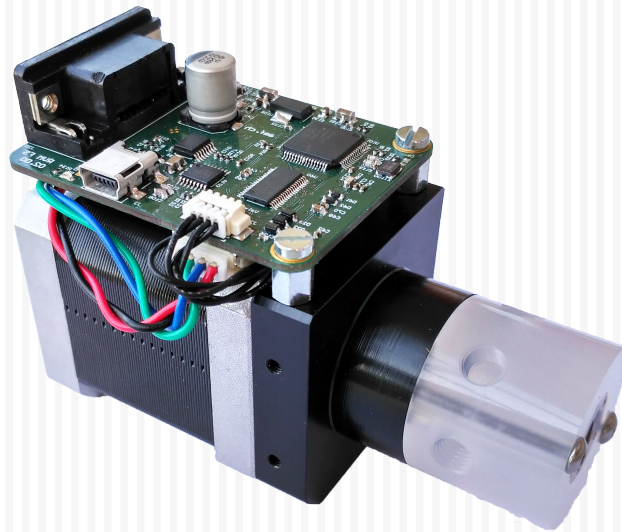
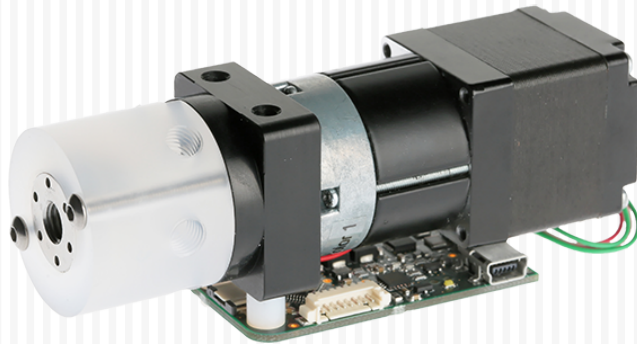


Operating Manual

Original instructions - February 2019

RVM Rotary valve

Advanced Microfluidics SA




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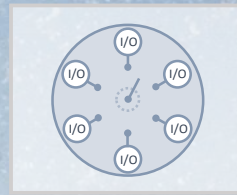
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1. Introduction



1.1 Foreword

Advanced Microfluidics SA's team thanks you for acquiring a RVM rotary valve. This operating manual is dedicated to help you make the most of this device and thus bring success to your microfluidic projects. We remain available for any questions or suggestions that you may have.

The RVM rotary valve system may only be operated after carefully reading and understanding this manual.

1.2 Application Purpose

The RVM rotary valve is a precision liquid handling system designed to control your fluidic paths. It is controlled by an external computer or microprocessor and is powered either by USB or by an 18-24V power supply, depending on the model.

1.3 Functional Description

1.3.1 Motor models



FIGURE 1.1 – Low power model - RVMLP

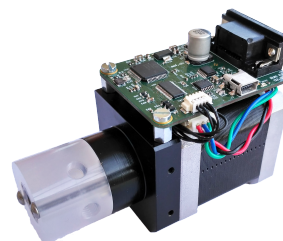


FIGURE 1.2 – Fast model - RVMFS

1.3.2 Valve models

Different valve models exist, as explained further, but here are some main details regarding all models.

The valve is made of fluoropolymers which have an outstanding chemical resistance. The plug which selects the connected channel is made of PTFE or UHMW-PE and the outer part, called valve seat, where the user can connect standard microfluidic fittings, is made of PCTFE.

The valve module, which is a closed loop system, works as follows:

- The user sends a command to connect a specific port
- The plug is rotated by a stepper motor through the plug drive
- A position sensor detects very precisely the position of the plug thanks to a number of indexes integrated in the plug itself
- Using this feedback the stepper motor can be stopped when the plug has reached the desired position

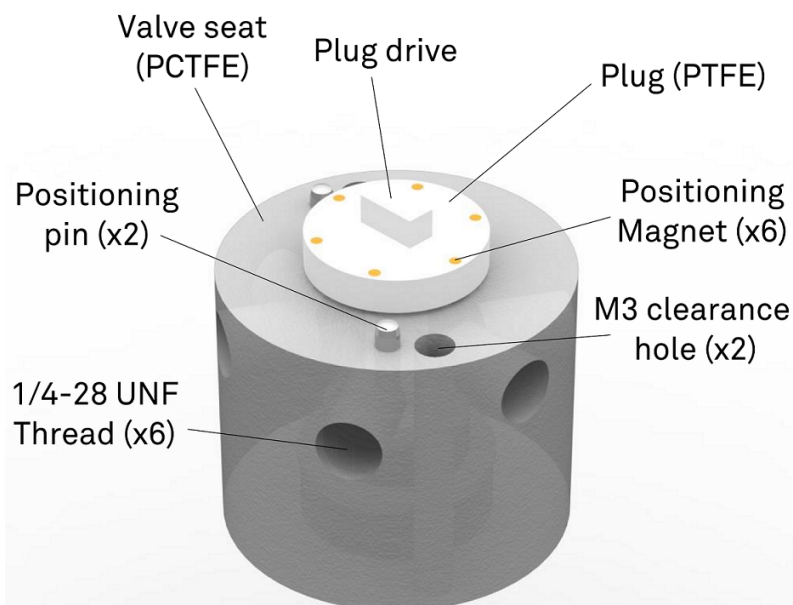


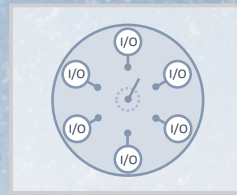
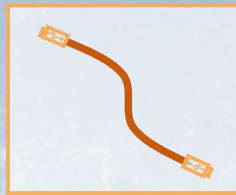
FIGURE 1.3 – Nomenclature for the valve module

The valve module is removable by unscrewing the two M3x30 screws. The entire procedure is described in the maintenance section. The rated pressure for the valve module is 5 bars (0.5 MPa or 72.5 PSI).



