3.3.2   Pump Configuration Commands

XLP 6000 pumps are preconfigured at the factory to the default settings. The firmware, however, allows the user to configure the pump to meet his or her specific requirements. Configuration options available to the user include resolution, backlash, valve type, and baud rate.

N <n>   Set Microstep Mode Off/On

The [N] command enables or disables microstepping (fine positioning). The syntax for this command is:

   [N<n>]

where <n> = 0 or 1 (0 is the default)

Value of <n>	Description
0	**Normal mode:** All positions set and reported in half-steps; all speed settings in half-steps/sec and all slopes in half-steps/sec^2.
1	**Fine positioning mode:** All positions set and reported in micro-steps; all speed settings in half-steps/sec and all slopes in half-steps/sec^2. Maximum cutoff frequency limited to 750 half-steps/sec; maximum on-the-fly set velocity limited to 750 half-steps/sec.
2	**Micro-step mode:** All positions set and reported in micro-steps; all speed settings in micro-steps/sec and all slopes in micro-steps/sec^2.

K<n> Backlash Increments

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

[K<n>]

where <n> = 0..31 in full step mode (12 is the default),
and <n> = 0..248 in fine positioning mode (96 is the default).

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

> Set User Data Command

The [>] command loads a byte of user data into non-volatile memory:

[> <n1>, <n2>], where: <n1> is 0..15 (location in non-volatile memory) and <n2> is 0..255 (data to load into non-volatile memory).

U<n> Write Pump Configuration to Non-Volatile Memory

The [U] command is used to write configuration information to the non-volatile memory. The pumps are configured during the manufacturing process but can be reconfigured at any time with the following [U] commands:

Table 3-5   Write Pump Configuration Command Values

Value<n>	Description
0	No Valve
1	3-Port valve
2	4-Port valve
3	3-Port distribution valve (face seal)
5	T Valve
7	6-port distribution valve
8	9-port distribution valve
9	Dual loop valve
11	3-Port distribution valve (plug)
30	Set Non-Volatile Memory Auto Mode
31	Clear Non-Volatile Memory Auto Mode
41	Set RS-232/RS-485 Baud rate to 9600

Table 3-5   Write Pump Configuration Command Values

Value<n>	Description
47	Set RS-232/RS-485 Baud rate to 38400
51	Set CAN Bus Baud rate to 100K
52	Set CAN Bus Baud rate to 250K
53	Set CAN Bus Baud rate to 500K
54	Set CAN Bus Baud rate to 1M
57	Set CAN Bus Baud rate to 125K

Note: [U] commands take effect upon the pump's next power-up.

3.4   Initialization

3.4.1   Initialization Forces

Initialization moves the plunger to the top of travel, then backs off a user-specified number of increments (see k command) and sets this as position 0. Also, the input and output positions of the valve are assigned depending on the initialization command. All other command parameters are reset to default values.

The top of the syringe is recognized when upward movement of the plunger causes an overload condition.

The force at which the plunger presses against the top of the syringe can be controlled via a parameter after the Initialization command (possible values are 0, 1 and 2).

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

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

Table 3-6   Recommended Initialization Forces by Syringe

Syringes	Force
1.0 mL and larger	Full
250, 500 µL	Half
50, 100 µL	Third

---

k <n>   **Syringe Dead Volume Command**

The [k] command sets the number of increments that the plunger drive is offset from the top of travel. This is to minimize dead volume. The syntax for this command is:

[k<n>]

where:

n = the offset in increments from top of travel
n = 0..255 (122 is the default)
n = 0..2040 in fine positioning and microstep modes (976 is the default)

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

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

For example, to offset 10 increments away from the top of travel, send the following commands:

– k10R
– ZR

3.4.2   Initialization Commands

Z <n$_1$, n$_2$, n$_3$>   **Initialize Plunger and Valve Drive (CW Polarity)**

The [Z] command initializes the plunger drive and homes the valve in a clockwise direction. Valve ports are numbered 1..X, starting in a *clockwise* direction at the first port after the syringe port. The default initialization speed is 500 pulses per second.

n$_1$ = Set initialization plunger force/speed
n$_2$ = Set initialization input port
n$_3$ = Set initialization output port

The parameters are described below.

Z Parameter	Value	Description
$<n_1>$	0	Initializes at full plunger force and at default initialization speed (default)
	1	Initializes at half plunger force and at default initialization speed
	2	Initializes at one-third plunger force and at default initialization speed
	10-40	Initializes at full force and at speed code $<n_1>$. See command <S> for a list of speed codes.
$<n_2>$	0	Sets initialization input port to port 1 (default)
	1..X	Sets initialization input port for distribution valves, where X is the number of ports on the valve.
$<n_3>$	0	Sets initialization output port to port X (default), where X is the number of ports on the valve.
	1..X	Sets initialization output port for distribution valves, where X is the number of ports on the valve.

Y $<n_1, n_2, n_3>$ Initialize Plunger and Valve Drive (CCW Polarity)

The [Y] command initializes the plunger drive and homes the valve in a *counter-clockwise* direction. Valve ports are numbered 1..X in a counter-clockwise direction starting with the first port after the syringe port. The default initialization speed is 500 pulses per second.

n_1 = Set initialization plunger force/speed
n_2 = Set initialization input port
n_3 = Set initialization output port

The parameters are described below.

Y Parameter	Value	Description
$<n_1>$	0	Initializes at full plunger force and at default initialization speed (default)
	1	Initializes at half plunger force and at default initialization speed
	2	Initializes at one-third plunger force and at default initialization speed
	10-40	Initializes at full force and at speed code $<n_1>$. See command <S> for a list of speed codes.

<n$_2$>	0	Sets initialization input port to port 1 (default)
	1..X	Sets initialization input port for distribution valves, where X is the number of ports on the valve.
<n$_3$>	0	Sets initialization output port to port X (default), where X is the number of ports on the valve.
	1..X	Sets initialization output port for distribution valves, where X is the number of ports on the valve.

W<n$_1$>   Initialize Plunger Drive

The [W] command initializes the plunger drive only (commonly used for valveless pumps). Because the valve is not initialized, only plunger force and/or speed can be set. The default initialization speed is 500 pulses per second.

n$_1$ = Set initialization plunger force/speed

The parameters are described below.

W Parameter	Value	Description
<n$_1$>	0	Initializes at full plunger force and at default initialization speed (default)
	1	Initializes at half plunger force and at default initialization speed
	2	Initializes at one-third plunger force and at default initialization speed
	10-40	Initializes at full force and at speed code <n$_1$>. See command <S> for a list of speed codes.

w<n$_1$, n$_2$> Initialize Valve Drive

The [w] command initializes the valve drive only. Because the plunger is not initialized, only the initialization port can be set.

n$_1$ = Set port

n$_2$ = Set valve homing and port numbering direction

The parameters are described below.

w Parameter	value	Description
<n$_1$>	1..X	Set initialization port, where X is the number of ports on the valve
<n$_2$>	0	Valve homes in a *clockwise* direction; valve ports numbered in a *clockwise* direction.
	1	Valve homes in a *counterclockwise* direction; valve ports numbered in a *counterclockwise* direction.

z   Simulated Plunger Initialization

The [z] command simulates an initialization of the plunger drive, however, no mechanical initialization occurs. The current position of the plunger is set as the zero (home) position.

This command can be used after a plunger overload error, to regain control of the pump. After recovering from the overload condition using the [z] command, the pump must be reinitialized using the Z<n$_1$, n$_2$, n$_3$> or Y<n$_1$, n$_2$, n$_3$> commands to set the true home position.

Caution! *Incorrect use of this command can damage the device.*

3.5   Operating Commands

3.5.1   Valve Commands

Valve commands position the input and output channels to the specified ports. Similar valve commands cause different actions depending on whether you are using non-distribution valves or distribution valves.

With *non-distribution valves*, any combination of two valve ports, including or excluding the syringe port, may be used. With *distribution valves*, the syringe port is a common port, always included as one of the two valve ports in use.

The initialization command (Z, Y, or w) determines:

◆ the direction in which the valve homes during initialization (clockwise or counterclockwise)

◆ the direction in which the ports are numbered, starting with the syringe port (clockwise or counterclockwise)

After initialization, the direction in which the valve moves is specific to the valve type and command.

With **non-distribution valves**, the I, O, B, or E command specifies the combination of valve ports to be connected. The valve moves following the shortest path available.

For example, in Figure 3-2, if the 3-port non-distribution valve has been initialized with the [Z] command, the ports will be numbered as shown in the top diagram (clockwise). Issuing an [O] command aligns the syringe port with port 2, as shown.

Figure 3-2   *Valve Position Examples for 3-Port Non-Distribution Valves*
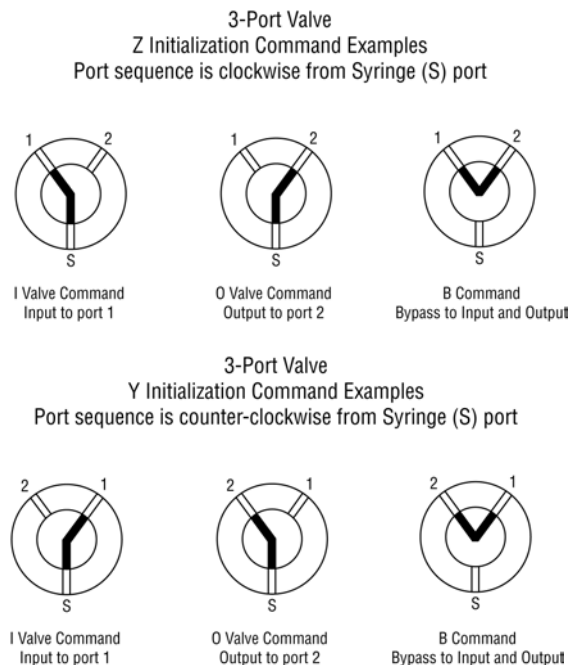
With **distribution valves**, the direction in which the valve moves is determined by the valve command. It will not necessarily follow the shortest path.

◆ The [I] command moves the valve in a clockwise direction.

◆ The [O] command moves the valve in a counterclockwise direction.

Note: Use of [I] and [O] in distribution valves is by convention, and does not pertain to input or output characteristics.

Because the syringe port is always a common port, in distribution valves, the [B] (Bypass) and [E] (Extra) commands are meaningless. However, the commands are available, to provide backward compatibility with earlier versions of firmware.

For example, in Figure 3-3, if the 3-port distribution valve has been initialized with the [Y] command, the ports will be numbered as shown in the bottom diagram (counterclockwise). Issuing an [O<3>] command will align the syringe port with port 3, as shown.

Figure 3-3   *Valve Position Examples for 3-Port Distribution Valves*
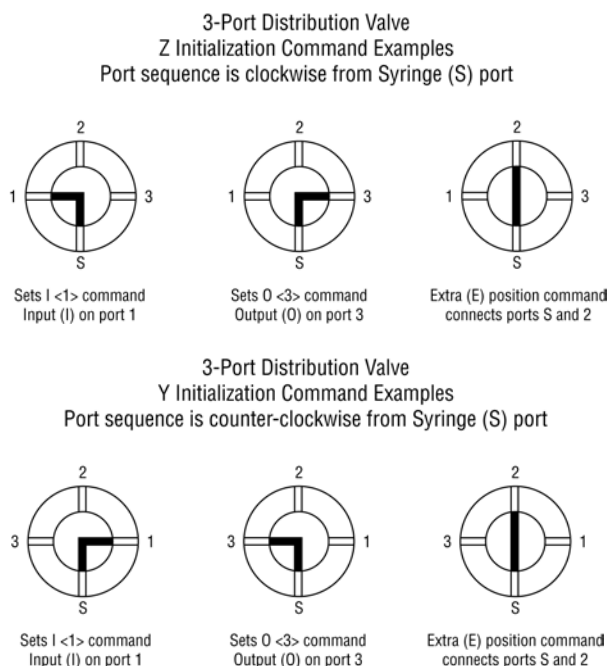
Following are more detailed descriptions of the various valve commands and what they do.

I   Move Valve to Input Position (Non-distribution Valves)

The [I] command moves the valve to the input port set by the initialization command, following the shortest path.

I<n>   Move Valve Clockwise to Port n (Distribution Valves)

The [I<n>] command sets the valve position to port [n], moving in a *clockwise* direction. This command is independent of input or output characteristics.

O   Move Valve to Output Position (Non-distribution Valves)

The [O] command moves the valve to the output port set by the initialization command, following the shortest path.

O<n> Move Valve Counterclockwise to Port n (Distribution Valves)

The [O<n>] command sets the valve position to port [n], moving in a *counter-clockwise* direction. This command is independent of input or output characteristics.

B Move Valve to Bypass (Non-distribution Valves)

The [B] command connects the input and output positions, bypassing the syringe. The valve moves following the shortest path.

E Move Valve to Extra Position (4-Port Non-distribution Valve)

The [E] command connects the extra position in the 4-port valve, bypassing the syringe. The valve moves following the shortest path.

Note: The [B] and [E] commands are useful when flushing fluid lines.
If a Valve command is issued to a valveless pump, the command is ignored.

