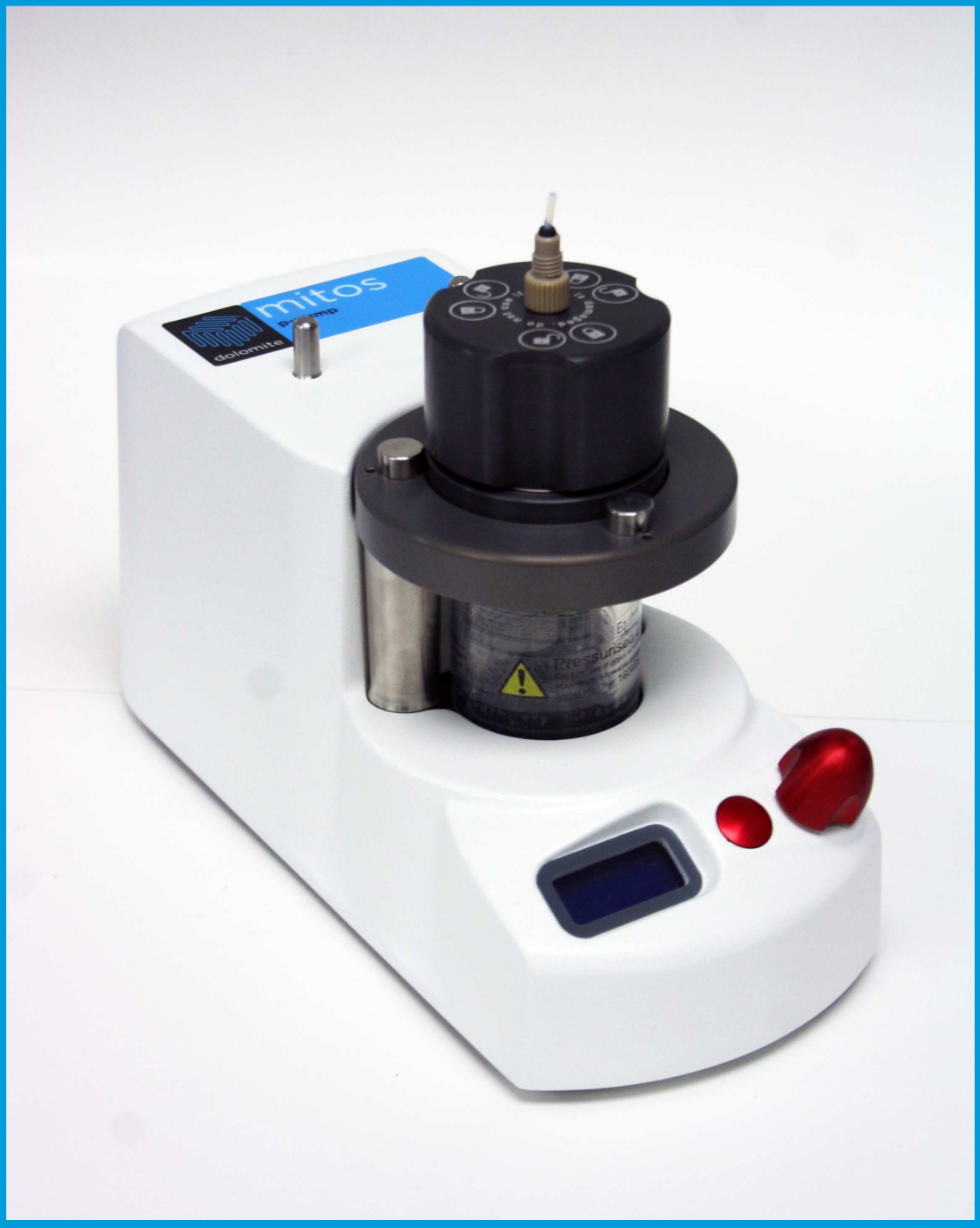


dolomite

MITOS P-Pump

PROGRAMMING INSTRUCTIONS

Contents

1 Summary

This document contains details of how to interface Mitos P-Pumps version 2 and 3 (serial numbers 160200 or greater) with a PC from your own application software. You can use any programming language that can directly use a standard PC serial ("COM") port on any version of Windows. Other operating systems that have FTDI drivers for virtual COM ports should also work – Linux, Mac OS and Android – though Dolomite does not directly support these. For support for P-Pumps earlier than 160200, please contact Dolomite Support – a similar but slightly less capable API exists.