Hardware

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2. Hardware description



2.1 Glossary

Carryover: Contamination of a volume of fluid by residual fluid from a previous pick up or dispense. Carryover causes variability in the final volume and concentration.

Carryover volume: Volume of liquid that will be mixed with the next liquid. It is not stuck, but will be swept next time a liquid passes.

Cavitation: Formation of vapor cavities in a liquid – i.e. small liquid-free zones ("bubbles" or "voids") – that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities where the pressure is relatively low.

Dead volume: Volume that is “stuck” in the system (dead end), which is not cleanly swept and relies on diffusion to clear out.

Internal volume: Volume inside the system, from entrance to exit.

Port: The connection or orifice through which sample may be injected or dispensed.

Priming: Completely filling the pump tubing and syringe with bubble-free fluid to allow sustained, reproducible pumping action.

Void volume: Sum of the carryover volume and dead volume.

Wetted surfaces: The surfaces which are contacted by the sample stream.

2.2 RVM motor models

The main differences between the RVMLP and RVMFS can be found hereafter:

Abbr.	Configuration	Power	Rotation time for 180°	Weight (total module)	Dimensions
RVMLP	Low power motor	5-10 VDC, 0.5 A peak	1.5 s	250 g	29 x 38.3 x 111.8 mm
RVMFS	Fast motor	18-24 VDC, 2 A peak	400 ms	450 g	42.3 x 60 x 95.9 mm

TABLE 2.1 – RVM motor models

2.3 Cabling

2.3.1 Power supply

Depending on the model that you have chosen, the power source is different.

Low power - RVMLP & Fast model - RVMFS

The low power model uses a single mini-USB cable for both the power and the communication. The female mini-USB connection works as a virtual serial port. The connection can be done by any mini-USB/USB cable provided that the provided ferrite of type 74271111S is locked around the cable. The fast model uses a mini-USB cable for the communication only.



FIGURE 2.1 – Generic mini-USB cable



FIGURE 2.2 – Ferrite 74271111S from Würth Elektronik to be locked around the USB cable connected to the RVM

Fast model - RVMFS

The fast rotary valve requires an additional AC/DC adaptor. The mini-USB cable is still required for data communication.

It is possible to use a custom cable that only plugs in the the DB9 connector for communication and power. Please contact us with your connection requirements if you'd like us to do this cable for you.

2.3.2 Data communication

Low power - RVMLP & Fast model - RVMFS

Data communication is possible for both modules with USB communication.

Fast model - RVMFS

The fast model can also be controlled using the DB9 connector¹.

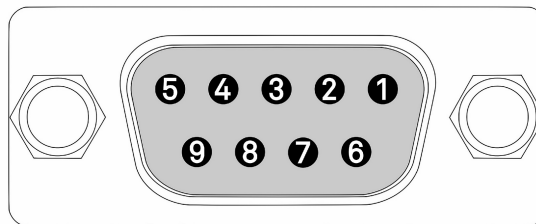


FIGURE 2.3 – DB9 pin-out on device side (RVMFS)

By default, the RS-232 protocol is installed on the RVM-FS. The protocols for RS-485 and RS-422 require an additional chip (connections are planned on the PCB) and a small firmware development. The CAN protocol also requires an additional chip (connection are planned on the PCB), but needs a more extensive firmware update and testing.

¹Proper designation is DE-9 but the DB9 appellation is the most commonly used.

In combination to all protocols, it is possible to have auxiliary connections, such as a power supply directly connected on the DB9 or a DCD (Data Carrier Detect) which can be adapted to your needs.

Pin	Abbreviation	Name	Typical Purpose
1			
2	TX	Transmitted Data	Carries data from DCE (RVM) to DTE
3	RX	Received Data	Carries data from DCE to DTE
4			
5	GND	Ground	Zero voltage reference
6			
7	CTS	Clear To Send	Not implemented
8	RTS	Request To Send	Not implemented
9			

TABLE 2.2 – Pin assignment of the DB9 connector female on the RVMFS for RS232 protocol

Pin	Abbreviation	Name	Typical Purpose
1			
2	D-	Data	Negative driver
3			
4			
5	GND	Ground	Zero voltage reference
6			
7			
8	D+	Data	Not implemented
9			

TABLE 2.3 – Pin assignment of the DB9 connector female on the RVMFS for RS485 protocol

Pin	Abbreviation	Name	Typical Purpose
1			
2	TX-	Transmitted Data	Carries data from DCE (RVM) to DTE. Negative output
3	RX+	Received Data	Carries data from DCE to DTE. Positive input
4			
5	GND	Ground	Zero voltage reference
6			
7	RX-	Received Data	Carries data from DCE to DTE. Negative input
8	TX+	Transmitted Data	Carries data from DCE (RVM) to DTE. Positive output
9			

TABLE 2.4 – Pin assignment of the DB9 connector female on the RVMFS for RS422 protocol

Pin	Abbreviation	Name	Typical Purpose
1			
2			
3			
4	CANH	CAN-High	CAN-High
5	GND	Ground	Zero voltage reference
6			
7			
8			
9	CANL	CAN-Low	CAN-Low

TABLE 2.5 – Pin assignment of the DB9 connector female on the RVMFS for CAN protocol

Pin	Abbreviation	Name	Typical Purpose
1	DCD	Data Carrier Detect	Not implemented
2			
3			
4			
5	GND	Ground	Zero voltage reference
6	PWR	Power	Power supply input (18-24 VDC)
7			
8			
9			

TABLE 2.6 – Pin assignment of the DB9 connector female on the RVMFS for auxiliary connections

The pin assignment is always given from the point of view of the AMF module.