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

Figure 3-4 *Valve Position Examples for 4-Port Non-Distribution Valves*
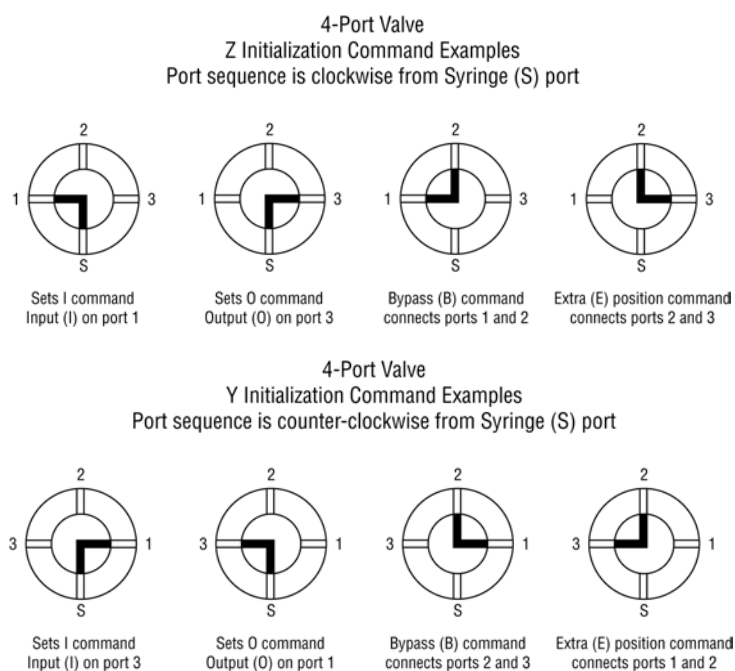
Figure 3-5   *Valve Position Examples for T Valves (Non-Distribution)*
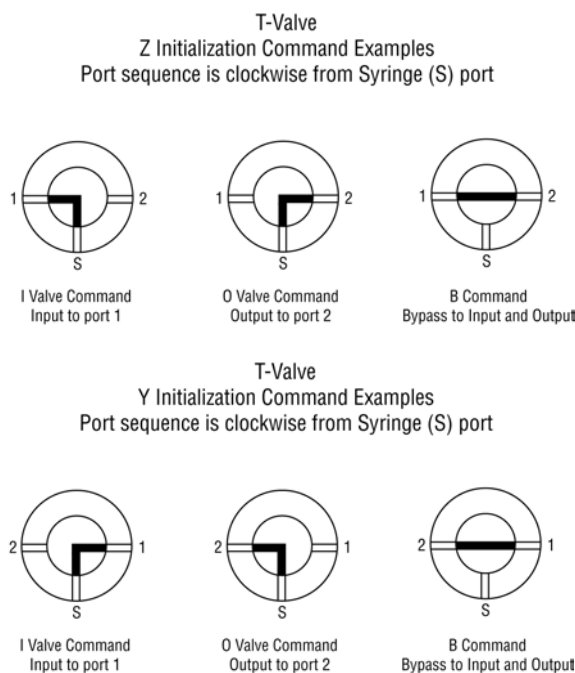
Figure 3-6   *Valve Position Examples for 6-Port Distribution Valves*
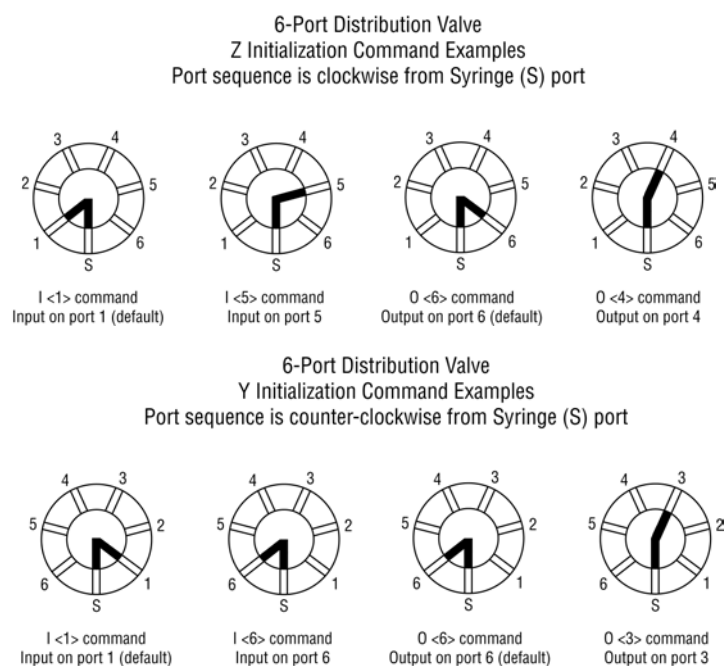
Figure 3-7   *Valve Position Examples for 9-Port Distribution Valves*
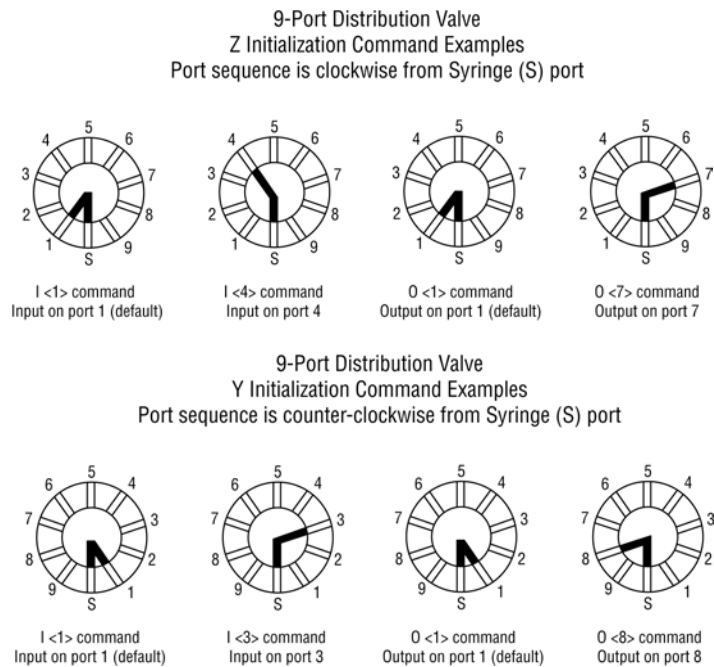
3.5.2   Plunger Movement Commands

A <n>   Absolute Position

The [A] command moves the plunger to the absolute position <n>, where <n> = 0..6000 in standard mode and 0..48000 in fine positioning and microstep mode.

Command	<n> Parameter Value	Description
A	0-6000	Absolute position in half increments (N=0)
	0-48000	Absolute position in microsteps (N=1)
	0-48000	Absolute position in microsteps (N=2)

For example:

– [A300] moves the syringe plunger to position 300.
– [A6000] moves the syringe plunger to position 6000.

a <n>   Absolute Position (Not Busy)

This is the same as the [A] command, except that the status bit within the reply string indicates that the pump is not busy.

P <n>   Relative Pickup

The [P] command moves the plunger down the number of increments commanded. The new absolute position is the previous position plus <n>, where
<n> = 0..6000 in standard mode and
<n> = 0..48000 in fine positioning and microstep mode.

Command	<n> Parameter Value	Description
P	0-6000	Relative position in half increments (N=0)
	0-48000	Relative position in microsteps (N=1)
	0-48000	Relative position in microsteps (N=2)

For example:

The syringe plunger is at position 0. [P300] moves the plunger down 300 increments. [P600] moves the plunger down an additional 600 increments to an absolute position of 900.

The [P] command will return error 3 (invalid operand) if the final plunger position is greater than 6000.

p <n>   Relative Pickup (Not Busy)

This is the same as the [P] command, except that the status bit of the reply string indicates that the pump is not busy..

D <n>   Relative Dispense

The [D] command moves the plunger upward the number of increments commanded. The new absolute position is the previous position minus <n>, where
<n> = 0..6000 in standard mode and
<n> = 0..48000 in fine positioning and microstep mode.

Command	<n> Parameter Value	Description
D	0-6000	Relative position in half increments (N=0)
	0-48000	Relative position in microsteps (N=1)
	0-48000	Relative position in microsteps (N=2)

For example:

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

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

d <n>   Relative Dispense (Not Busy)

This is the same as the [D] command, except that the status bit of the reply string indicates that the pump is not busy..

3.5.3   Set Commands (Speed and Acceleration)

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

◆   **Ramping Up.** Plunger movement begins with the start speed and accelerates with the programmed slope to the constant or top speed.
◆   **Constant or Top Speed.** The plunger moves at the constant or top speed. Plunger speed can be programmed in Hz (half-increments/second) or in preprogrammed Set Speeds. The actual time the plunger travels is dependent on the ramping up and down. If the plunger move is short, it may never reach top speed.
◆   **Ramping Down.** The plunger will decelerate based on the programmed slope. To enhance fluid breakoff, the Cutoff command ([c]) can be used to define the end speed of the plunger just before it stops.

Note: The Cutoff command is only active in a dispense move. During aspiration the move will end at the start speed [v].

For each plunger move, the firmware calculates how many increments the plunger must travel during each phase in order to move the total number of increments commanded. If the plunger is moving at a rate less than 900 Hz, the pump automatically microsteps to reduce the pulsation.

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

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

Changing Speed on the Fly

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

Speeds can be decreased or increased between 5 and 750 Hz (i.e., in the fine positioning region).

To change speed on the fly:

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

2 Issue a new top speed in the range 5 to 750 (e.g. [V600]) while the plunger is moving, to change the speed on the fly.

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

Note: When changing speed on the fly in CAN, use frame type 0.

L <n>   Set Slope

During the beginning and end of a move, the plunger speed ramps up and down respectively. The ramp is programmed using the Slope command. It is calculated as <n> x 2.5 pulses/sec^2. The syntax for this command is:

[L<n>]

where <n> = 1..20 (7 is the default)

In normal or fine positioning modes (N0, N1) pulses are in half steps. In micro-step mode (N2) pulses are in micro-steps.
The corresponding slopes in pulses/sec^2 are listed below.

Slope Code	Pulses/sec^2 (KHz)
1	2500
2	5000
3	7500
4	10000
5	12500
6	15000
7	17500

8	20000
9	22500
10	25000
11	27500
12	30000
13	32500
14	35000
15	37500
16	40000
17	42500
18	45000
19	47500
20	50000

v <n>   Set Start Speed

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

Command	<n> Parameter Value	Default Value	Description
v	50-1000	900	Set start speed in pulses/sec

V <n>   Set Top Speed

The [V] command sets the top speed in pulses/second. This command may be sent while a command string is already executing. (See section on Changing Speed on the Fly, earlier in this chapter.)

Command	<n> Parameter Value	Default Value	Description
V	5-6000	900	Set top speed in pulses/sec

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

S <n>   Set Speed

The [S] command sets a predefined top plunger speed, in pulses/sec. As <n> increases, the plunger speed decreases.

Command	<n> Parameter Value	Default Value	Description
S	0-40	14	Set plunger drive speed in pulses/sec

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

The [S] command sets top speed without changing start speed, slope, and cutoff speed, except under the following conditions:
- If the start speed is higher than the (new) top speed, start speed is changed to equal the top speed.
- If the cutoff speed is higher than the (new) top speed, cutoff speed is changed to equal the top speed.

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

Speed Code	Value (pulses/sec)	Seconds/stroke (N=0, N=1)	Seconds/stroke (N=2)
0	6000	1.25	8.25
1	5600	1.30	8.80
2	5000	1.39	9.79
3	4400	1.52	11.1
4	3800	1.71	12.8
5	3200	1.97	15.1
6	2600	2.37	18.5
7	2200	2.77	21.9
8	2000	3.03	24.0
9	1800	3.36	26.7
10	1600	3.77	30.0

Speed Code	Value (pulses/sec)	Seconds/stroke (N=0, N=1)	Seconds/stroke (N=2)
11	1400	4.30	34.3
12	1200	5.00	40.0
13	1000	6.00	48.0
14	800	7.50	60.0
15	600	10.00	80.0
16	400	15.00	120
17	200	30.00	240
18	190	31.58	253
19	180	33.33	267
20	170	35.29	282
21	160	37.50	300
22	150	40.00	320
23	140	42.86	343
24	130	46.15	369
25	120	50.00	400
26	110	54.55	436
27	100	60.00	480
28	90	66.67	533
29	80	75.00	600
30	70	85.71	686
31	60	100.00	800
32	50	120.00	960
33	40	150.00	1200
34	30	200.00	1600
35	20	300.00	2400
36	18	333.33	2667
37	16	375.00	3000

Speed Code	Value (pulses/sec)	Seconds/stroke (N=0, N=1)	Seconds/stroke (N=2)
38	14	428.57	3429
39	12	500.00	4000
40	10	600.00	4800

Note: To achieve maximum stroke time of 20 minutes for N=0, N=1 or 160 minutes for N=2, a set speed [S] cannot be used. The pump must be programmed using the [V5] command.

c <n>   Cutoff Speed in Pulses/Second

The [c] command sets the speed at which the plunger ends its movement, in pulses/sec. The plunger will ramp down (slope) from the peak speed. The [c] command overwrites the [C] command.

Command	<n> Parameter Value	Default Value	Description
c	50-2700	900	Set cutoff speed in half-steps/sec (N=0, N=1)
	50-750	500	Set cutoff speed in micro-steps/sec (N=2)

Note: [c] is only valid in a dispense move. During aspiration, [c] = [v].

3.5.4   Interaction of Set Commands

The Start Speed [v], Top Speed [V], and Cutoff Speed [c] commands interact according to the following rules:

$$[v] \leq [c] \leq [V]$$

1 Start Speed should always be less than or equal to Top Speed. Changing the Start Speed will change the Cutoff Speed if Cutoff Speed is less than the Start Speed set. If the Start Speed [v] is greater than the Top Speed, the Start Speed will be set equal to the Top Speed.

2 Top Speed should always be greater than or equal to the Start Speed and Cutoff Speed. Changing the Top Speed will modify the Cutoff Speed and Start Speed if they were improper, but will not modify the stored Start Speed. For instance, values of 750, 100 and 1200 will cause the pump to run simply at the top speed of 100.

3 Cutoff Speed [c] should always be less than or equal to Top Speed [V] and greater than or equal to Start Speed [v]. Changing the Cutoff Speed will not modify the Start Speed or Top Speed. However, if Cutoff Speed is greater than

Top Speed it will be ignored and the Cutoff Speed will be set equal to the Top Speed. And if the Cutoff Speed is set less than Start Speed, it will be ignored and the Cutoff Speed will be set equal to the Start Speed.

3.5.5   Control Commands

R   Execute Command or Program String

The [R] command tells the pump to execute a new or previously loaded but unexecuted command string. This command will also cause the resumption of a halted ("H") or terminated ("T") command string.

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

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

Note: The [R] command (frame type 1) is valid in CAN communication. An equivalent command is ASCII 1 for frame type 2.

X   Execute the Last Command or Program String

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

Note: The [X] command (frame type 1) is valid in CAN communication. An equivalent command is ASCII 3 for frame type 2.