2 Introduction

This pump uses an embedded computer and a microcontroller to control all functions of the display and pump. All communications takes place via RS232 using a simple ASCII protocol. Communications are always one of:

- Set a control mode
- Read some value(s) from the pump
- Write a value to the pump

3 Safety

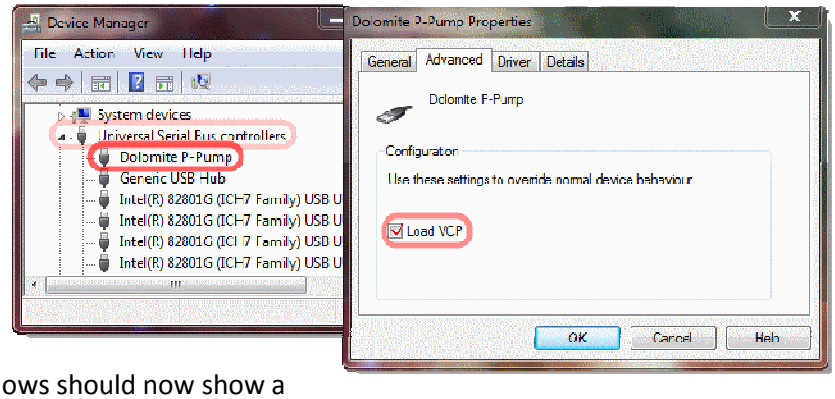
It is responsibility of the user to ensure that all pressure equipment used with the Mitos P-Pump complies with all relevant directives and guidelines. Always use suitable personal protective equipment – e.g. safety glasses and shields etc. – when dealing with pressurised gases.

4 RS232 protocol

The standard interface to the P-Pump is USB. However, it is simple and convenient for the user API to make the USB port expose a "virtual" COM port and this documentation assumes this. If you need to use the device via raw USB please contact Dolomite Support.

To make the USB port appear as a COM port under Windows proceed as follows:

- Connect the P-Pump to your PC with a standard USB cable and install all requested USB drivers.
- Open Device Manager (you may need administrator rights to do this).
- Find the entry for the P-Pump under Universal Serial Bus controllers
- Double click the entry for the Dolomite P-Pump and, on the Advanced tab, check the "Load VCP" checkbox and click OK.



- Disconnect and reconnect the USB lead and Windows should now show a new COM port listed under "Ports (COM & LPT)" – note the port number.

- If the new COM port cannot find a driver, force it to install the standard FTDI serial port driver version 2.8.14 or later. This is available from Dolomite Support.

The RS232 protocol settings for the pump are:

57600 baud, 8 data bits, 1 stop bit, no parity, no handshaking.

Each command or response is terminated with a two character <CR><LF> combination (characters 13 and 10).

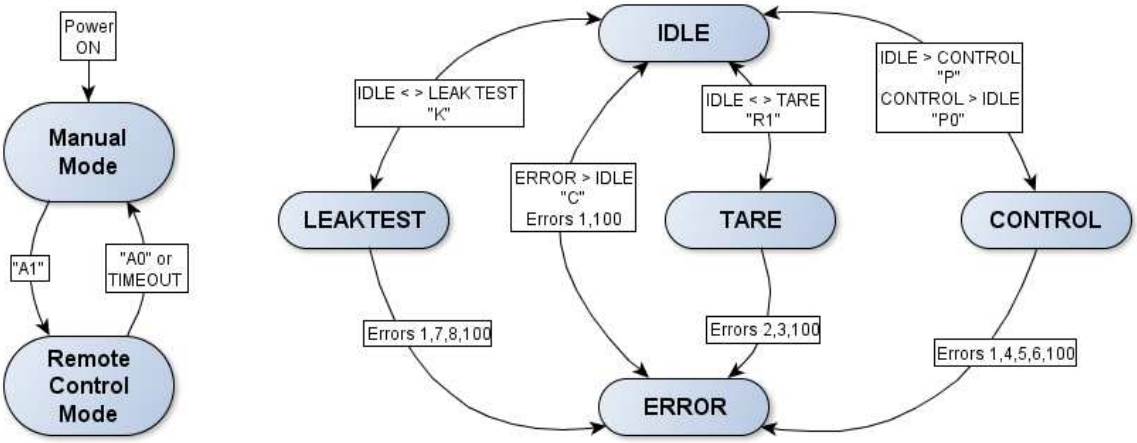
Commands and responses take the form of ASCII strings, typically a single character, sometimes plus parameters. All responses start with "#*x*" where *x* is the single character command sent. Details of the command and response syntax are given in section 6 below.