2.4 Chemical compatibility

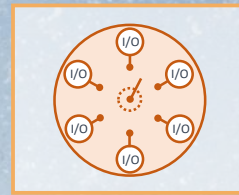
The following parts can be in contact with the liquid:

1. The valve seat: PCTFE
2. The valve plug: PTFE or UHMW-PE

These materials offer an excellent chemical compatibility. However Advanced Microfluidics SA cannot be held responsible for damages caused by the use of a specific chemical. Before using the device with a given chemical, please make sure that it is compatible with the aforementioned materials.



The valve should not be used to process explosive or highly flammable fluids.



3. Valve module description



The RVM is available with 3 valve model families:

- The **distribution series**, where a single port is selected to connect to the top of the valve
- The **on/off series**, a simple switch to determine if the liquid passes or not
- The **switch series**, where the ports are connected to their neighbour, two-by-two

For all valve types, the channels have a standard diameter of 0.5 mm in the valve seat and in the plug. Standard 1/4-28 UNF fittings can be connected to these channels.

You will find the standard models below. For any other request, please contact us directly.

Type	Reference	Nb ports	Internal volume	Carryover volume	Fluid Path Diameter	Wetted Materials
distribution	V-D-1-6-050-C-P	6	2.5 μL	1.5 μL	0.5 mm	PCTFE, PTFE
distribution	V-D-1-8-050-C-P	8	2.5 μL	1.5 μL	0.5 mm	PCTFE, PTFE
distribution	V-D-1-8-100-C-U	8	13.7 μL	6.7 μL	1 mm	PCTFE, UHMW-PE
distribution	V-D-1-10-050-C-U	10	3.5 μL	1.7 μL	0.5 mm	PCTFE, UHMW-PE
distribution	V-D-1-10-100-C-U	10	13.7 μL	6.7 μL	1 mm	PCTFE, UHMW-PE
distribution	V-D-1-12-050-C-U	12	3.5 μL	1.7 μL	0.5 mm	PCTFE, UHMW-PE
on/off	V-O-1-2-050-C-P	2	-	0.98 μL	0.5 mm	PCTFE, PTFE
on/off	V-O-1-2-075-C-P	2	6.6 μL	-	0.75 mm	PCTFE, PTFE
switch	V-S-1-4-050-C-P	4	2.8 μL	0.8 μL	0.5 mm	PCTFE, PTFE
switch	V-S-1-6-050-C-P	6	2.5 μL	0.6 μL	0.5 mm	PCTFE, PTFE

3.1 Distribution series

3.1.1 Description

The distribution valve features N microfluidics ports that can be connected **one at a time** to the top part of the valve, where N is the number of ports of the specific model. The very small channel diameters allow for a minimal carryover volume when changing position.

Note — Known aliases for the VD1-6.

7-port/1-channel valve, 6-port selection valve, 7-port/6-position valve

The same aliases can be used for the other distribution models, changing the number of ports

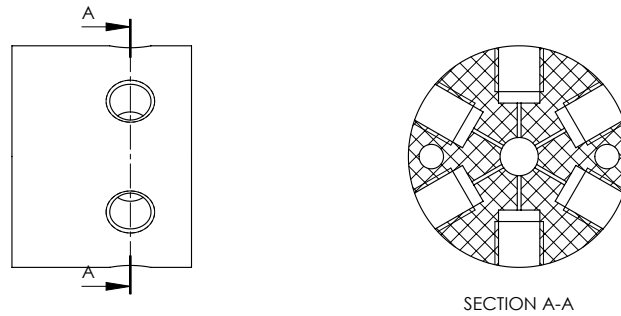


FIGURE 3.1 – [VD1-6] Section view of the PCTFE valve seat revealing the microchannels

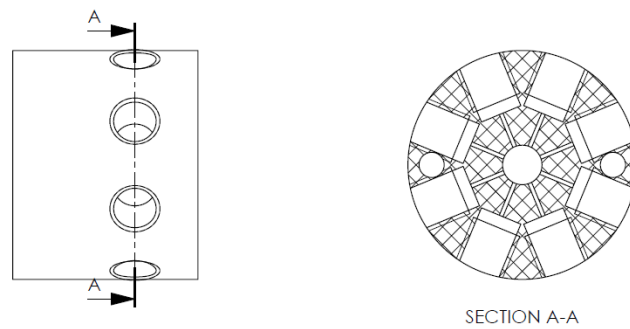


FIGURE 3.2 – [VD1-8] Section view of the PCTFE valve seat revealing the microchannels

3.1.2 Port numbering

You will find the port numbers in Figure 3.3 for the VD1-6 model and in Figure 3.4 for the VD1-8 model:

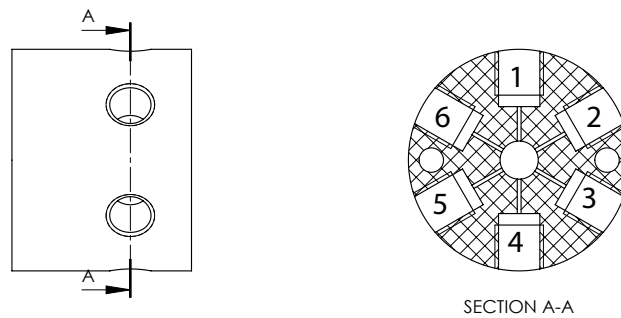


FIGURE 3.3 – [VD1-6] Section view of the PCTFE valve seat with port numbering

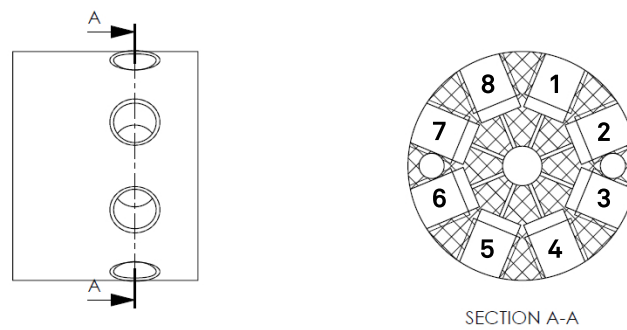


FIGURE 3.4 – [VD1-8] Section view of the PCTFE valve seat with port numbering

Note — Direction of rotation.

The command $I\langle n \rangle$ corresponds to a clockwise rotation of 60° or 45° when incrementing the port number by 1. The command $O\langle n \rangle$ corresponds to a counterclockwise rotation of 60° or 45° when decrementing the port number by 1.

If you are on port 3, the command $I\langle 4 \rangle$ will be executed with a 60° or 45° rotation of the plug, while the command $O\langle 4 \rangle$ will be executed with a 300° or 315° rotation of the plug.

3.2 On/off series

The on/off series allows to stop a flow and act as a switch. Currently, a 2-port model is available (Reference VO1-2), where the ports are opposite each other (i.e. separated by 180°).

Note — Known aliases.

Isolation valve, shutoff valve

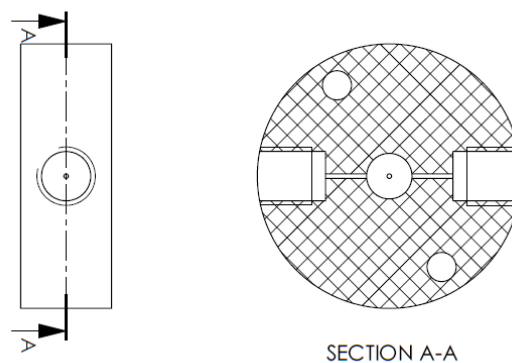


FIGURE 3.5 – [VO1-2] Section view of the PCTFE valve seat revealing the microchannels

3.2.1 Port numbering

You will find the port numbers in Figure 3.6:

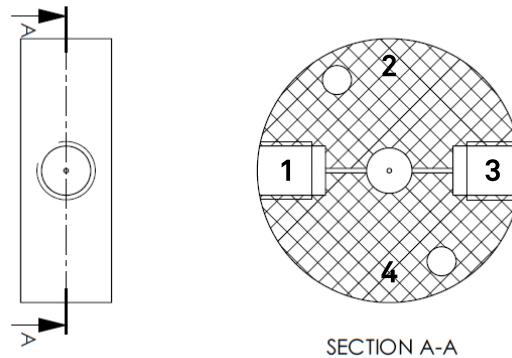


FIGURE 3.6 – [VO1-2] Section view of the PCTFE valve seat with port numbering

Note — Direction of rotation.

The command `I<n>` corresponds to a clockwise rotation of 90° when incrementing the port number by 1. The command `O<n>` corresponds to a counterclockwise rotation of 270° when decrementing the port number by 1.

If you are on port 3, the command `I<4>` will be executed with a 90° rotation of the plug, while the command `O<4>` will be executed with a 270° rotation of the plug.

3.3 Switch series

The switch series allows to connect neighbouring ports two-by-two. Currently, a 6-port model is available (Reference VS1-6), where the ports are separated by 60° .

Note — Known aliases.

6-port/2-position valve, 6-port/3-channel valve, loop valve

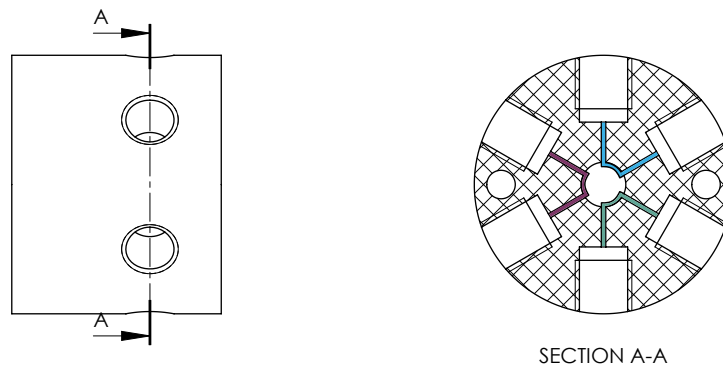


FIGURE 3.7 – [VS1-6] Section view of the PCTFE valve seat revealing the microchannels