G <n>   Repeat Command Sequence

This command repeats a command or program string the specified number of times. If a GR or a G0R is sent, the sequence is repeated until a Terminate command [T] is issued. The G command can be used to nest up to 10 loops and can be repeated up to 48,000 times.

The syntax for this command is:

[G<n>]

where <n> = 0..48000

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

g   Mark the Start of a Repeat Sequence

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

Table 3-7, Example Program String, shows the various segments of the command string [A0gP50gP100D100G10G5R].

Table 3-7 *Example Program String*

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

M <n> Delay Command Execution

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

[M<n>]

where <n> = 0..30,000 milliseconds (5 is the default)

H <n> Halt Command Execution

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

The syntax for this command is:

[H<n>]

where <n> = 0..2

Two TTL inputs are available, input 1 (J5 pin 7) and input 2 (J5 pin 8). They control execution as follows:

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

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

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

T   Terminate Command

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

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

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

Caution! When a plunger move is terminated, lost increments may result. Reinitialization is recommended following termination.

Note: The [T] command (frame type 0) is valid in CAN communication. An equivalent command is ASCII 4 for frame type 2.

J <n>   Auxiliary Outputs

The [J] command sets the TTL output lines.

The syntax for this command is:

   [J<n>]

where <n> = 0..7 (0 is the default)

The XLP 6000 provides three TTL outputs on J5 (pins 13, 14, and 15) that correspond to outputs 1, 2, and 3. They are controlled as shown in the following table:

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

0 = low; for example, Gnd
1 = high; for example, +5V DC

3.5.6   Non-Volatile Memory (EEPROM) Commands

The non-volatile memory in the XLP 6000 can store a program string thus providing the user with the option of computer-free operation. The pump can be configured to run stored programs using the U<30> command. See "Pump Configuration Commands" earlier in this chapter.

s <n>   Load Program String into Non-Volatile Memory

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

[s<n>]

where <n> = 0..14

Up to 15 program strings (numbered 0 through 14) can be loaded into the non-volatile memory. Each string can use up to 128 characters. For example, [IA3000OA0R] requires 10 bytes.

Example Program String: [s8ZS1gIA3000OA0GR]

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

e <n>   **Execute Non-Volatile Memory Program String**

Non-volatile memory command strings are executed by sending an [e] command. The executing program string can be terminated using the [T] command.

   [e<n>]

where <n> = 0..14 (the string number)

Note: An Initialization command should always be included in the non-volatile memory command string if the pump will be used in standalone mode.

U30   **Set Run from Non-Volatile Memory Auto Mode**

The [U30] command sets the "Run from Non-Volatile Memory Auto Mode" flag in the non-volatile memory and begins operating the pump in stand alone mode. The pump will run one of 15 command strings <n> as selected by the address switch,

where <n> = 0..E

U31   **Clear Run From Non-Volatile Memory**

The [U31] command clears the "Run from Non-Volatile Memory Auto Mode" flag in the EEPROM and begins operating in the default mode.

Note: U commands take effect upon the pump's next power up.

Linking Program Strings in the Non-Volatile Memory

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

Example Program Strings:

   [slZgIA3000OA0G5e2R]

   [s2gIA3000OgHD300G10GR]

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

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

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

3.5.7   Report Commands

Report commands do not require an [R] command.

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

?   Report Absolute Plunger Position

The [?] command reports the absolute position of the plunger in half-steps [N0] or in microsteps [N1, N2].

?1   Report Start Speed

The [?1] command reports the start speed in pulses/sec [50..1000].

?2   Report Top Speed

The [?2] command reports the top speed in pulses/sec [5..6000].

?3   Report Cutoff Speed

The [?3] command reports the cutoff speed in pulses/sec [50..2700].

?4   Report Actual Position of Plunger

The [?4] command reports the plunger encoder position in increments.

?6   Report Valve Position

The [?6] command reports the valve position in mnemonics (i = input, o = output, e = extra, and b = bypass for non-distribution valves.

For distribution valves, the [?6] command reports ASCII values 1..X, where X is the number of distribution valve ports.

?10 or F   Report Command Buffer Status

The [?10] or [F] command reports the command buffer status. If the buffer is empty, the pump returns status code 0. If the buffer is not empty, the pump returns a 1. If a program string is sent to the pump without an [R] command, the string is loaded into the buffer and the buffer status becomes 1. An [R] command will then execute the command stored in the buffer.

   0 = empty
   1 = commands in buffer

?12   Report Number of Backlash Increments

The [?12] command reports the number of backlash increments as set by the "K" command.

?13   Report Status of Auxiliary Input #1 (J5, Pin 7)

0 = low
1 = high

?14   Report Status of Auxiliary Input #2 (J5, Pin 8)

0 = low
1 = high

?15   Report Number of Pump Initializations

Command [?15] reports the number of pump initializations. This value cannot be reset.

?16   Report Number of Plunger Movements

Command [?16] reports the number of plunger moves. This value cannot be reset.

?17   Report Number of Valve Movements

Command [?17] reports the number of valve movements. This value cannot be reset.

?18 or % Report Number of Valve Movements (Since Last Report)

The [?18] or [%] command reports the number of valve movements since the last [?18] or [%] command.

?20 or # Report Firmware Checksum

The [?20] or [#] command reports back the firmware checksum. The checksum is the same for all part numbers at the same revision level.

?23 or & Report Firmware Version

The [?23] or [&] command reports the firmware part number and version in ASCII characters.

?24   Report the Zero Gap increments

The [?24] command reports the value set by the "k" command.The value reported is in half steps (N=0) or in microsteps (N=1, N=2).

?25   Report Slope Code Setting

The [?25] command reports the slope code setting as set by the "L" command.

?28   Report Current Mode

The [?28] command reports the current mode as set by the "N" command (normal, fine positioning, or microstep).

?29 or Q   Report the Device Status

The [?29] command reports device status (error code).

?76   Report Pump Configuration

The [?76] command reports pump configuration in ASCII text.

*   Report Voltage

The [*] command reports the value of the device power supply. The value is multiplied by 10. For example, if V = 24.0 VDC, the * command reports 240.

<   Report User Data

The [<] command returns the value of user data stored in the EEPROM. The value <n> is between 0 and 15; 0 is the default.

3.6   Error Codes and Pump Status

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

Note: [Q] is the only valid method for obtaining pump status in serial mode.

Note: The Query command is invalid in CAN communication.

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

3.6.1 Status Bit

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

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

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

◉TECAN.

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

3.6.2 Error Codes

Error codes describe problem conditions that may be detected in the XLP 6000 (excluding error code 0). Error codes are returned in the least significant four bits of the status byte. If an error occurs, the pump stops executing commands, clears the command buffer, and inserts the error code into the status byte.

Some errors continue to appear, such as syringe overloads, until they are cleared by the Initialization command. On a plunger overload, the device will not execute another valve or syringe Move command until it is reinitialized. The last error has precedence in the status byte. For example, if a command overflow occurs, an error 15 results. If the next command causes an error #3, the status byte reflects the error #3 (invalid operand).

Table 3-8   Error Codes

Error Code	Description
0 (00h)	Error Free Condition.
1 (01h)	Initialization error. This error occurs when the pump fails to initialize. Check for blockages and loose connections before attempting to reinitialize. The pump will not accept commands until it has been successfully initialized. This error can only be cleared by successfully initializing the pump.
2 (02h)	Invalid Command. This error occurs when an unrecognized command is issued. Correct the command and operation will continue normally.
3 (03h)	Invalid Operand. This error occurs when an invalid parameter (<n>) is given with a command. Correct the parameter and pump operation will continue normally.
6 (06h)	EEPROM Failure. This error occurs when the EEPROM is faulty. If you receive this error, please call Tecan Systems Technical Service.
7 (07h)	Device Not Initialized. This error occurs when the pump is not initialized. To clear the error, initialize the pump.
8 (08h)	Internal failure. If this error occurs, please call Tecan Systems Technical Services. See Chapter 6, "Technical Service."
9 (09h)	Plunger Overload. This error occurs when movement of the syringe plunger is blocked by excessive backpressure. The pump must be reinitialized before normal operation can resume. This error can only be cleared by reinitializing the pump.

Error Code	Description
10 (0Ah)	Valve Overload. This error occurs when the valve drive loses increments by blockage or excess backpressure. The pump must be reinitialized before normal operation can resume. Sending another Valve command reinitializes the valve and sets it to the correct location. Continual valve overload errors are an indication the valve should be replaced.
11 (0Bh)	Plunger Move Not Allowed. When the valve is in the bypass or throughput position, Plunger Movement commands are not allowed.
12 (0Ch)	Internal failure. If this error occurs, please call Tecan Systems Technical Services. See Chapter 6, "Technical Service."
14 (0Eh)	A/D converter failure. This error occurs when the internal A/D converter is faulty. If this error occurs, please call Tecan Systems Technical Services. See Chapter 6, "Technical Service."
15 (0Fh)	Command Overflow. This error occurs when action commands are sent to the pump before it has completed the current action. Commands in the buffer must be executed before more commands can be sent.

3.6.3 Error Types

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

Immediate Errors

These include "Invalid Command" (error 2), "Invalid Operand" (error 3). After the command is sent, the answer block immediately returns an error. Once a valid command is sent, the pump will continue to function normally. Since the [Q] command is a valid command, the pump will not return an error. In this case, the [Q] command is not required.

Note: There is no need to reinitialize the pump following this error type.

Initialization Errors

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

To ensure that the pump initializes successfully, send a [Q] command after the Initialization command.
- If the [Q] command indicates both a successful initialization and that the pump is ready, subsequent Move commands can be sent.

- ◆ If the [Q] command indicates the pump has not initialized, the pump must be reinitialized until the [Q] command indicates successful initialization.
- ◆ If initialization is not successful, a "Device Not Initialized" error is returned as soon as the next Move command is sent. A successful reinitialization must be executed before subsequent commands can be sent.

Overload Errors

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

Command Overflow Error

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

Note: There is no need to reinitialize the pump following this error type.

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

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

Table 3-9   Error Codes and ASCII and Hexadecimal Values

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
7 6 5 4 3 2 1 0	**0**	**or 1**	**0**	**or 1**	**Number**	**Error**
0 1 X 0 0 0 0 0	40h	60h	64	96	0	No Error
0 1 X 0 0 0 0 1	41h	61h	65	97	1	Initialization
0 1 X 0 0 0 1 0	42h	62h	66	98	2	Invalid Command
0 1 X 0 0 0 1 1	43h	63h	67	99	3	Invalid Operand
0 1 X 0 0 1 1 0	46h	66h	70	102	6	EEPROM Failure

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
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 0 0	4Ch	6Ch	76	108	12	Internal Failure
0 1 X 0 1 1 1 0	4Eh	6Eh	78	110	14	A/D converter failure
0 1 X 0 1 1 1 1	4Fh	6Fh	79	111	15	Command Overflow

Error Reporting Examples

[A7000R]	Does not move the plunger and reports a "No Error" status; when queried ([Q] command), returns error. A second try returns error 3 (67).
[P6000P600R]	Moves to position 6000, then stops. A [Q] command returns an error.
[t2000R]	Returns an invalid command error immediately. The pump status is "Not Busy".
[A6000t2000R]	Returns an invalid command error immediately. The pump is "Not Busy."
Valve in Bypass [A1000R]	Returns an error immediately; when queried ([Q] command), does not return an error.

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4 Setting Up the XLP 6000 for Your Application

The XLP 6000 is capable of providing precision pumping in a wide variety of liquid handling systems. The interplay of fluid viscosity, aspiration and dispense speeds, and system geometry (syringe size, tubing inner diameter, and valve inner diameter) determine the behavior of the XLP 6000 in a particular application. Following is a description of the hardware, fluid, and pump control parameters to be evaluated and optimized in managing these interdependencies for optimal pump performance.

4.1 Glossary

air gap

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

aspirate/dispense tubing

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

backlash

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

backpressure

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

breakoff

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

breakup

Undesired air gaps created by overly rapid aspiration.

carryover

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

cavitation

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

dilution effect

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

I.D. ("inner diameter")

Diameter of the constraining wall of a fluid path.

priming

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

reagent tubing

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

system fluid

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

syringe speed profile

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

Figure 4-1 *Syringe Speed*
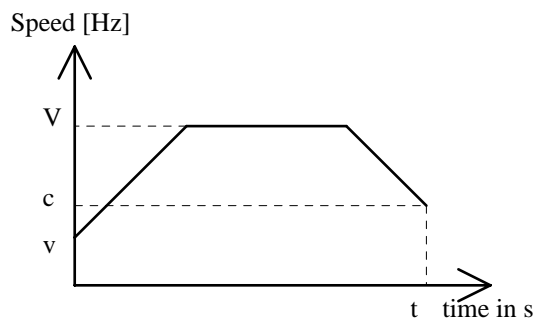
start speed (v)

The speed at which the syringe plunger starts moving.

top speed (V)

The maximum speed at which the syringe plunger moves.

cutoff speed (c)

The speed of the syringe plunger just before stopping.

slope (L)

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

volume calculation

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

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

For example, to aspirate 100 μL using an XLP 6000 pump with 1 mL syringe, move the plunger as follows:

$$\text{\# of increments} = \frac{\text{6000 increments x 100 } \mu\text{L}}{\text{1 mL x 1000 } \mu\text{L/mL}} = 300 \text{ increments}$$

4.2   Optimizing XLP 6000 Performance

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

For command details, see Chapter 3, "Software Communication".

To optimize XLP 6000 performance, follow these steps:

1   Check chemical compatibility.

Check the chemical compatibility chart in Appendix D, "Chemical Resistance Chart" to determine if the fluids in your application are compatible with the XLP 6000 syringe and valve materials. If not, a system fluid is required. Complete the optimization procedure with the fluids you will use in your final system.