5 Controlling the pump

Normally, the pump is used in pressure control mode but with the correct attached flow sensor equipment, flow control mode can be used. These sections talks primarily about pressure control, but are equally applicable to both control modes. More details about using flow control are given below.

5.1 General

From the programming point of view the pump operates the following *state machine*. There are two control modes and five pump states.



Control is achieved by moving the pump between modes/states with appropriate commands. The ERROR state can be arrived at either spontaneously (a real physical error) or through an incorrect command. A detailed explanation of the characteristics of each state is given below.

5.1.1 IDLE (State: 0)

This state means the pump is not running any operation. If the pump is in the REMOTE_CONTROL mode your application can issue any control command. Otherwise, it can only issue query commands.

To return to IDLE when in CONTROL send a "P0" command. TARE and LEAKTEST states revert to IDLE automatically on successful completion. The ERROR state can only return to IDLE using the "C" command.

5.1.2 CONTROL (State: 1)

In this state the pump controls at a target pressure. Getting to this state is possible only from IDLE by issuing a "control pressure" command, e.g. "P2500" – this starts CONTROL and sets the target pressure to 2500mbar.

Issuing another control pressure command sets a new target but the pump stays in the CONTROL state.

If your application issues a control pressure command when the pump is in any other state, the command will be rejected and the pump will continue its current operation.

5.1.3 TARE (State: 2)

Your application should issue a “tare” command only when the status is IDLE. If the pump is in any other state the command will be rejected. The pump automatically moves back to the IDLE state when taring is complete.

During the tare operation, your application may see the TARE state, but that will depend on the frequency of communication. Once the TARE is complete, any subsequent request for status from the pump will only return IDLE or ERROR.

5.1.4 ERROR (State: 3)

The pump can get into the ERROR state from any other state if an error condition arises. The only state to which the pump can move from ERROR is IDLE. To clear the ERROR state (move back to IDLE) the following conditions must be met:

- The cause of an error must cease: you cannot clear the ERROR state unless the error condition has been removed.
- Your application must clear the ERROR state by explicitly sending a “C” command. This ensures your application cannot "miss" any errors.

5.1.5 LEAKTEST (State: 4)

You can leak test the system by connecting a sealed chamber, a gas supply and setting the state to LEAKTEST by issuing a “K” command. The test takes about 1 minute and performs a leak test at two pressures - close to the supply and close to atmospheric pressure. The system is deemed leak tight if neither test shows a change in pressure of more than ±5mbar/bar/minute. The test assumes a system volume of about 30mls (the standard P-Pump chamber)[1].

When your application sees the status change back to IDLE, it can read the leak test result using the “k” command. See command list below for details.

5.2 Control strategy

The pump only sends data in direct response to a command. As communication is asynchronous, it is safest to write commands to the pump immediately following a completed response from the pump to avoid collisions on the bus.

You can use the API to completely control the pump by setting the pump in full remote control mode or leave the pump in manual mode and simply read pressure and state information back from it when required. Full remote control mode has a timeout limit - you must send a command to the pump at least once every 30 seconds or the pump will revert to manual mode and IDLE. This acts as a safety watchdog in the event of PC, application or communications failure.