3.3.1 Port numbering

You will find the port numbers in Figure 3.8:

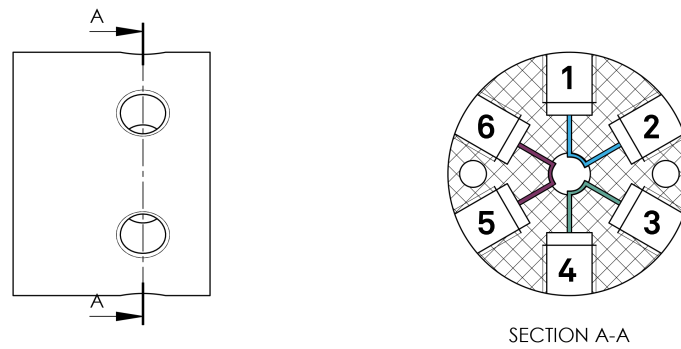
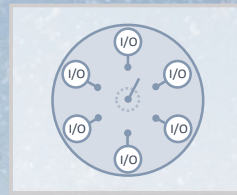


FIGURE 3.8 – [VS1-6] Section view of the PCTFE valve seat with port numbering

Note — Direction of rotation.

The command I<n> corresponds to a clockwise rotation of 60° when incrementing the port number by 1. The command O<n> corresponds to a counterclockwise rotation of 60° when decrementing the port number by 1.

If you are on port 3, the command I<4> will be executed with a 60° rotation of the plug, while the command O<4> will be executed with a 300° rotation of the plug.



4. Maintenance operations



4.1 Cleaning procedure

A cleaning procedure should be performed at the end of each day or in between two different experiments. For an effective cleaning, pass one of the solutions below (depending of your application) at least twice in each tube connected:

- Bleach solution to kill microorganisms : 1% chlorine bleach and deionized water
- Detergent solution to remove debris: 0.1% detergent and deionized water
- Rinsing water to prepare the valve for your next experiment: deionized water

Thanks to our small internal volume, each cleaning cycle is extremely efficient.

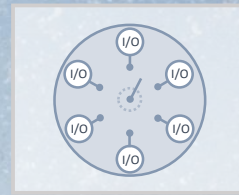
These solutions can be directly added to your system for automatic cleaning between experiments.

Note — Additional cleaning. If your experiment creates precipitates, you may need to do a more extensive cleaning cycle, by manually removing the valve head. Please contact us for further details.



Software

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5. Software Communication



5.1 Communication Protocol

The RVM rotary valve offers a data terminal protocol.

5.1.1 Data Terminal Protocol

The data terminal protocol enables communication through the following pattern:

Character Format	
Parameter	Setting
Baud rate	9600
Data bits	8
Parity	None
Stop bit	1
Command Block	
1	Start command (ASCII “/”)
2	Pump address (by default 1)
3	Data block (length n)
...	
3+n-1	
3+n	Carriage Return (<CR>)
Answer Block	
1	Start answer (ASCII “/”)
2	Master address (ASCII “0”)
3	Error/Status character
4	Data block (length n)
...	
4+n-1	
4+n	ETX (0x03)
5+n	Carriage Return (<CR>)
6+n	Line feed (0x0A)

TABLE 5.1 – Data Terminal Protocol Format

Please note that due to the buffer size limitation, the length of the command block is limited to 512 characters. If necessary, the command string has to be split to avoid overflow. The looping functions will also help to reduce the number of required characters for a given sequence.

Example 5.1 “/1ZR<CR>” will be sent to initialize the valve (see serial command description) In return, the pump will answer with “/0@<ETX><CR><LF>”.

5.1.2 Using DT Protocol with Microsoft Windows

The RVM can be controlled in the following manner:

1. Connect the valve to the PC (connect the mini-USB for the low power model, and mini-USB + power cord for the fast model)
2. Open the *Device Manager* to identify which COM port is connected.
3. Open a Terminal or Terminal emulator such as RealTerm or HTerm.
4. Establish the connection by selecting the baud rate (9600), the correct communication port (here for example COM5), 8 data bits, 1 stop bit, no parity and no flow control.