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

2   Select syringe size.

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

Table 4-1   *Flowrate Ranges*

Syringe Size	Minimum Flow Rate (mL/min)	Maximum Flow Rate (mL/min)
50 µL	3.125×10^{-4}	2.5
100 µL	6.25×10^{-4}	5.0
250 µL	1.563×10^{-3}	12.5
500 µL	3.125×10^{-3}	25.0

Syringe Size	Minimum Flow Rate (mL/min)	Maximum Flow Rate (mL/min)
1 mL	6.25×10^{-3}	50.0
5 mL	3.125×10^{-2}	250.0
10 mL	6.25×10^{-2}	500.0
25 mL	0.15625	1250.0

3 Select tubing.

In tubing selection, the general rule is that smaller syringes work best with smaller I.D. tubing and larger syringes with larger I.D. tubing. The 3-port XLP 6000 valve has an internal I.D. of 0.059" (approx. 1/16"). For aspirate/ dispense tubing, a thermal-drawn tip or tapered tip is most common, providing good breakoff and excellent accuracy and precision for most applications. A necked-down tip may be used when aspirating very small volumes of sample, i.e., 1 - 5 μL. A blunt-cut tip is better suited for large volume applications. For tubing recommendations, see Table 4-2, Tubing Recommendations; for a description of the various types of tubing, see Appendix A, "Ordering Information"."

Table 4-2 *Tubing Recommendations*

Syringe Size	Aspirate/Dispense Tubing P/N	Reagent Tubing P/N
50 μL, 100 μL, 250 μL	5133	NA
	5723	NA
500 μL, 1 mL, 2.5 mL	5133	4609
	720595	5729
	720597	721370
5 mL, 10 mL, 25 mL	4333	720592
	720595	721370

4 Make pump connections.

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

5 Check communications to the pump.

– Open the Pump:Link program to the XL3000 menu (full page), or use your own communications program.

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

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

6 Initialize pump and set initialization speed.

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

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

Possible errors:
– Error 1 (initialization error). Check for tubing blockage and reinitialize. If you are using very narrow I.D. tubing or pumping a viscous fluid, the initialization speed may need to be reduced.
– This is accomplished (only if using a 1 mL or larger syringe) by sending the command [Z16R] (initializes at full-force, reduced speed). Repeat with decreasing initialization speed (increase "Z_" value) until the pump successfully initializes.

7 Prime the syringe.

– Send the command [IA6000OA0R] to pull fluid through the valve input position and into the syringe.
– Inspect the pump tubing and syringe for bubbles and re-prime until all bubbles are completely gone.
If bubbles remain after several priming strokes, disassemble the syringe and clean it with alcohol. Also check to ensure the fittings are tight and the syringe is tight within the Teflon fitting.
– Re-prime.

Possible errors:
– Error 9 (plunger overload). See step 8.

8 Check aspirate/dispense.

Send the command [IA6000OA0R] to aspirate a full syringe stroke (6000 increments) from input and dispense it to output. Successful execution will move the syringe plunger to position "6000" then back to "0," then it will return a "Ready" status.

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

9 Set start speed and top speed.

The XLP 6000 plunger speed can be controlled from 1.2 seconds per stroke to 160 minutes per stroke (top speed) using the [S] or [V] commands. (The [V] command allows a slightly larger speed range.) As a general rule, aspiration

should be slow (to avoid cavitation) and dispense fast (to promote breakoff). Since cavitation and breakoff will affect both accuracy and precision, speed settings may be optimized separately for aspiration and dispense.

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

– Send the command [v50IA6000OA0R]. Repeat with increasing start speed (increase "v_" value) to find the maximum value.

– Send the command [v*x*V*x*IA6000OA0R] to set top speed equal to start speed (*x*). Repeat with increasing top speed (increase "V_" value) to the maximum value that does not overload the plunger or cause cavitation.

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

10 Set cutoff speed and slope.

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

To optimize the slope, send the command [v*x*V*x*L14IA6000OA0R]. Repeat with modified slope ("L_" value) to achieve the overall time suited to your application without plunger overload.

To optimize the cutoff speed, start with the maximum cutoff speed allowed for your application (the lower of 2700 Hz or the top speed). Send the command [c*x*IA6000OA0R] and monitor the dispense for plunger overload or any splattering of the fluid dispensed outside of the dispense vessel. If any of these conditions occur, lower the cutoff speed until the pump can dispense the fluid with clean breakoff.

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

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

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

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

– [S24IA6000OA5S1A0R] - no drop will be left

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

– [V100IA6000OA5V5500A0R] - no drop will be left

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

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

4.3 Helpful Hints

To maintain pump performance, keep the following in mind when operating the XLP 6000:

◆ Wipe up all spills immediately.

◆ Pumping cold fluids may cause leaks, the result of differing coefficients of expansion of Teflon and glass. Leaks may occur when pumping fluids that are at or below 15°C (61°F).

◆ To reduce the amount of carryover, a ratio of three parts reagent to one part sample is recommended.

◆ Before pumping any organic solvent, please refer to Appendix D, "Chemical Resistance Chart" in this manual. Using organic solvents may reduce tubing and seal life.

◆ Replace the valves and syringe seals as needed. (Interval may vary depending on the application.)

5 Maintenance

Although required maintenance may vary with your application, the following procedures are recommended for optimal performance of the Cavro® XLP 6000 Modular Syringe Pump.

Perform maintenance tasks in these intervals:
- daily
- weekly
- periodically

Caution! *Chemical reaction of reagents and/or sample fluids with the cleaning solutions recommended for use on the XLP 6000 may generate hazardous substances.* **Always operate the pump in a well ventilated area and be aware of possible hazards.**

5.1 Daily Maintenance

To ensure proper operation of the XLP 6000, perform these tasks daily:
- Inspect the pump(s) for leaks, and correct any problems.
- Wipe up all spills on and around the pump.
- Flush the pump(s) thoroughly with distilled or de-ionized water after each use and when the pump is not in use.

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

5.2 Weekly Maintenance

The fluid path of the XLP 6000 must be cleaned weekly to remove precipitates such as salts, eliminate bacterial growth, and so on. Any of the three following cleaning procedures can be used:
- Weak detergent
- Weak acid and base
- 10% bleach

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

5.2.1 Weak Detergent Cleaning

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

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

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

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

Note: CONTRAD® 100 can be purchased through Fisher Scientific. Order catalog number 04-355-27 for a 1 gallon container.

Note: RoboScrub is a phosphate-free detergent for cleaning and conditioning liquid handling systems. RoboScrub is available from Tecan (PN 70-736) in a 16 oz. container.

5.2.2 Weak Acid-Base-Sequence Cleaning

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

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

2 Flush the pump with distilled or de-ionized water.

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

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

5 Prime the pump a minimum of 10 cycles with distilled or de-ionized water.

5.2.3 10% Bleach Cleaning

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

1 Make a solution of 10% bleach by adding one part of commercial bleach to nine parts of water.

2 Prime the pump with the 10% bleach and allow the solution to remain in the pump with the syringes fully lowered for 30 minutes.

3 After the 30-minute period, remove the reagent tubing from 10% bleach solution and cycle all the fluid from the syringes and tubing into a waste container.

4 Prime the pump a minimum of 10 cycles with distilled or de-ionized water.

5.3 Periodic Maintenance

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

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

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

1 input and output tubing

2 plunger seal

3 valve

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

5.3.1 Quality Control Assurance

Check the accuracy and precision of the XLP 6000 on a regular basis.

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

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

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

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

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

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

where:

sg = specific gravity of $H_2 0$ @ 25°C = 0.99707

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

n = number of replicate

X = individual result

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

5.3.2 Replacing Dispense or Reagent Tubing

To replace dispense or reagent tubing, follow these steps:

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

2 Unscrew the fittings and remove the tubing.

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

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

5.3.3 Replacing a Syringe

To replace a syringe, follow these steps:

1 Remove the liquid from the syringe.

2 Remove the plunger lock screw.

3 Lower the plunger drive by sending the [A6000R] command. If power is not applied, the plunger drive can be manually lowered by pushing down firmly on the plunger holder assembly.

4 Unscrew the syringe from the valve.

5 To install the syringe: (as shown in Figure 5-1)
a. Screw the syringe into the valve.
b. Pull the syringe plunger down to the plunger holder assembly.
c. Screw the syringe plunger into place.
d. Slide the plunger lock screw through the plunger buttons and fasten to the carriage.

6 Re-initialize the pump.

Note: Make sure the plunger lock screw is securely tightened and the plunger button is free to move on the plunger lock screw.

Figure 5-1 *Syringe Replacement*
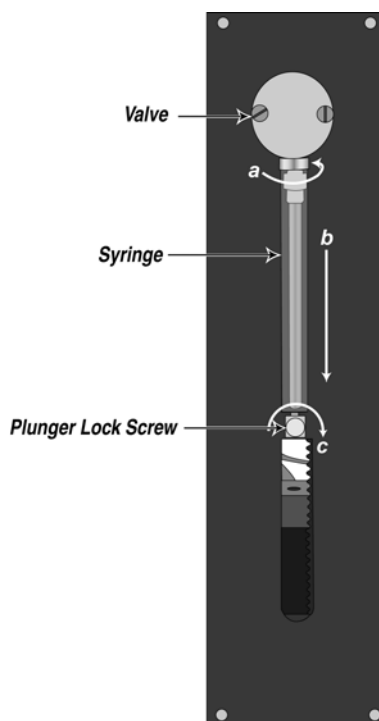

5.3.4 Replacing the Reagent Syringe Seals

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

To replace the reagent syringe seals, follow these steps:

1 Remove the syringe from the pump.

2 Remove the plunger guide.

3 Remove the syringe plunger from the barrel.

4 Using a single edged razor or precision knife, carefully slice the old seal lengthwise and remove them from the plunger.

5 Replace the "O"-ring and wet the new "O" ring and plunger tip with distilled or deionized water.

6 Place the seal in the installation tool with the open end facing up. Press the plunger tip firmly into the hole until it snaps into position.

7 Lay the plunger on a flat table top, and position it so that the seal (from the "O"-ring up) hangs over the edge.

8 Slowly roll the plunger along the table edge pressing firmly on the portion of the seal below the "O"-ring. See Figure 5-2.

Figure 5-2 *Syringe Seal Assembly*
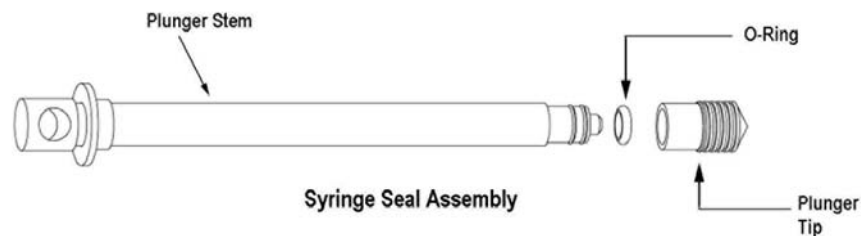
9 Rotate the plunger three complete turns. This is necessary to make the sharp raised edge of the plunger bite into the seal for a secure fit.

10 Wet the seal with distilled or deionized water, then insert the plunger/seal assembly into the glass barrel.

Note: Syringe sizes 1 mL and above have "O"-rings.

5.3.5 Replacing the XLP 6000 Valve

To replace the XLP 6000 valve, follow these steps:

1 Remove as much fluid as possible from the system by cycling the pump and using air as the system fluid.

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

3 Remove the syringe and tubing.

4 Remove the two socket head screws on the front of the valve, then remove the valve from the pump. **Do not remove the spacer.**

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

6   Replace the valve screws but do not tighten completely. Move the plunger carriage to the bottom of travel and install the syringe. Pull the syringe plunger until it is above the carriage and align the valve using the plunger as a guide. Tighten from 1/4 to 1/2 turn after the screws contact the valve body.

Figure 5-3   *XLP 6000 Valve Replacement (3-Port Valve Shown)*
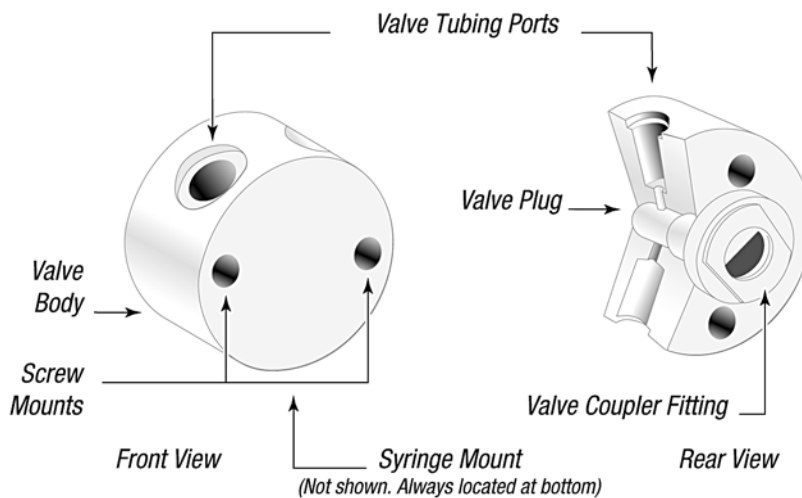
5.4   On-Site Replacements

5.4.1   Replacing the Printed Circuit Assembly (PCA)

To replace the printed circuit board assembly, follow these steps:

1   Power off the pump.
2   Remove the two screws that hold the printed circuit board to the pump.
3   Note the cable connection locations and unplug the cables from the board.
4   Plug the cables into the new board.
5   Install the new board and screw it into place.
6   Power on and reinitialize the pump.

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6   Technical Service

For information or questions regarding ordering or operating the Cavro® XLP 6000 Modular Syringe Pump, please contact Tecan Systems Technical Service using one of the methods listed below.

By phone	408-953-3100 or
	800-231-0711
By fax	408-953-3101
By e-mail	helpdesk-sy@tecan.com

Technical support is available 7:00 a.m. to 5:30 p.m. PST, Monday – Friday.

Our mailing address is:

Tecan Systems, Inc.
2450 Zanker Road
San Jose, CA   95131
USA

When calling for technical service, please have the following information ready:
- Part number
- Serial number
- Model type
- Description of the problem

Note: See the following diagram for the location of the label containing part number and serial number information.