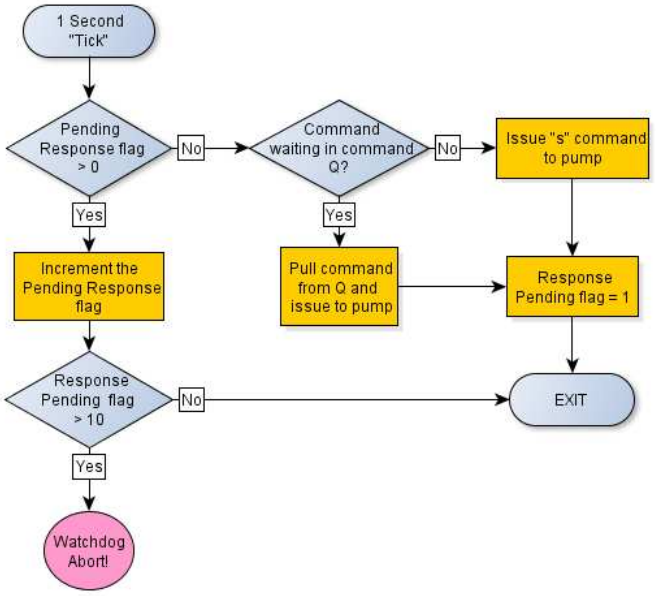
The schematics below show a simple way of handling the data flow to and from the pump. There are other methods that will work equally well or may be better or easier to implement in your system. The system outlined has four main elements.

1. An interrupt driven timer

[1] An acceptable leak rate of <±5mbar/bar/minute maximum is specified. Typical values are <±3mbar/bar/minute. The apparent leak rate reported is inversely related to system volume – the specification assumes a standard 30ml volume sealed system.

2. A first in first out (FIFO) command queue
3. A “Response Pending” counter/flag
4. An interrupt driven response procedure

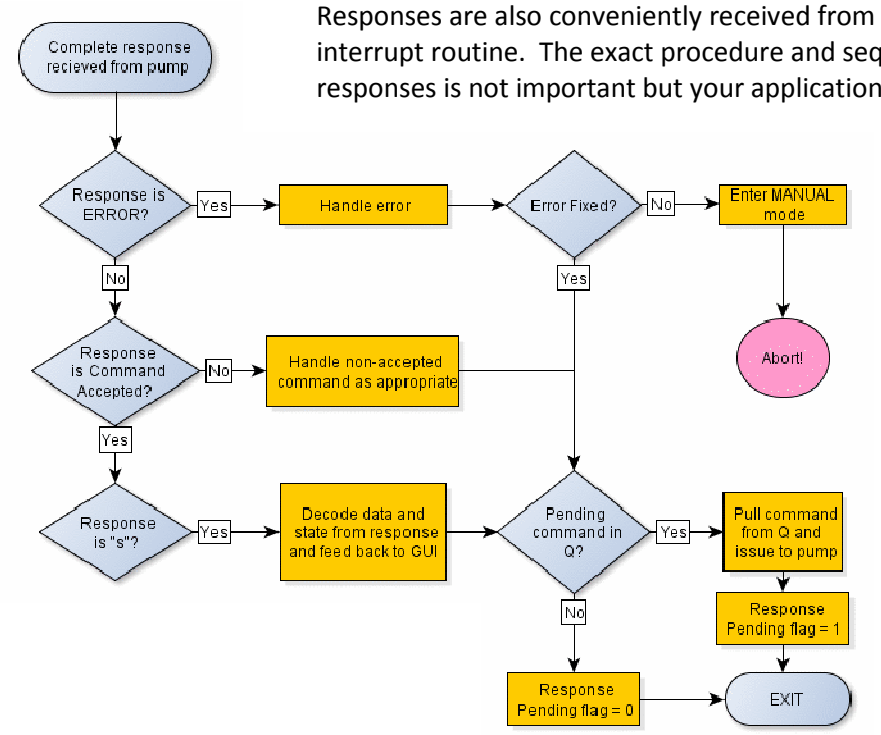
An interrupt based timer function is used to continually send “s” commands to the pump every second. This will keep the remote control session alive and provides a continuous stream of current state and pressure information from the pump back to your application.



New control commands are simply added to the tail of the FIFO command queue and the timer interrupt sends them on the next tick.