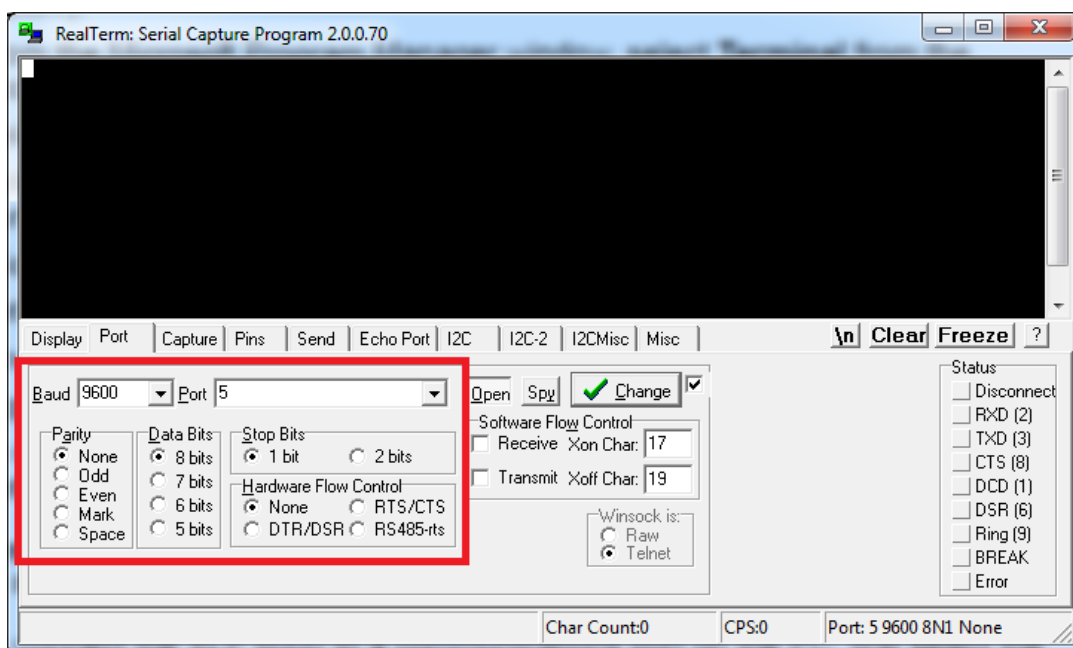


FIGURE 5.1 – Settings for serial communication

5. Press *Change* to start the connection.
6. Send /1ZR<CR> with the *Send ASCII* button. The *End of Line* chars can usually be added automatically (here by ticking the +CR box).

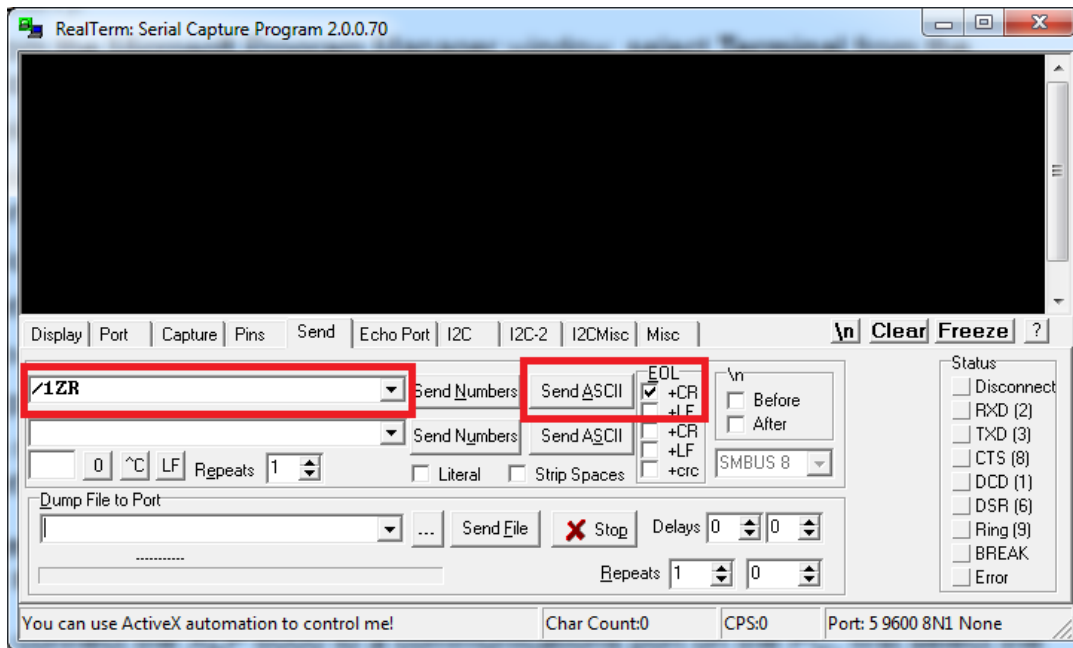


FIGURE 5.2 – Sending command configuration

7. Refer to the complete set of commands to use the pump according to your need.

5.1.3 RVM Command Set

The RVM simplifies your microfluidic automation thanks to a wide and well-tried command set.

Command Execution Guidelines

- All commands, apart from commands starting with "?" or "!" and from the abort command T, must be followed by the character [R] to be run.
- During the execution of a command, no new command is accepted, except for interrupt and report commands.
- The valve answers immediately after a command was sent. If an invalid command has been sent in the command string, the valve reports an error immediately.

Valve Configuration Commands

Command	Operand Range	Default Operand	Operand Description	Command Description
@ADDR=<n>	1..9 or A..E	1	1-character address	Valve address, "_" is broadcast address
!80<n>	4, 6, 8 or 12	6	Number of valve positions, No trailing [R]	Valve configuration (no trailing [R])
!17			No trailing [R]	Reset valve motion counter (no trailing [R])
-			slow mode	Speed configuration (RVMFS only)
+			fast mode	Speed configuration (RVMFS only) not available for 12-port valve

Control Commands

Command	Operand Range	Default Operand	Operand Description	Command Description
R	N/A	N/A		Execute command string
X	N/A	N/A	No trailing [R]	Re-execute last executed command string
G<n>	0...60000	0	0 = Loop forever	Repeat command sequence
g	N/A	N/A	Loop depth = max 10	Mark the start of a repeat sequence
M<n>	0..86400000		Milliseconds	Delay command execution

Initialization Commands

Command	Operand Range	Default Operand	Operand Description	Command Description
Z	N/A	N/A		Home the valve
Y	N/A	N/A		Home the valve

Valve commands

Command	Operand Range	Default Operand	Operand Description	Command Description
O<n>	1..12	N/A	Counter-clockwise plug movement (valve seen from above)	Move to valve port. For on/off: open positions are 1 and 3 (1 and 3 are diametrically opposed)
I<n>	1..12	N/A	Clockwise plug movement (valve seen from above)	Move to valve port. Port numbering has been configured so that incrementing the argument of I by 1 triggers a plug rotation of 60 degrees only
B<n>	1..12	N/A	Shortest plug movement	Move to valve port with shortest path clockwise direction preferred

Report Commands

These commands do not need a trailing [R] character.