Figure 6-1   *XLP 6000 Label Location*

Part Number/
Serial Number
Label
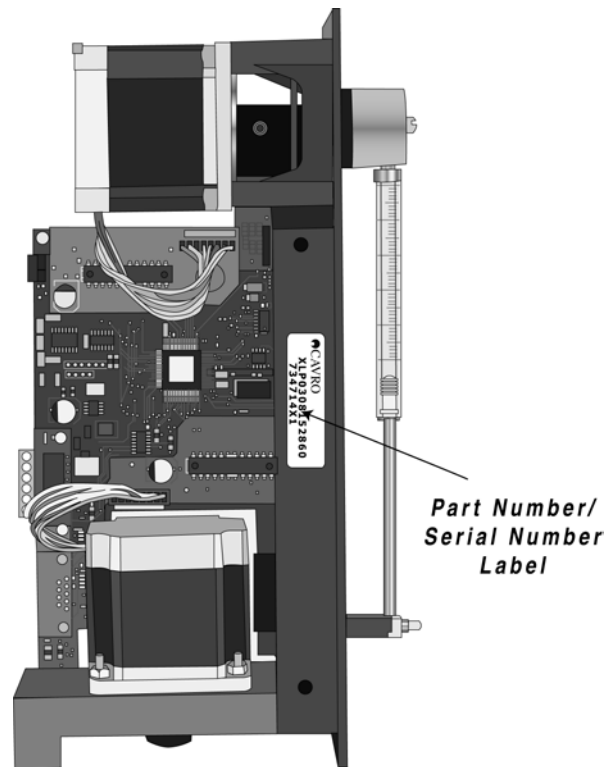
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A   Ordering Information

This appendix is a summary of available XLP 6000 configurations, other Tecan Systems liquid handling components, and spare parts for the XLP 6000.

A.1   Available Configurations

All configurations support RS-232, RS-485, and CAN communications.

Table A-1   *XLP 6000 Configurations*

Description	RoHS Compliant Part Number
XLP 6000 3-Port Valve, ¼-28	20738421
XLP 6000 3-Port Valve, M6	20738423
XLP 6000 4-Port Valve, ¼-28	20738425
XLP 6000 4-Port Valve, M6	20738427
XLP 6000 T Valve, ¼-28	20739285 *
XLP 6000 T Valve, M6	20739287 *
XLP 6000 Y Block Valve, ¼-28	20738429
XLP 6000 Y Block Valve, M6	20738431
XLP 6000 3-Port Distribution Valve, ¼-28	20738449
XLP 6000 3-Port Distribution Valve, M6	20739293*
XLP 6000 3-Port Distribution Valve, ¼-28, 50 mL	20739269
XLP 6000 6-Port Distribution Valve, ¼-28	20739263
XLP 6000 6-Port Distribution Valve, M6	20739290
XLP 6000 9-Port Distribution Valve, ¼-28	20738707
XLP 6000 9-Port Distribution Valve, M6	20739291*

* Part numbers followed by an asterisk (*) have been reserved pending release. Please check with your local Tecan Systems representative for availability.

A.2 XLP 6000 Spare Parts

The following spare parts are available:

- Syringes
- Seals
- Valves
- Printed Circuit Boards

- Interconnect Tubing
- Pump Evaluation Accessories
- Miscellaneous Parts

A.2.1 Syringes

Table A-2   *Syringes*

Part Number	Description
20734801	Syringe, 50 µL
20734802	Syringe, 100 µL
20734803	Syringe, 250 µL
20734804	Syringe, 500 µL
20734805	Syringe, 1.0 mL
20734806	Syringe, 2.5 mL
20734807	Syringe, 5.0 mL
20734808	Syringe, 10.0 mL
20734809	Syringe, 25.0 mL
20736652	Syringe, 50 mL

A.2.2 Seals and Seal Kits

Table A-3   *Seals*

Part Number	Description
20734810	Seal, 50 µL (4/pkg)
20734811	Seal, 100 µL (4/pkg)
20734812	Seal, 250 µL (4/pkg)
20734813	Seal, 500 µL (4/pkg)
20734814	Seal, 1.0 mL (4/pkg)
20734815	Seal, 2.5 mL (4/pkg)
20734816	Seal, 5.0 mL (4/pkg)
20734817	Seal, 10.0 mL (4/pkg)
20734818	Plunger, 25.0 mL (1/pkg)

A.2.3 Valves

Table A-4 *Valves*

Part Number	Description
20729370	Valve, 120° 3-Port (1/4-28" fitting)
20731305	Valve, 120° 3-Port (M6 fitting)
20736658	Valve, 90° 4-Port (1/4-28" fitting)
20736656	Valve, 90° 4-Port (M6 fitting)
20736759	Valve, T (1/4-28" fitting)
20736766	Valve, T (M6 fitting)
20736329	Valve, Y Block (1/4-28" fitting)
20736328	Valve, Y Block (M6 fitting)
20736615	Valve, 90° 3-Port Distribution (1/4-28" fitting)/plug
20736613	Valve, 90° 3-Port Distribution (M6 fitting)/plug
20739304	Valve, 6-port Distribution (1/4-28" fitting)/face seal
20739308	Valve, 6-port Distribution (M6 fitting)/face seal
20736623	Valve, 9-port Distribution (1/4-28" fitting)/face seal

* Part numbers followed by an asterisk have been reserved pending release. Please check with your local Tecan Systems representative for availability.

A.2.4 Printed Circuit Board Assemblies

Table A-5 *Printed Circuit Board Assembly*

Part Number	Description
20739173	PCBA, XLP 6000

A.2.5 Interconnect Tubing

Table A-6 *Tubing*

Part Number	Description	Material	Length (Inches)	Units	Tube Ends
201067	Reagent tube	TFE	16"	.063	1/4-28" to blunt cut
204333	Aspirate/Dispense tube	TFE	33"	.055	Necked
204410	Aspirate/Dispense tube	FEP	40"	.031	Thermal drawn
204609	Reagent tube	FEP	12"	.027	1/4-28" to blunt cut
205133	Aspirate/Dispense tube	FEP	29"	.031	Thermal drawn
205723	Aspirate/Dispense tube	FEP	33"	.031	Necked
205729	Reagent tube	TFE	21"	.031	1/4-28" to blunt cut
205402	Aspirate/Dispense coiled tube	FEP	64"	.027	Thermal drawn
206865	Interconnect tube	FEP	3"	.054	1/4-28" to 1/4-28"
20720592	Reagent tube	TFE	61.5"	.063	1/4-28" to blunt cut
20720595	Aspirate/Dispense tube	FEP	61.5"	.055	Necked
20720597	Aspirate/Dispense tube	FEP	60"	.031	Thermal drawn
20721370	Reagent tube	TFE	27"	.055	1/4-28" to blunt cut
20722540	Reagent tube	FEP	36"	.076	M6 to blunt cut
20724169	Aspirate/Dispense tube	FEP	33"	.027	Thermal drawn, M6
20724170	Reagent tube	TFE	27"	.051	M6 to blunt cut
20724275	Aspirate/Dispense tube	FEP	22"	.051	1/4-28" to M6
20724780	Aspirate/Dispense tube	FEP	39"	.076	1/4-28" to 1/4-28"
20725788	Interconnect tube	FEP	8"	.051	1/4-28" to 1/4-28"
20725876	Aspirate/Dispense tube	FEP	30"	.059	1/4-28" to M6
20725896	Interconnect tube	TFE	20"	.060	1/4-28" to 1/4-28"
20726172	Aspirate/Dispense tube	TFE	24"	.060	1/4-28" to 1/4-28"

Note: *Custom tubing is available upon request.*

A.2.6 Miscellaneous Parts

Table A-7   *Miscellaneous Parts*

Part Number	Description
201590	Fitting, Tube, 0.076 ID, (2/pk)
201589	Fitting, Tube, 0.138 ID, (2/pk)
20724757	Wrench, 5/16" and 9/64"
20734237	Manual, Operator's XLP 6000
20724052	Packaging
20725772	Connector, DA-15
20973309	Fitting, Tube, 0.085 ID, M6
20973308	Fitting, Tube, 0.100 ID, M6
20973307	Fitting, Tube, 0.125 ID, M6

A.3   Mating Connector Suppliers

Tecan Systems does not sell mating connectors beyond those found on its evaluation power supply. For customer convenience, a list of DA-15 mating connectors and their suppliers is provided below.

Table A-8   *DA-15 Mating Connectors*

Manufacturer	Description	Manufacturing Part Number
Cable Connector, Receptacle		
AMP	15 pin female - solder cup, receptacle	747909-2
Cinch	15 pin female - solder cup, receptacle	DA-15S
Cable Connector, Housing		
AMP	Plastic housing with locks	207908-4
Cinch	Plastic housing with locks	SDH-15GL-CS
Circuit Board Connectors		

Manufacturer	Description	Manufacturing Part Number
AMP	15 pin female - straight for .62 to .93 mm thick PCB	745411-1
Flat Ribbon		
3M	15 pin female - 15 pin flat ribbon receptacle	89815-8000
3M	15 pin female - strain relief	3448-8D15A

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B   Plunger Information

B.1   Typical Plunger Force

Tecan Systems specifies that all new XLP 6000 Pumps running at a speed of 5600 pulses/sec will lift a 15-pound weight attached to the plunger drive pin. Tecan Systems cannot warrant the pump for use beyond these specifications.

B.2   Plunger Time Calculations

Following are calculations for determining XLP 6000 plunger speeds. Four different cases are presented below.

1   Start, top, and cutoff speeds are equal, or top speed is less than 50 Hz.
2   Typical move with ramp up, constant speed and ramp down.
3   Move is too small to reach cutoff speed.
4   Move is too small to reach top speed.

Note: Plunger move times have been calculated with backlash compensation set to 0. [K<0>]

B.2.1   Symbol Definitions

Table B-1   Symbol Definitions

Symbol	Name	Range (n)	Unit
v <n>	Start Speed	50..1000	Pulses/sec or Hz
V<n>	Top Speed	5..6000	Pulses/sec or Hz
c<n>	Cutoff Speed	50..2700	Pulses/sec or Hz
L<n>	Slope	1..20	n*2500 pulses/sec²
A	Move Distance	0..6000 0..48000	Full increments Microsteps
t_1	Ramp Up Time		Seconds
t_2	Constant Speed Time		Seconds
t_3	Ramp Down Time		Seconds

| Symbol	Name	Range (n)	Unit
t	Total Move Time	$t_1 + t_2 + t_3$	Seconds
A_1	Ramp Up increments		Half increments
A_2	Ramp Up increments		Half increments
A_3	Ramp Up increments		Half increments

Note:

- *Cutoff speed cannot be less than start speed.*
- *During aspiration, v is used in place of c.*
- *The XLP 6000 uses 6000 full increments per stroke.*

B.2.2 Move Calculations

Case 1. Start, Top, and Cutoff Speeds are Equal or Top Speed is Less than 50 Hz

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

Diagram of move:
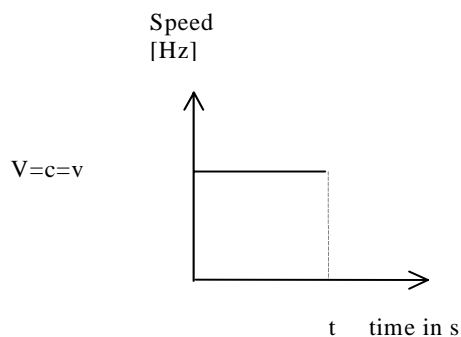
Calculation:

  v = 900 Hz   L = 14

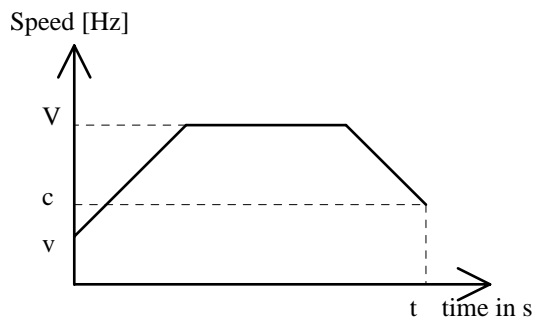 V = 900 Hz   A = 3000 full increments

  c = 900 Hz

Total Move Time:

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

Case 2. Ramp Up, Constant Speed, Ramp Down

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

Diagram of Move:

Calculation:

v = 50 Hz   L = 14

V = 5800 Hz   A = 3000 full increments

c = 500 Hz

Ramp Up increments

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

Ramp Down increments

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

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

Ramp Up Time

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

Ramp Down Time

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

Constant Speed increments

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

Constant Speed Time

$$t_2 = \frac{A_2}{V} = \frac{5042}{5800} = .87 \quad \text{seconds}$$
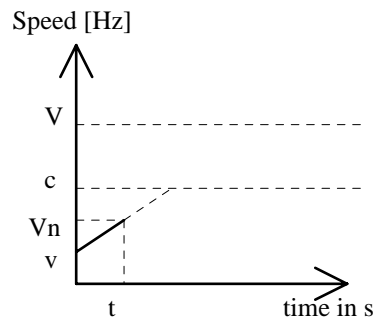
Total Move Time

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

Case 3. Move Too Small to Reach Cutoff Speed

Case 3 is used when Vn < c

Diagram of Move:

Calculation:

v = 50 Hz   L = 14

V = 5800 Hz   A = 5 full increments

c = 900 Hz

Theoretical Top speed

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

If $Vn < c$ then:

Total Move Time

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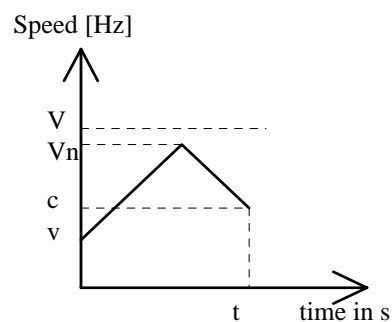
Ramp Up increments

$$A_1 = A = 5 \;\; \text{full increments}$$

Case 4. Move Too Small to Reach Top Speed

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

Diagram of Move:

Calculation:

v = 50 Hz		L = 14
V = 5800 Hz		A = 350 full increments
c = 900 Hz		

Top speeds

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

Total Move Time

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

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C ASCII Chart of Codes for U.S. Characters