Having sent a command, the timer sets the “Response pending” flag and won’t send another command from the FIFO queue until the flag is cleared. Thus the Pending Response flag can be used as a watchdog to ensure communication with the pump is not lost.

Responses are also conveniently received from the pump using an interrupt routine. The exact procedure and sequence for handling responses is not important but your application needs to take the following steps:



- Handle only complete responses. A complete response starts with “#” and ends with the <CR><LF> terminator. In some systems longer responses may not all appear simultaneously – you may need to wait for the response to be completed.

- Check for ERROR states first and handle as required. Some errors can be reset programmatically, some physical errors cannot and will require user intervention. See section 6.4 below.
- Check the command acknowledgment character to make sure this command was correctly interpreted by the pump and handle accordingly.

- Parse the actual response.
    - For “s” commands, parse out all the pump data and present to your application GUI for display, logging etc. See section 6.3 for details.
    - OK acknowledgments of other commands probably require no further action.
- After receiving a response, it is safe to check the FIFO queue for any commands waiting and send them.
- Finally, set the “Pending Response” flag as required.

These are the basic steps required to control the pump. Exact implementations will vary depending on the operating system and programming languages utilised.

6 Command/Response syntax

6.1 Response syntax

The pump responds to commands sent with a response that is always constructed the same way. A standard response is of the form “#L*n*” where L is the previous command and *n* is the command acknowledgment value.

Command acknowledgment values are:

Response description	Value (*n*)
CMD_ACCEPTED	0
CMD_REJECT_pump_BUSY	1
CMD_REJECT_pump_ERROR	2
CMD_REJECT_MANUAL	3
CMD_REJECT_INVALID_ARG	4
CMD_REJECT_WRONG_NUM_ARGS	5
CMD_REJECT_UNKNOWN_CMD	6
CMD_REJECT_INVALID	8

Simply put, command acknowledgments where *n* is 0 have been accepted and actioned by the pump. All other endings indicate some form of problem that your application will need to address.

6.2 Command List

The tables below show a complete list of commands and responses available to control the pump. All commands and responses are terminated with <CR><LF>.

Command	Description	Pump State (before⇨after)	Control Mode (before⇨after)
A1	Enter remote control mode. Response “#A0”	ANY	Man.⇨Remote
A0	Leave remote control mode. If the pump is controlling this will return the pump to IDLE and vent.	ANY⇨IDLE	Remote⇨Man.

Command	Description	Pump State (before⇨after)	Control Mode (before⇨after)
	Response “#A0”		
If pump does not receive any command, e.g. a status query "s", for 30 seconds it will automatically return to manual mode.			
C	Your application sends this to move the pump out of ERROR state and back into IDLE. C will also stop control and force the pump back to IDLE. You must explicitly clear all error conditions. This ensures your application has noted the error and corrected it. The ERROR state will not clear unless any physical error condition has been corrected.	ERROR ⇨ IDLE (ANY ⇨ IDLE)	
e	Returns text string of the last error message. This may a P-Pump specific error or an error from the underlying micro controller board. Note, this command will *always* return the last error message no matter how old. *The message is only valid when the pump is in the ERROR state.* See section 6.4 below, Error codes, below Returns two strings: date and error information separated by <LF>.	ANY [response only guaranteed valid if in ERROR state]	ANY
L	“Lpump Z” sets display name on the pump to “pump Z”. The label is limited to a max of 8 characters - alphanumeric plus underscores. Name will be upper case only.	IDLE	Remote
l	Lower case L. Returns current label on the pump, e.g. “#lpump Z”	ANY	ANY
n	Returns the serial number for the pump, e.g. “#n160295”	ANY	ANY
T	Send "Tx" where x is UTC time in seconds since 1/1/1970	IDLE	ANY
t	Responds "#txxxxxx" where xxxxxx is UTC time in seconds since 1/1/1970	ANY	ANY
s	Replies with “#sErr,Sp,Src,Pc,Ps,Pt,Qc,Qt,Ft”, see section 6.3, Status command response, below for details.	ANY or ERROR⇨IDLE	ANY
P	“P1000” sets target pressure to 1000 mbar and starts control. Replies “#P0” and starts pressure control if in remote control mode (see A1). Setting target pressure to 0 (sending the "P0" command) moves the pump to the IDLE state. It means the pump stops controlling pressure and opens the vent valve.	IDLE⇨ CONTROL, CONTROL ⇨CONTROL or CONTROL ⇨ IDLE	REMOTE