Command	Description
Q	Current status
?6	Report valve position
?17	Report number of valve movements
?18 or %	Report number of valve movements (since last report)
?19	Report speed mode the valve (RVMFS only)
?20 or #	Report firmware checksum
?23 or &	Report firmware version
?26	Report valve address
?29	Same as Q (query, status and error bytes)
?76	Report valve configuration
?801	Number of valve positions
\$	Internal reset
*	Report supply voltage (x0.1 V)
?9000	Unique ID
?9200	Detailed status of the valve

Error codes

The RVM immediately sends a response every time an instruction is sent to it. Only errors 2 and 3 can be found through this immediate response. The user must send the command Q to get the status in case of further errors.

Bit	7	6	5	4	3	2	1	0
Value	0	1	Status Bit	0	Error Code			

TABLE 5.2 – Detail of the error byte as returned after a query “/1Q”

Status Bit 5	Description
X=0	The valve will only accept report commands
X=1	The valve is ready to accept new instructions

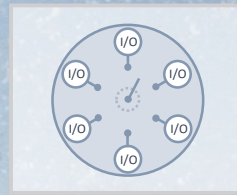
TABLE 5.3 – Status bit description

Error Byte 7 6 5 4 3 2 1 0	Symbol ASCII		Error	
	if Bit 5 = 0	if Bit 5 =1	Code	Description
0 1 X 0 0 0 0 0	@	'	0	No Error
0 1 X 0 0 0 0 1	A	a	1	Initialization
0 1 X 0 0 0 1 0	B	b	2	Invalid command
0 1 X 0 0 0 1 1	C	c	3	Invalid operand
0 1 X 0 0 1 0 0	D	d	4	Missing trailing [R]
0 1 X 0 0 1 1 1	G	g	7	Device not initialized
0 1 X 0 1 0 0 0	H	h	8	Internal failure (valve)
0 1 X 0 1 0 0 1	I	i	9	Plunger overload
0 1 X 0 1 0 1 0	J	j	10	Valve overload
0 1 X 0 1 1 1 0	N	n	14	A/D converter failure
0 1 X 0 1 1 1 1	O	o	15	Command overflow

TABLE 5.4 – Error codes

Status code	Name	Description
0xFF = 255	Busy	Valve currently executing an instruction
0x00 = 0	Done	Valve available for next instruction
0x80 = 128	Unknown command	Check that the command is written properly.
0x90 = 144	Not homed	You forgot the homing! Otherwise, check that you have the right port configuration and try again.
E0 = 224	Blocked	Something prevented the valve to move.
E1 = 225	Sensor error	Unable to read position sensor. This probably means that the cable is disconnected.
E2 = 226	Missing main reference	Unable to find the valve's main reference magnet during homing. This can mean that a reference magnet of the valve is bad/missing or that the motor is blocked during homing.
E3 = 227	Missing reference	Unable to find a valve's reference magnet during homing. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. This can also mean that a reference magnet of the valve is bad/missing or that the motor is blocked during homing.
E4 = 228	Bad reference polarity	One of the magnets of the reference valve has a bad polarity. Please check that you have the correct valve number configuration with command "/1?801". If not, change it according to the valve you are working with. This can also mean that a reference magnet has been assembled in the wrong orientation in the valve.

TABLE 5.5 – Detailed status of the valve (see command ?9200)



6. Coding examples



6.1 Labview VI

6.1.1 Description

For ease of use, a sub-VI in Labview was created. You can directly integrate it in your current Labview setup, providing the COM port and string command as input, and observe the response from the valve to check that everything is acting as wanted.