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

Decimal	Hexadecimal	Character or Function	Decimal	Hexadecimal	Character or Function
0	00	none	65	41	A
1	01	SOH	66	42	B
2	02	STX	67	43	C
3	03	ETX	68	44	D
4	04	EOT	69	45	E
5	05	ENQ	70	46	F
6	06	ACK	71	47	G
7	07	BEL	72	48	H
8	08	BS	73	49	I
9	09	HT	74	4A	J
10	0A	LF	75	4B	K
11	0B	VT	76	4C	L
12	0C	FF	77	4D	M
13	0D	CR	78	4E	N
14	0E	SO	79	4F	O
15	0F	SI	80	50	P
16	10	DLE	81	51	Q
17	11	DC1	82	52	R
18	12	DC2	83	53	S
19	13	DC3	84	54	T
20	14	DC4	85	55	U
21	15	NAK	86	56	V
22	16	SYN	87	57	W
23	17	ETB	88	58	X
24	18	CAN	89	59	Y

Decimal	Hexadecimal	Character or Function	Decimal	Hexadecimal	Character or Function
25	19	EM	90	5A	Z
26	1A	SUB	91	5B	[
27	1B	ESC	92	5C	\ (backslash)
28	1C	FS	93	5D	]
29	1D	GS	94	5E	^ (control)
30	1E	RS	95	5F	— (emdash)
31	1F	US	96	60	` (tick)
32	20	SP	97	61	a
33	21	!	98	62	b
34	22	"	99	63	c
35	23	#	100	64	d
36	24	$	101	65	e
37	25	%	102	66	f
38	26	&	103	67	g
39	27	' (apostrophe)	104	68	h
40	28	(	105	69	i
41	29	)	106	6A	j
42	2A	*	107	6B	k
43	2B	+	108	6C	l
44	2C	, (comma)	109	6D	m
45	2D	- (en dash)	110	6E	n
46	2E	. (period)	111	6F	o
47	2F	/	112	70	p
48	30	0	113	71	q
49	31	1	114	72	r
50	32	2	115	73	s
51	33	3	116	74	t
52	34	4	117	75	u

Decimal	Hexadecimal	Character or Function	Decimal	Hexadecimal	Character or Function
53	35	5	118	76	v
54	36	6	119	77	w
55	37	7	120	78	x
56	38	8	121	79	y
57	39	9	122	7A	z
58	3A	:	123	7B	{ (left brace)
59	3B	;	124	7C	| (vertical bar)
60	3C	<	125	7D	} (right brace)
61	3D	=	126	7E	~ (tilde)
62	3E	>	127	7F	DEL
63	3F	?			
64	40	@			

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D Chemical Resistance Chart

The information provided in the table that starts on the next page has been supplied to Tecan Systems by other reputable sources and is to be used ONLY as a guideline. Before permanent installation, test the equipment with the chemicals under the specific conditions of your application.

Ratings of chemical behavior listed in this chart apply to a 48-hour exposure period; Tecan Systems has no knowledge of possible effects beyond this period. Tecan Systems does not warrant (neither express or implied) that the information in this chart is accurate or complete or that materials are suitable for any purpose.

Caution! *Failure to test chemicals used in individual applications with the XLP 6000 may result in damage to the pump and/or test results.*

DANGER! *Variations in chemical behavior during handling due to factors such as temperature, pressure and concentration can cause equipment to fail, even though it passed an initial test.* *SERIOUS INJURY MAY RESULT. Use suitable guards and/or personal protection when handling chemicals.*

The materials listed are used in the following areas of the XLP 6000:

Table D-1 *Plastic Materials Used in Tecan Pumps*

Plug Valve	
Plug	Teflon® (PTFE)
Valve body	PCTFE
Face Seal Valve	
Rotor	UHMWPE
Stator	PPS

Ratings – Chemical Effect

A = Excellent

B = Good – Minor Effect, slight corrosion or discoloration

C = Fair – Moderate Effect, not recommended for continuous use. Softening, loss of strength, swelling may occur.

D = Severe Effect, not recommended for **ANY** use.

N/A = Information Not Available

Explanation of Footnotes

1. Satisfactory to 72°F (22°C)
2. Satisfactory to 120°F (48°C)

Table D-2 *XLP Chemical Compatibility Results*

Chemical	PCTFE	Teflon	PPS	UHMWPE
Acetaldehyde	A- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Acetamide	A- Excellent	A- Excellent	A-Excellent	N/A
Acetate Solvent	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Acetic Acid	A- Excellent	A- Excellent	A-Excellent	B1-Good
Acetic Acid 20%	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Acetic Acid 80%	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Acetic Acid, Glacial	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Acetic Anhydride	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Acetone	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Acetyl Chloride (dry)	A- Excellent	A- Excellent	A-Excellent	N/A
Acetylene	A- Excellent	A- Excellent	A-Excellent	N/A
Acrylonitrile	N/A	A- Excellent	N/A	N/A
Adipic Acid	N/A	A- Excellent	N/A	N/A
Alcohols:Amyl	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Alcohols:Benzyl	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Alcohols:Butyl	N/A	A- Excellent	A-Excellent	A-Excellent
Alcohols:Diacetone	B1- Good	A- Excellent	N/A	N/A
Alcohols:Ethyl	A- Excellent	A- Excellent	N/A	A-Excellent
Alcohols:Hexyl	N/A	A- Excellent	N/A	N/A
Alcohols:Isobutyl	N/A	A2- Excellent	N/A	N/A
Alcohols:Isopropyl	N/A	A2- Excellent	N/A	A-Excellent
Alcohols:Methyl	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Alcohols:Octyl	N/A	N/A	N/A	N/A
Alcohols:Propyl	N/A	A- Excellent	A-Excellent	A-Excellent
Aluminum Chloride	A- Excellent	A- Excellent	A- Excellent	A2- Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Aluminum Chloride 20%	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Aluminum Fluoride	N/A	A- Excellent	A- Excellent	A2- Excellent
Aluminum Hydroxide	A1- Excellent	A- Excellent	N/A	A2- Excellent
Aluminum Nitrate	A1- Excellent	A- Excellent	N/A	N/A
Aluminum Potassium Sulfate 100%	A- Excellent	A- Excellent	N/A	A2- Excellent
Aluminum Sulfate	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Amines (General)	A- Excellent	A2- Excellent	B-Good	A2- Excellent
Ammonia, anhydrous	A- Excellent	A- Excellent	A1- Excellent	A2- Excellent
Ammonia, Aqueous	A- Excellent	A- Excellent	N/A	N/A
Ammonia Nitrate	N/A	A- Excellent	A- Excellent	N/A
Ammonium Acetate	N/A	A- Excellent	N/A	N/A
Ammonium Bifluoride	N/A	A- Excellent	N/A	N/A
Ammonium Carbonate	N/A	A- Excellent	A- Excellent	C1-Fair
Ammonium Chloride	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Ammonium Hydroxide	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Ammonium Nitrate	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Ammonium Oxalate	N/A	N/A	N/A	N/A
Ammonium Persulfate	A- Excellent	A- Excellent	N/A	A2- Excellent
Ammonium Phosphate, Dibasic	A- Excellent	A2- Excellent	A- Excellent	A1- Excellent
Ammonium Phosphate, Monobasic	N/A	A- Excellent	N/A	A1- Excellent
Ammonium Phosphate, Tribasic	N/A	A- Excellent	N/A	A1- Excellent
Ammonium Sulfate	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Ammonium Thiosulfate	N/A	N/A	N/A	N/A
Amyl Acetate	A1- Excellent	A- Excellent	A- Excellent	A1- Excellent
Amyl Alcohol	A- Excellent	A- Excellent	A- Excellent	A2- Excellent
Amyl Chloride	A- Excellent	A- Excellent	N/A	D-Severe Effect
Aniline	A2- Excellent	A- Excellent	A- Excellent	A1- Excellent
Aniline Hydrochloride	N/A	A- Excellent	N/A	N/A
Antifreeze	N/A	N/A	N/A	A2-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Antimony Trichloride	A- Excellent	A- Excellent	N/A	D-Severe Effect
Aqua Regia (80% HCl, 20% HNO3)	A- Excellent	A- Excellent	D-Severe Effect	B1-Good
Arochlor 1248	A1- Excellent	A- Excellent	N/A	N/A
Aromatic Hydrocarbons	N/A	N/A	N/A	B1-Good
Arsenic Acid	N/A	A- Excellent	A-Excellent	A1-Excellent
Arsenic Salts	N/A	N/A	N/A	N/A
Asphalt	A- Excellent	A1- Excellent	A-Excellent	A1-Excellent
Barium Carbonate	A- Excellent	A- Excellent	A2-Excellent	N/A
Barium Chloride	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Barium Cyanide	N/A	A1- Excellent	N/A	N/A
Barium Hydroxide	A- Excellent	A- Excellent	A-Excellent	A2- Excellent
Barium Nitrate	A- Excellent	A- Excellent	N/A	N/A
Barium Sulfate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Barium Sulfide	N/A	A- Excellent	N/A	A2- Excellent
Benzaldehyde	A- Excellent	A1- Excellent	A-Excellent	A1-Excellent
Benzene	B- Good	A- Excellent	A-Excellent	B1-Good
Benzene Sulfonic Acid	N/A	A- Excellent	A-Excellent	A2- Excellent
Benzoic Acid	A- Excellent	A2- Excellent	A1-Excellent	A2- Excellent
Benzol	A- Excellent	A- Excellent	N/A	N/A
Benzonitrile	A2- Excellent	A2- Excellent	N/A	N/A
Benzyl Chloride	N/A	N/A	N/A	N/A
Bleach Solutions	A- Excellent	A- Excellent	N/A	N/A
Borax (Sodium Borate)	A- Excellent	A- Excellent	A-Excellent	A2- Excellent
Boric Acid	A- Excellent	A- Excellent	A-Excellent	A2- Excellent
Bromine Water	A- Excellent	A- Excellent	D-Severe Effect	D-Severe Effect
Butadiene	A- Excellent	A2- Excellent	A1-Excellent	D-Severe Effect
Butane	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Butanol (Butyl Alcohol)	A1- Excellent	A2- Excellent	A-Excellent	A-Excellent
Butyl Amine	D- Severe Effect	A2- Excellent	D-Severe Effect	N/A

Chemical	PCTFE	Teflon	PPS	UHMWPE
Butyl Ether	A1- Excellent	A1- Excellent	A2-Excellent	N/A
Butyl Phthalate	A1- Excellent	A2- Excellent	A-Excellent	A2-Excellent
Butylacetate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Butylene	B1- Good	A- Excellent	A-Excellent	A1-Excellent
Butyric Acid	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Calcium Bisulfate	N/A	N/A	N/A	N/A
Calcium Bisulfide	A- Excellent	A- Excellent	N/A	N/A
Calcium Bisulfite	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Calcium Carbonate	N/A	A- Excellent	N/A	N/A
Calcium Chloride	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Calcium Hydroxide	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Calcium Hypochlorite	B1- Good	A- Excellent	A-Excellent	A-Excellent
Calcium Nitrate	A1- Excellent	A2- Excellent	A-Excellent	N/A
Calcium Oxide	N/A	A- Excellent	A-Excellent	N/A
Calcium Sulfate	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Carbon Bisulfide	N/A	N/A	N/A	D-Severe Effect
Carbon Tetrachloride	A1- Excellent	A- Excellent	A-Excellent	C1-Fair
Carbon Tetrachloride (dry)	D- Severe Effect	A- Excellent	N/A	N/A
Carbon Tetrachloride (wet)	A1- Excellent	A- Excellent	N/A	N/A
Carbonated Water	N/A	A- Excellent	N/A	N/A
Carbonic Acid	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Chloric Acid	A- Excellent	A- Excellent	N/A	N/A
Chlorine Water	A- Excellent	A- Excellent	D-Severe Effect	A-Excellent
Chlorine, Anhydrous Liquid	B2- Good	A- Excellent	D-Severe Effect	B1-Good
Chloroacetic Acid	A2- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Chlorobenzene (Mono)	A1- Excellent	B- Good	A-Excellent	C1-Fair
Chlorobromomethane	N/A	A- Excellent	N/A	N/A
Chloroform	A1- Excellent	A1- Excellent	A-Excellent	B1-Good
Chlorosulfonic Acid	A2- Excellent	A- Excellent	D-Severe Effect	D-Severe Effect

Chemical	PCTFE	Teflon	PPS	UHMWPE
Chromic Acid 10%	A- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Chromic Acid 30%	A- Excellent	A- Excellent	B-Good	A-Excellent
Chromic Acid 5%	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Chromic Acid 50%	A2- Excellent	A- Excellent	A1-Excellent	A-Excellent
Citric Acid	A2- Excellent	A- Excellent	A-Excellent	A-Excellent
Citric Oils	N/A	N/A	N/A	N/A
Clorox® (Bleach)	A- Excellent	A- Excellent	D-Severe Effect	A-Excellent
Copper Chloride	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Copper Cyanide	N/A	A- Excellent	A-Excellent	A1-Excellent
Copper Nitrate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Copper Sulfate >5%	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Copper Sulfate 5%	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Cresols	A1- Excellent	N/A	A-Excellent	N/A
Cresylic Acid	N/A	A- Excellent	N/A	B1-Good
Cupric Acid	A2- Excellent	A- Excellent	A-Excellent	N/A
Cyanic Acid	N/A	A- Excellent	N/A	N/A
Cyclohexane	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Cyclohexanone	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Detergents	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Diacetone Alcohol	B1- Good	A- Excellent	N/A	N/A
Dichlorobenzene	N/A	A- Excellent	N/A	N/A
Dichloroethane	A2- Excellent	A1- Excellent	N/A	C1-Fair
Diesel Fuel	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Diethyl Ether	C- Fair	A- Excellent	A-Excellent	C1-Fair
Diethylamine	A1- Excellent	A- Excellent	N/A	N/A
Diethylene Glycol	N/A	A- Excellent	N/A	N/A
Dimethyl Aniline	A- Excellent	A- Excellent	A-Excellent	N/A
Dimethyl Formamide	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Diphenyl	B1-Good	A- Excellent	N/A	N/A