Command	Description	Pump State (before⇨after)	Control Mode (before⇨after)
F (Not available in P-Pump version 1)	"F2000" sets flow rate to 2000 pl/s. Replies "#F0" and starts flow control if in remote control mode (see A1). For this command to work there must be a flow sensor connected either via USB (3200095) or I2C (3200200) connection on the back of the pump. Note "F0" is a valid flow target **and does not set the pump to IDLE!**	IDLE⇨ CONTROL, CONTROL ⇨CONTROL	REMOTE
Rx	Tares pump and/or connected flow sensor and drops back to idle when completed. Pump must be in remote mode. x selects the tare options: 0 pressure and flow (if present); 1 pressure only; 2 flow only (if present). *The pump MUST be disconnected from the pressure supply to tare or an ERROR is raised.*	IDLE⇨ TARE⇨IDLE	REMOTE
The pump will enter TARE state (see TARE) on receiving this command and attempt to tare. On completion (some number of seconds later), the pump will re-enter IDLE state. If the tare fails an error is raised. You should monitor the pump state during tare using "s".			
v	Replies with the version of pump firmware, e.g. "#v1.0.48"	ANY	ANY
m	Get the current maximum and minimum target ranges from pump. Replies with "#mxxx,yyy" where xxx is the max and yyy is the minimum (in mbar).	ANY	ANY
K	Perform leak tests (does leak test twice, once at high pressure and once at low pressure)	IDLE⇨ LEAKTEST⇨ IDLE	REMOTE
You must have a pressure supply connected. For the leak test results to be meaningful, a 30ml chamber volume (or equivalent) should be connected to the pump. The pump will enter LEAK TEST and when leak test completes (about one minute) the pump will re-enter IDLE state.			
k	Get leak test data result from pump. Replies with "#kxxxxxxxx,yyyyyyyy"	ANY	ANY
Where xxxxxxxx and yyyyyyyy are each signed 4 byte integers. High two bytes are pressure change (in mbar/bar/minute, positive or negative) and the lower two bytes are a pass/fail flag (high/sign bit, 0 is pass, 1 is fail) plus the test pressure (in mbar). See below for an example of how to extract these numbers. These values are invalid if an error occurs during the leak test or if the value is 0x8000. e.g. Response is #k-2941957,-2517092 -2941957 = 0xFFFB 823F3. 0xFFFB = -5 mbar/bar/min 0x82F3 = 0x8000 (fail flag bit) plus 0x02F3 = 755mbar. -2517092 = 0xFFD9 979C. 0xFFD9 = -39mbar/bar/min			

Command	Description	Pump State (before⇨after)	Control Mode (before⇨after)
	0x979C is 0x8000 (fail flag bit) plus 0x179C = 6044mbar.		
b (Not available in P-Pump version 1)	Get flow sensor type and fluid name for fluid calibration from connected flow sensor. Replies with "#bx,ssss" where x is the flow sensor type and ssss is the 4 letters fluid name For example: #b5, H2O See section 7.1 for sensor types and 7.2 for fluid names.	ANY	REMOTE
Xn (Not available in P-Pump version 1)	Switch control mode when in control state between n = 0 selects PRESSURE control n = 1 selects FLOW control If used when not controlling, pump returns CMD_REJECT_INVALID. The pump changes modes in such a way that the chamber pressure is initially unchanged ("bumpless") by changing the new flow or pressure target to the existing actual flow or pressure at the time this command is issued.	CONTROL	REMOTE

6.3 Status command response

The "s" command returns the status of the pump as a comma separated text sting of values. Each field gives a value for one aspect of the pump.