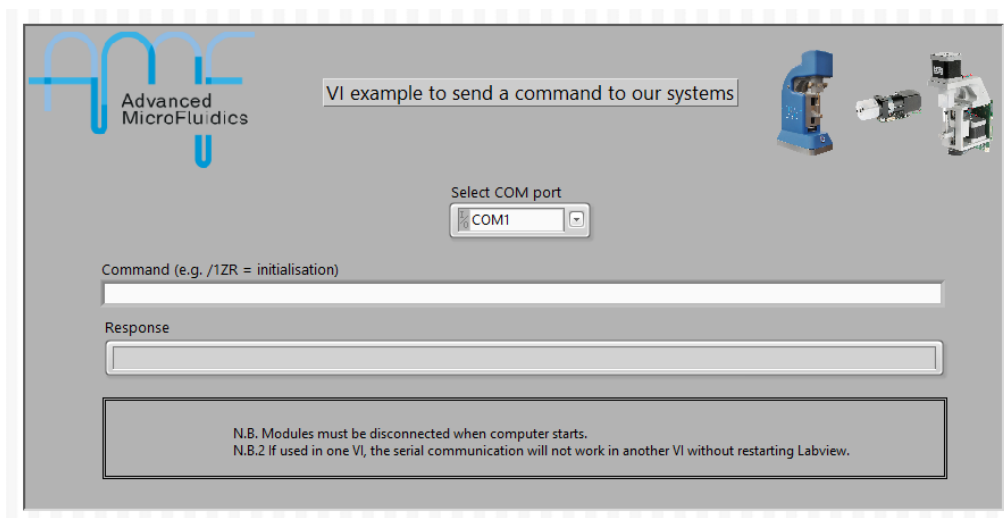


FIGURE 6.1 – Labview sub-VI, front panel - 1 apparatus

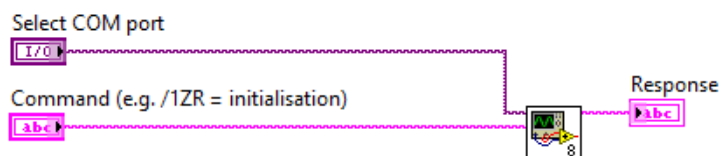


FIGURE 6.2 – Labview sub-VI, bloc diagram - 1 apparatus

It is then very simple to include several of our systems in the same setup. In the following example, the same command is sent to 2 apparatus, but it is also possible to send 2 different commands if you don't link them together.

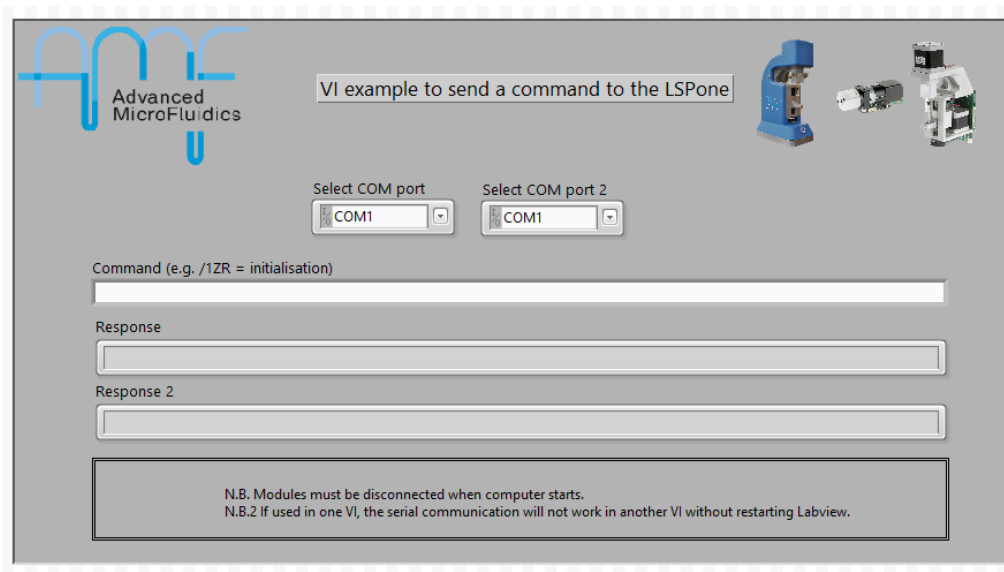


FIGURE 6.3 – Labview sub-VI, front panel - 2 apparatus (same command to both)

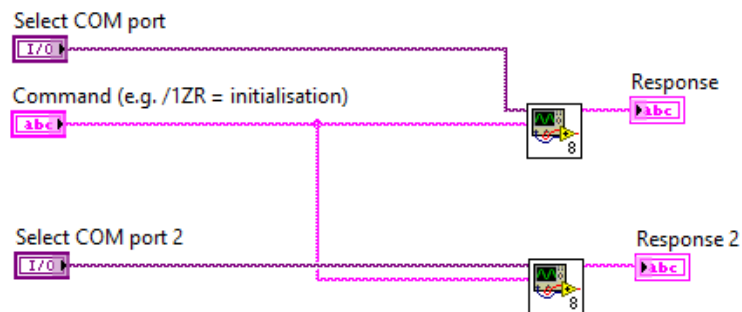


FIGURE 6.4 – Labview sub-VI, bloc diagram - 2 apparatus (same command to both)

6.1.2 Requirements

Nothing special is required, other than Labview from National Instruments. Tested with Labview 2016.

N.B. In case the VI does not seem to respond, please restart Labview.

6.2 Python scripting

6.2.1 Description

Serial commands can be sent via python scripting using the *pySerial* library. A very simple example is shown below. Python scripting will be of specific interest when using different devices and trying to automate a sequence involving these devices.

```
"""
RVM_example.py
~~~~~

This program shows how to connect to to the RVM (OEM rotary valve)
using python.
The different commands can be found in the user manual.

:copyright: (c) 2017, E. Collot
:license: Proprietary, see LICENSE for details.

"""
#include python libraries
import sys
import serial
import time

# Open serial connection -> check COM port on your device
rvm = serial.Serial('COM7', 9600, timeout=1000)
print('RVM connected on ', rvm.name)

# Initialise RVM
rvm.write(b"/1ZR\r")
time.sleep(5)
rvm.write(b"/103R\r")
time.sleep(10)
print("RVM ready")

#Here is the detail
# /1 - command start
# 03 - go to port 3, clockwise rotation
# R - command end

#Finishing the script
sys.exit(0)
```

FIGURE 6.5 – Python example script

6.2.2 Requirements

Python has to be installed on your computer. Additionnaly, the script requires the *pySerial* library (<https://pythonhosted.org/pyserial/>).