Chemical	PCTFE	Teflon	PPS	UHMWPE
Diphenyl Oxide	N/A	A- Excellent	A-Excellent	N/A
Epsom Salts (Magnesium Sulfate)	A- Excellent	A- Excellent	A-Excellent	N/A
Ethane	A1- Excellent	A- Excellent	N/A	A1-Excellent
Ethanol	A- Excellent	A- Excellent	N/A	A-Excellent
Ethanolamine	D- Severe Effect	A1- Excellent	A-Excellent	N/A
Ether	B1- Good	A- Excellent	A-Excellent	B1-Good
Ethyl Acetate	A1- Excellent	A- Excellent	A-Excellent	A2-Excellent
Ethyl Benzoate	A1- Excellent	A- Excellent	N/A	N/A
Ethyl Ether	A1- Excellent	A- Excellent	A-Excellent	C1-Fair
Ethyl Sulfate	A- Excellent	A- Excellent	N/A	N/A
Ethylene Bromide	B- Good	A- Excellent	N/A	N/A
Ethylene Chloride	A1- Excellent	A- Excellent	A-Excellent	C1-Fair
Ethylene Chlorohydrin	A- Excellent	A- Excellent	N/A	N/A
Ethylene Diamine	D- Severe Effect	A- Excellent	A-Excellent	A1-Excellent
Ethylene Dichloride	A1- Excellent	A- Excellent	A-Excellent	C1-Fair
Ethylene Glycol	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Ethylene Oxide	A2- Excellent	A- Excellent	D-Severe Effect	A1-Excellent
Fatty Acids	A- Excellent	A- Excellent	N/A	A-Excellent
Ferric Chloride	A2- Excellent	A- Excellent	A-Excellent	A-Excellent
Ferric Nitrate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Ferric Sulfate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Ferrous Chloride	B1- Good	A- Excellent	A-Excellent	A1-Excellent
Ferrous Sulfate	N/A	A- Excellent	A-Excellent	A1-Excellent
Fluoboric Acid	B1-Good	A- Excellent	A-Excellent	A-Excellent
Fluorine Liquid	N/A	N/A	D-Severe Effect	C1-Fair
Fluorosilicic Acid	A1- Excellent	A- Excellent	N/A	N/A
Formaldehyde 100%	N/A	A- Excellent	B-Good	A-Excellent
Formaldehyde 40%	A- Excellent	A- Excellent	A-Excellent	A-ExcellentA
Formic Acid	A- Excellent	A- Excellent	A-Excellent	A-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Freon 113	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Freon 12	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Freon 22	A1- Excellent	A- Excellent	A-Excellent	N/A
Freon® 11	A1- Excellent	A- Excellent	A-Excellent	N/A
Fuel Oils	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Furan Resin	A1- Excellent	A- Excellent	A-Excellent	N/A
Furfural	D- Severe Effect	A- Excellent	A-Excellent	A1-Excellent
Gallic Acid	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Gasoline (high-aromatic)	A1- Excellent	A- Excellent	A-Excellent	N/A
Glucose	N/A	A- Excellent	B-Good	A1-Excellent
Glycerin	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Glycolic Acid	A1- Excellent	A- Excellent	A-Excellent	N/A
Heptane	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Hexane	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Hydraulic Oil (Petro)	A1- Excellent	A- Excellent	D-Severe Effect	B1-Good
Hydrazine	N/A	A- Excellent	N/A	N/A
Hydrobromic Acid 100%	A- Excellent	A- Excellent	A1-Excellent	A-Excellent
Hydrobromic Acid 20%	A- Excellent	A- Excellent	N/A	A-Excellent
Hydrochloric Acid 100%	A- Excellent	A- Excellent	D-Severe Effect	A-Excellent
Hydrochloric Acid 20%	A- Excellent	A- Excellent	D-Severe Effect	A-Excellent
Hydrochloric Acid 37%	A- Excellent	A- Excellent	D-Severe Effect	A-Excellent
Hydrofluoric Acid 100%	B- Good	A- Excellent	D-Severe Effect	A2-Excellent
Hydrofluoric Acid 20%	A- Excellent	A- Excellent	A-Excellent	A2-Excellent
Hydrofluosilicic Acid 100%	B- Good	A- Excellent	A1-Excellent	B1-Good
Hydrofluosilicic Acid 20%	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Hydrogen Peroxide 10%	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Hydrogen Peroxide 100%	B- Good	A- Excellent	C--Fair	A1-Excellent
Hydrogen Peroxide 30%	B- Good	A- Excellent	A1-Excellent	A-Excellent
Hydrogen Peroxide 50%	A- Excellent	A- Excellent	N/A	B2-Good

Chemical	PCTFE	Teflon	PPS	UHMWPE
Hydrogen Sulfide (Aqueous)	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Hydroxyacetic Acid 70%	A1- Excellent	A- Excellent	N/A	N/A
Iodine	A1- Excellent	A- Excellent	D-Severe Effect	A1-Excellent
Iodine (in alcohol)	NA	A- Excellent	N/A	A1-Excellent
Isooctane	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Isopropyl Acetate	N/A	A- Excellent	N/A	N/A
Isopropyl Ether	A1- Excellent	A- Excellent	N/A	A1-Excellent
Kerosene	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Ketones	A1- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Lacquer Thinners	A2- Excellent	A- Excellent	N/A	A1-Excellent
Lacquers	A1- Excellent	A- Excellent	N/A	N/A
Lactic Acid	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Lead Acetate	A- Excellent	A- Excellent	N/A	N/A
Lead Nitrate	N/A	A- Excellent	N/A	N/A
Lead Sulfamate	N/A	B- Good	N/A	N/A
Ligroin	N/A	A- Excellent	N/A	N/A
Linoleic Acid	N/A	A- Excellent	N/A	N/A
Lithium Chloride	N/A	A- Excellent	N/A	D-Severe Effect
Lithium Hydroxide	N/A	A- Excellent	N/A	D-Severe Effect
Lye: Ca(OH)2 Calcium Hydroxide	A2- Excellent	A- Excellent	A-Excellent	A-Excellent
Magnesium Bisulfate	N/A	A- Excellent	N/A	N/A
Magnesium Carbonate	N/A	A1- Excellent	N/A	N/A
Magnesium Chloride	A- Excellent	A- Excellent	A1-Excellent	A2-Excellent
Magnesium Hydroxide	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Magnesium Nitrate	N/A	A- Excellent	A-Excellent	A1-Excellent
Magnesium Oxide	N/A	A- Excellent	N/A	N/A
Magnesium Sulfate (Epsom Salts)	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Maleic Acid	N/A	A- Excellent	B-Good	A-Excellent
Maleic Anhydride	N/A	A- Excellent	N/A	N/A

Chemical	PCTFE	Teflon	PPS	UHMWPE
Malic Acid	N/A	A- Excellent	N/A	N/A
Manganese Sulfate	A1- Excellent	A- Excellent	A2-Excellent	N/A
Mercury	A1- Excellent	A- Excellent	N/A	A-Excellent
Methanol (Methyl Alcohol)	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Methyl Acetate	A1- Excellent	A- Excellent	N/A	A1-Excellent
Methyl Acetone	N/A	A- Excellent	N/A	N/A
Methyl Acrylate	A1- Excellent	A- Excellent	N/A	N/A
Methyl Bromide	A1- Excellent	A- Excellent	N/A	N/A
Methyl Butyl Ketone	N/A	A- Excellent	N/A	N/A
Methyl Cellosolve	N/A	A- Excellent	N/A	N/A
Methyl Chloride	A1- Excellent	A- Excellent	B-Good	B1-Good
Methyl Dichloride	N/A	A- Excellent	N/A	N/A
Methyl Ethyl Ketone	A1- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Methyl Isobutyl Ketone	A- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Methyl Isopropyl Ketone	N/A	A- Excellent	N/A	N/A
Methyl Methacrylate	N/A	A- Excellent	N/A	N/A
Methylamine	A1- Excellent	A- Excellent	N/A	N/A
Methylene Chloride	A1- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Mineral Spirits	A1- Excellent	A- Excellent	A-Excellent	N/A
Monochloroacetic acid	A2- Excellent	A- Excellent	N/A	D-Severe Effect
Monoethanolamine	D- Severe Effect	A- Excellent	A-Excellent	N/A
Morpholine	A1- Excellent	A- Excellent	C-Fair	N/A
Motor oil	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Naphthalene	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Nickel Chloride	A2- Excellent	A- Excellent	A-Excellent	A2-Excellent
Nickel Nitrate	A2- Excellent	A- Excellent	N/A	A1-Excellent
Nickel Sulfate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Nitric Acid (20%)	A1- Excellent	A- Excellent	C-Fair	A-Excellent
Nitric Acid (50%)	A1- Excellent	A- Excellent	C-Fair	A2-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Nitric Acid (5-10%)	A1- Excellent	A- Excellent	B1-Good	A-Excellent
Nitric Acid (Concentrated)	A1- Excellent	A- Excellent	C-Fair	D-Severe Effect
Nitrobenzene	A- Excellent	A- Excellent	A2-Excellent	A1-Excellent
Nitrous Acid	B- Good	A- Excellent	N/A	N/A
Oil Crude, Sour	A- Excellent	A- Excellent	N/A	N/A
Oil Crude, Sweet	A- Excellent	A- Excellent	N/A	N/A
Oil Mineral	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Oleic Acid	A1- Excellent	A- Excellent	A-Excellent	A2-Excellent
Oleum 100%	A1- Excellent	A- Excellent	A1-Excellent	D-Severe Effect
Oxalic Acid (cold)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Ozone	A1- Excellent	A- Excellent	N/A	B1-Good
Palmitic Acid	N/A	A- Excellent	N/A	N/A
Perchloroethylene	A1- Excellent	A- Excellent	A-Excellent	B1-Good
Petrolatum	N/A	A- Excellent	N/A	A1-Excellent
Petroleum	A- Excellent	A- Excellent	N/A	A2-Excellent
Phenol (10%)	A- Excellent	A- Excellent	A-Excellent	B1-Good
Phosphoric Acid (>40%)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Phosphoric Acid (40%)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Phosphoric Acid (crude)	A2- Excellent	A- Excellent	A-Excellent	A-Excellent
Phosphoric Acid Anhydride	N/A	A- Excellent	D-Severe Effect	N/A
Phosphorus	N/A	A- Excellent	N/A	N/A
Phosphorus Trichloride	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Photographic Developer	A- Excellent	A- Excellent	N/A	A-Excellent
Photographic Solutions	A- Excellent	A- Excellent	A2-Excellent	A-Excellent
Phthalic Acid	N/A	A- Excellent	N/A	A-Excellent
Phthalic Anhydride	A- Excellent	A- Excellent	N/A	N/A
Picric Acid	A1- Excellent	A- Excellent	A-Excellent	N/A
Potash (Potassium Carbonate)	A1- Excellent	A- Excellent	N/A	A1-Excellent
Potassium Bicarbonate	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Potassium Bromide	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Potassium Chlorate	A2- Excellent	A- Excellent	A-Excellent	A-Excellent
Potassium Chloride	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Potassium Chromate	N/A	A- Excellent	N/A	A1-Excellent
Potassium Cyanide Solutions	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Potassium Ferricyanide	A1- Excellent	A- Excellent	N/A	A1-Excellent
Potassium Ferrocyanide	A1- Excellent	A- Excellent	N/A	A1-Excellent
Potassium Hydroxide (Caustic Potash)	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Potassium Hypochlorite	A1- Excellent	A- Excellent	A-Excellent	B1-Good
Potassium Iodide	N/A	A- Excellent	A2-Excellent	B1-Good
Potassium Nitrate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Potassium Oxalate	N/A	A- Excellent	N/A	A1-Excellent
Potassium Permanganate	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Potassium Sulfate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Potassium Sulfide	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Propane (liquefied)	A1- Excellent	A- Excellent	N/A	N/A
Pyridine	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Pyrogallic Acid	A1- Excellent	A- Excellent	N/A	N/A
Resorcinal	A1- Excellent	A- Excellent	N/A	N/A
Salicylic Acid	A1- Excellent	A2- Excellent	N/A	N/A
Salt Brine (NaCl saturated)	A- Excellent	A2- Excellent	A-Excellent	A-Excellent
Sea Water	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Silver Bromide	A- Excellent	A2- Excellent	N/A	N/A
Silver Nitrate	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Soap Solutions	N/A	A- Excellent	A-Excellent	A-Excellent
Sodium Acetate	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Aluminate	N/A	A- Excellent	A-Excellent	N/A
Sodium Benzoate	N/A	A- Excellent	N/A	A1-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Sodium Bicarbonate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Bisulfate	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Bisulfite	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Borate (Borax)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Bromide	A1- Excellent	A- Excellent	N/A	N/A
Sodium Carbonate	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Chlorate	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Chloride	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Chromate	A1- Excellent	A- Excellent	A-Excellent	N/A
Sodium Cyanide	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Ferrocyanide	N/A	A- Excellent	N/A	N/A
Sodium Fluoride	A1- Excellent	A1- Excellent	N/A	N/A
Sodium Hydrosulfite	N/A	A- Excellent	N/A	N/A
Sodium Hydroxide (20%)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Hydroxide (50%)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Hydroxide (80%)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Sodium Hypochlorite (<20%)	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Hypochlorite (100%)	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Hyposufite	A- Excellent	A- Excellent	N/A	A-Excellent
Sodium Metaphosphate	N/A	A- Excellent	N/A	A1-Excellent
Sodium Metasilicate	N/A	A- Excellent	N/A	A-Excellent
Sodium Nitrate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Perborate	A1- Excellent	A- Excellent	N/A	A1-Excellent
Sodium Peroxide	A1- Excellent	A- Excellent	N/A	A-Excellent
Sodium Polyphosphate	N/A	A- Excellent	N/A	N/A
Sodium Silicate	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Sulfate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Sulfide	A1- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sodium Sulfite	N/A	N/A	N/A	A1-Excellent