`#sErr,Sp,Src,Pc,Ps,Pt,Qc,Qt,Ft`

Field	Description
`Err`	Error code. These are numeric codes defining the response state. 0 is CMD_ACCEPTED - OK. For a detailed description see section 6.1 above.
`Sp`	State of the pump 0. IDLE 1. CONTROLLING 2. TARE 3. ERROR 4. LEAK TEST The status returned by the pump reflects the latest command sent from the PC to the pump.
`Src`	State of the remote control. 0 is manual, 1 is remote controlled.
`Pc`	Chamber pressure in mbar.
`Ps`	Supply pressure in mbar.
`Pt`	Target pressure in mbar.

Field	Description
Qc	Current flow rate in pl/s. Requires a connected Mitos Sensor Display flow meter. Note the actual accuracy is given by flow sensor type below. Contact Dolomite Support for more information on this feature.
Qt	Target flow rate in pl/s. Requires a connected Mitos Sensor Display flow meter. Contact Dolomite Support for more information on this feature.
Ft	Flow sensor type plus flow control mode. Requires a connected Mitos Sensor Display or sensor interface flow meter. This consists of an upper nibble, middle nibble and lower nibble: • The high nibble describes flow control mode: 0x100 means it is flow control or 0x000 otherwise. This is only meaningful when the pump is controlling mode. • The middle nibble describes the connection to the Flow Sensor: 0x10 means it is connected to the Sensor Display Module (3200095); 0x00 means it is connected to the Sensor Interface Module (3200200) • The lower nibble is defined as (Flow Sensor Types, see 7.1).

6.4 Error Codes

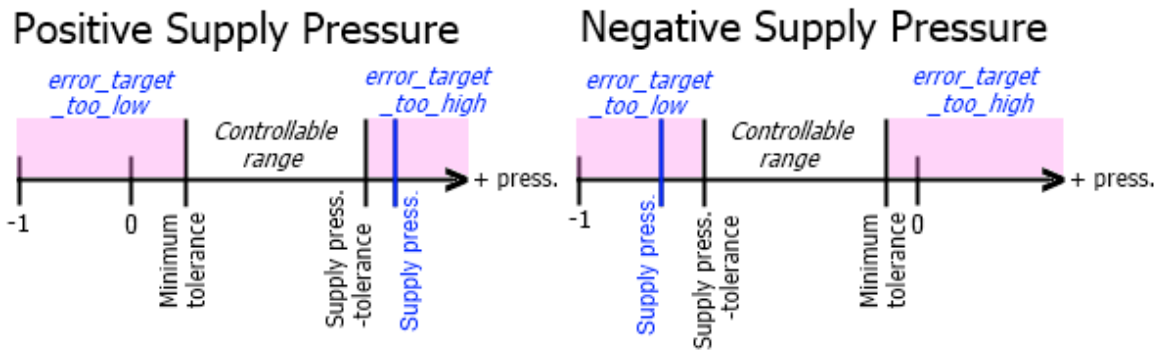
If the pump state is ERROR, you can get the exact error code, date and time and limited description by using the “e” command. The table below shows the possible values of the error codes that may be returned from the pump when the pump state becomes ERROR.

Code	Meaning	Description
0	None	There is no current error.
1	Supply larger than maximum	The connected supply pressure is too high for the device (>11.5bar).
2	Tare time out	The tare did not complete successfully, no steady base line detected
3	Tare supply still connected	The microcontroller cannot tare because the supply pressure is still connected.
4	Control start time out	This error occurs if open/closing the valves does not change the chamber pressure within a given time period, suggesting something is mechanically wrong (valve stuck/broken?). Contact Dolomite Support.
5	Pressure target too low	The pressure target set or required is too low, below the current minimum pressure for the current supply pressure.
6	Pressure target too high	The pressure target set or required is too high, above the current maximum pressure for the current supply pressure.
7	Leak test supply pressure too low	The pressure is too low (<400mb) for leak test.
8	Leak test time out	Leak test times out if either the pressure cannot reach target or after reaching target is not stable in 30 seconds
100	Broken	The main board has failed to communicate with the microcontroller board. This indicates something is very wrong internally with the pump. Contact Dolomite Support.

The ERROR state ***must*** be explicitly cleared by sending the "C" command and subsequently confirming the state with "s".