Chemical	PCTFE	Teflon	PPS	UHMWPE
Sodium Tetraborate	A- Excellent	A- Excellent	N/A	A-Excellent
Sodium Thiosulfate (hypo)	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Stannic Chloride	A- Excellent	A- Excellent	A-Excellent	N/A
Stannous Chloride	A1- Excellent	A- Excellent	A1-Excellent	N/A
Starch	A1- Excellent	A- Excellent	N/A	N/A
Stearic Acid	N/A	A- Excellent	N/A	A1-Excellent
Styrene	N/A	A- Excellent	N/A	N/A
Sulfur Chloride	A1- Excellent	A- Excellent	N/A	N/A
Sulfur Dioxide	N/A	A- Excellent	A-Excellent	A-Excellent
Sulfur Trioxide	A1- Excellent	A- Excellent	N/A	N/A
Sulfuric Acid (10-75%)	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Sulfuric Acid (75-100%)	A- Excellent	A- Excellent	A1-Excellent	A1-Excellent
Sulfurous Acid	A1- Excellent	A- Excellent	A-Excellent	B1-Good
Sulfuryl Chloride	N/A	A- Excellent	N/A	N/A
Tartaric Acid	A2- Excellent	A- Excellent	A-Excellent	A1-Excellent
Tetrachloroethane	A1- Excellent	A- Excellent	N/A	N/A
Tetrachloroethylene	A1- Excellent	A- Excellent	N/A	B1-Good
Tetrahydrofuran	A1- Excellent	A- Excellent	A-Excellent	D-Severe Effect
Toluene (Toluol)	B2- Good	A- Excellent	A-Excellent	A1-Excellent
Trichloroacetic Acid	A1- Excellent	A- Excellent	A-Excellent	N/A
Trichloroethane	A1- Excellent	A- Excellent	N/A	C1-Fair
Trichloroethylene	B2- Good	A- Excellent	A1-Excellent	D-Severe Effect
Trichloropropane	A1- Excellent	A1- Excellent	N/A	N/A
Tricresylphosphate	N/A	A- Excellent	N/A	A1-Excellent
Triethylamine	A1- Excellent	A- Excellent	N/A	N/A
Trisodium Phosphate	N/A	A- Excellent	A-Excellent	A-Excellent
Turpentine	A- Excellent	A- Excellent	A-Excellent	A1-Excellent
Urea	N/A	A- Excellent	A-Excellent	A-Excellent
Uric Acid	N/A	A- Excellent	N/A	N/A

Chemical	PCTFE	Teflon	PPS	UHMWPE
Urine	N/A	A1- Excellent	N/A	N/A
Varnish	A- Excellent	A- Excellent	N/A	N/A
Vinyl Acetate	N/A	A2- Excellent	N/A	N/A
Vinyl Chloride	N/A	A2- Excellent	N/A	C1-Fair
Water, Deionized	A1- Excellent	A2- Excellent	A-Excellent	A-Excellent
Water, Distilled	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Water, Fresh	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Water, Salt	A- Excellent	A- Excellent	A-Excellent	A-Excellent
Xylene	A- Excellent	A- Excellent	A-Excellent	C1-Fair
Zinc Chloride	A1- Excellent	A- Excellent	A-Excellent	A-Excellent
Zinc Hydrosulfite	N/A	A1- Excellent	A-Excellent	N/A
Zinc Sulfate	A- Excellent	A- Excellent	A-Excellent	A1-Excellent

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E XLP 6000 Physical Specifications

Table E-1 *XLP 6000 Physical Specifications*

Note: Specifications listed here are subject to change without notice.

Dimensions	Height	10.00 in. (254 mm)
	Width	2.56 in. (65 mm)
	Depth	4.76 in. (121 mm) from front panel to connector
	Weight	4.70 lb. (2.13 kg)
Resolution		6,000 steps in standard mode and 48,000 steps in fine-positioning and microstep mode
Plunger Drive	Principle	Stepper motor driven lead screw with quadrature encoder for step loss detection
	Travel	60 mm
	Plunger Speed	5 - 6000 pulses per second
Syringes	Sizes	50 μL, 100 μL, 250 μL, 500 μL, 1.0 mL, 2.5 mL, 5.0 mL, 10.0 mL, 25.0 mL and 50.0 mL
	Barrel Material	Borosilicate glass
	Plunger Material	Stainless steel
	Seal Material	Virgin Teflon (PTFE, TFE) and UHMWPE (Black seals)
	Precision	$\leq$ 0.05% CV at full stroke (500 μL syringe and above) $\leq$ 0.5% CV at full stroke (250 μL and 100 μL syringe) $\leq$ 1% CV at full stroke (50 mL syringe)
	Accuracy	$\leq$ 1% at full stroke
Valve Drive	Turn time	$\leq$ 250 ms between adjacent ports
	Drive	Stepper motor with optical encoder for positioning feedback

Valves	Plug	Plug: Teflon Body: PCTFE
	Face Seal	Rotor: UHMWPE Stator: PPS
	Fittings	1/4-28 and M6 tubing fittings
		1/4-28" syringe fitting
	Valve Options	120° 3-port 90° 4-port 3-port distribution Y block T valve 6-port distribution 9-port distribution
	Fluid Contact	Glass, PCTFE, Teflon
Power Requirements	Voltage	24V DC ± 2%
	Current	2 A (peak)
Interface	Type	RS-232, RS-485 and CAN
	Baud Rate	9600 or 38400 (RS-232 and RS-485) 100K, 125K, 250K, 500K and 1M (CAN)
	Format	Data bits: 8
		Parity: No
		Stop bit: 1
		Half duplex
Communications	Addressing	Up to 15 individual addresses available
	Communications	Data terminal and OEM protocol (with error recognition)

Firmware		Programmable ramps
		Programmable plunger speeds
		Cutoff speed
		Backlash compensation
		Programmable delays and loops
		Change speed on the fly
		Terminate moves
		Diagnostics
		Absolute or relative positions
		Programmable non-volatile memory
Inputs		Two TTL level inputs with 4.7k pull-ups
Outputs		Three outputs, CMOS (HC) level
Environmental	Operating temperature (mechanism)	59°F (15°C) to 104°F (40°C)
	Operating humidity (mechanism)	20-80% RH at 104°F (40°C)
	Storage temperature	-4°F (-20°C) to 149°F (65°C)
Safety and Regulatory Compliance		The XLP 6000 is a UL recognized electronic component and bears the UL Recognized component mark. Tecan Systems' UL customer file number is E164638. Tecan Systems' Quality System is ISO 13485 Certified. The XLP 6000 meets the requirements set by the European Union's Directive 2002/95/EC on the Restriction of Hazardous Substances.

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F CAN Communication Commands

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

Command Type	Command	Valid/Invalid	CAN Equivalent
Report	#	Invalid	Frame type = 6 Command = "20" (ASCII)
Report	%	Invalid	Frame type = 6 Command = "18" (ASCII)
Report	$	Invalid	Frame type = 6 Command = "19" (ASCII)
Report	*	Invalid	None

G Command Quick Reference

G.1   Pump Configuration Commands

Command	Values of \<n\>	Description
N	0 = fine positioning mode off 1 = fine positioning mode on 2 = microstep mode on	Enables or disables microstepping or fine positioning mode
U	0 = No Valve 1 = 3-Port Valve 2 = 4-Port Valve 4 = T Valve 7 = 6-Port Distribution Valve 8 = 9-Port Distribution Valve 9 = Dual loop valve 11 = 3-Port Distribution Valve (plug) 30 = Set Non-Volatile Memory Auto Mode 31 = Clear Non-Volatile Memory Mode 41 = Set RS baud rate to 9600 47 = Set RS baud rate to 38400 51 = Set CAN baud rate to 100K 52 = Set CAN baud rate to 250K 53 = Set CAN baud rate to 500K 54 = Set CAN baud rate to 1M 57 = Set CAN baud rate to 125K	Writes configuration information to non-volatile memory.
K	0..31 in full step mode (default 12) 0..248 in fine positioning mode (default 96)	Sets number of backlash increments.

G.2   Initialization Commands

Command	Values of <n>	Description
Z	$<n_1>$ 0 = initializes at full plunger force 1 = initializes at half plunger force 2 = initializes at one-third plunger force 10 – 40 = initializes at the defined speed	Initializes the plunger drive and homes the valve in a *clockwise* direction.
	$<n_2>$ 0 = Set initialization input port to Port 1 1..X = Set initialization input port for distribution valves, where X is the number of ports on the valve	Sets initialization input port
	$<n_3>$ 0 = Set initialization output port to Port X 1..X = Set initialization output port for distribution valves, where X is the number of ports on the valve	Sets initialization output port
Y	$<n_1>$ 0 = initializes at full plunger force 1 = initializes at half plunger force 2 = initializes at one-third plunger force 10 – 40 = initializes at the defined speed	Initializes the plunger drive and homes the valve in a *counterclockwise* direction.
	$<n_2>$ 0 = Set initialization input port to Port 1 1..X = Set initialization input port for distribution valves, where X is the number of ports on the valve	Sets initialization input ports
	$<n_3>$ 0 = Set initialization output port to Port X 1..X = Set initialization output port for distribution valves, where X is the number of ports on the valve	Sets initialization output port
W	$<n_1>$ 0 = initializes at full plunger force 1 = initializes at half plunger force 2 = initializes at one-third plunger force 10 – 40 = initializes at the defined speed	Initializes the plunger drive only (commonly used for valveless pumps).

Command	Values of <n>	Description
w	<n$_1$> 1..X = Set initialization port where X is the number of ports on the valve	Initializes the valve drive only.
	<n$_2$> 0 = Valve homes in a *clockwise* direction; valve ports numbered in a *clockwise* direction. 1 = Valve homes in a *counterclockwise* direction; valve ports numbered in a *counterclockwise* direction.	Initializes the valve drive only.
z		Simulates initialization and sets the current position of the plunger as the home position
k	0..80 in standard mode (50 default) 0..640 in fine positioning or microstep mode (400 default)	Set zero gap (increments)

G.3   Valve Commands

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

G.4   Plunger Movement Commands/Status Bit Reports

Command	Value of \<n\>	Description	Status
A \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	[A]bsolute Position	Busy
a \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	[a]bsolute Position	Ready
P \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	Relative [P]ickup	Busy
p \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	Relative [p]ickup	Ready
D \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	Relative [D]ispense	Busy
d \<n\>	0..6,000 0..48,000 in fine positioning or microstep mode	Relative [d]ispense	Ready

G.5 Set Commands

Command	Value of <n>	Description	Default Setting
L <n>	1..20	Slope	(14)
v <n>	50..1000	Start speed (Hz/sec)	(900)
V <n>	5..6000	Peak speed (Hz/sec)	(1400)
S <n>	0..40	Set speed	(11)
c <n>	50..2700	Cutoff speed (Hz/sec)	(900)
K <n>	0..31	Set backlash steps	(12)
> <n>	0..15	Set user data	(0)

G.6 Control Commands

Command	Value of <n>	Description
R		Executes command or command string
X		Repeats last command string
G <n>	0..48000	Repeats command sequence
g		Marks start of a repeat sequence
M <n>	0..30000	Delay in milliseconds
H <n>	0..2	Halts command string execution
T		Terminate command
J <n>	0..7	Auxiliary outputs

G.7   Non-Volatile Memory (EEPROM) Commands

Command	Value of <n>	Description
s <n>	0..14	Loads command string in Non-Volatile Memory
e <n>	0..14	Executes Non-Volatile Memory command string
U31		Clears "Run from Non-Volatile Memory" flag.
U30		Sets "Run from Non-Volatile Memory" flag

G.8   Report Commands

Command	Description
Q	Query, Status and Error Bytes
?	Report absolute plunger position
?1	Report start speed
?2	Report top speed
?3	Report cutoff speed
?4	Report actual position of plunger
?6	Report valve position
?10 or F	Report command buffer status
?12	Report number of backlash increments
?13	Report status of input #1 (J5, Pin7)
?14	Report status of input #2 (J5, Pin 8)
?15	Report number of pump initializations
?16	Report number of plunger movements
?17	Report number of valve movements
?18 or %	Report number of valve movements (since last report)
?20 or #	Report firmware checksum
?23 or &	Report firmware version
?24	Report zero gap increments

?29	Same as Q (query, status and error bytes)
?76	Report pump configuration
*	Report supply voltage
< <n>	Report user data (0..15)

G.9   Error Codes

Command	Description	Notes
0	Error free condition	
1 (01h)	Initialization error	Fatal error. Reinitialize pump before resuming normal operation.
2 (02h)	Invalid command	
3 (03h)	Invalid operand	
6 (06h)	EEPROM failure	
7 (07h)	Device not initialized	
8 (08h)	Internal failure	
9 (09h)	Plunger overload	Fatal error. Reinitialize pump before resuming normal operation.
10 (0Ah)	Valve overload	Fatal error. Reinitialize pump before resuming normal operation.
11 (0Bh)	Plunger move not allowed	
12 (0Ch)	Internal failure	
14 (0Eh)	A/D converter failure	
15 (0Fh)	Command overflow	

G.10 Error Codes and Status Byte

Status Byte	Hex # if Bit 5 =		Dec # if Bit 5 =		Error Code	
7 6 5 4 3 2 1 0	0	or 1	0	or 1	Number	Description
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 1 0	46h	66h	70	102	6	EEPROM failure
0 1 X 0 0 1 1 1	47h	67h	71	103	7	Device not initialized
0 1 X 0 1 0 0 1	49h	69h	73	105	9	Plunger overload
0 1 X 0 1 0 1 0	4Ah	6Ah	74	106	10	Valve overload
0 1 X 0 1 0 1 1	4Bh	6Bh	75	107	11	Plunger move not allowed
0 1 X 0 1 1 0 0	4Ch	6Ch	76	108	12	Internal failure
0 1 X 0 1 1 1 0	4Eh	6Eh	78	110	14	A/D converter failure
0 1 X 0 1 1 1 1	4Fh	6Fh	79	111	15	Command overflow

G.11 DA-15 Connector Pin Assignments

Pin	Function	Remarks
1	24 V DC	
2	RS-232 TxD line	Output data
3	RS-232 RxD line	Input data
4	Unused	
5	CAN high signal line	
6	CAN low signal line	
7	Auxiliary input #1	TTL level
8	Auxiliary input #2	TTL level
9	Ground	Power and logic

Pin	Function	Remarks
10	Ground	Power and logic
11	RS-485 A line	Data +
12	RS-485 B line	Data -
13	Auxiliary output #1	TTL level
14	Auxiliary output #2	TTL level
15	Auxiliary output #3	TTL level

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A

B

C

W

X

XLP 6000