Below is a diagram showing where the pressure target errors come into force for systems with positive and negative supply pressures.

These error codes meanings stay the same regardless of supply pressure. Applications can read the current minimum and maximum target pressures using the "m" command.



The X axis is the ***gauge*** pressure in bar increasing to the right.

7 Flow Control

With the later model P-Pump's equipped with the connected Sensor Display (or sensor interface), the P-Pump can also be run using flow control rather than pressure control. The commands to control this are shown in section 6.2 above. Note that all flows sent to or received from the P-Pump are in units of picolitres/second. To convert to µl/minute, multiply by 0.00006.

To move to flow control, you can either simply set a flow target ("Fxxxx" command) or establish the flow you need by setting an appropriate pressure, then move to flow control using the "X1" command, which will give a "bumpless" transfer to flow control. To stop flow control, you must issue "P0" to vent the chamber as "F0", that is zero flow, may well be a perfectly reasonable setting in some multi-pump systems and may not equate to zero pressure.

To return to pressure control from flow control, use "Pxxx" or, for bumpless transfer, "X0".

7.1 Types of Flow Sensor

This is an enumeration used to identify flow Sensors. 0 implies no flow sensor is connected.

Type number	0	1	2	3	4	5
Part number	-	3200100	3200099	3200098	3200097	3200096
Range (water)	none	0.07-1.5 µl/min	0.4-7µl/min	1-50µl/min	30-1000 µl/min	200-5000 µl/min
Flow sensor units/ dp		µl/min / x.xxx or µl/min / -x.xx	µl/min / x.xx or µl/min / -x.xx	µl/min / xx.x or µl/min / -xx.x	µl/min / xxxx or µl/min / -xxx	ml/min / x.xx or ml/min / -x.xx
calibration pre-divisor		1	1	100	2	1

Note when using a vacuum pump to provide a negative pressure supply, it is possible to control flow "backwards", that is the negative version the flow rates above are possible. However different flow sensors have different accuracies for positive and negative flow rates as can be

seen above, so when converting these values for display you need to convert the units from pl/s to the units for the flow sensor in the table above and then pay attention to the number of decimal places it supports.

7.2 Fluid names

Note the minimum flow rate actually means the minimum *calibrated* flow rate, lower values can measured but will be less accurate.

Fluid	Short Name
Water	<SPACE>H2O
FC-40	FC40
Novec 7500	NOVE
Hexadecane	HEXA
Mineral Oil	<SPACE>OIL

8 Programming Example

The table below shows a brief example of a set of commands and the responses produced using pressure control. The example starts the pump, tares it and then controls it at pressure before generating and clearing an error. The termination characters are omitted for clarity.

Cmd.	Response	Comment
s	#s0,0,0,-2,-3,0,0,0,0	OK – manual mode, no connected supply
A1	#A0	Entering remote mode, command accepted
s	#s0,0,1,-2,-3,0,0,0,0	OK – remote mode and IDLE
R1	#R0	Start TARE, command accepted
s	#s0,2,1,-2,-3,0,0,0,0	Taring….
		… wait a few seconds for tare to…
s	#s0,0,1,0,0,0,0,0,0	…succeed. Back to IDLE. Now connect supply
s	#s0,0,1,0,7500,0,0,0,0	OK
P2000	#P0	Set target to 2000 and CONTROL, command accepted
s	#s0,1,1,1589,7500,2000,0,0,0	…pressurising…
s	#s0,1,1,2001,7500,2000,0,0,0	… and controlling at 2000mbar
P8000	#P0	Attempt to set target too high…
s	#s6,3,1,27,7562,8000,0,0,0	… results in ERROR state, so use “e” to read the error then clear it
e	#eMon Aug 6 10:38:18 2012:Error on ppbLoglet: 6, Target beyond range	
C	#C0	Error state cleared and return to IDLE
s	#s0,0,1,2,7500,0,0,0	OK
A0	#A0	Back to manual…
s	#s0,0,0,7500,0,0,0	… in IDLE and vented

9 Further Information

For more information about Dolomite and our range of other microfluidic products, please visit:

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