FLUIGENT

MicroFluidics Control System

User Manual

MFCS User Manual version 2.0 www.fluigent.com

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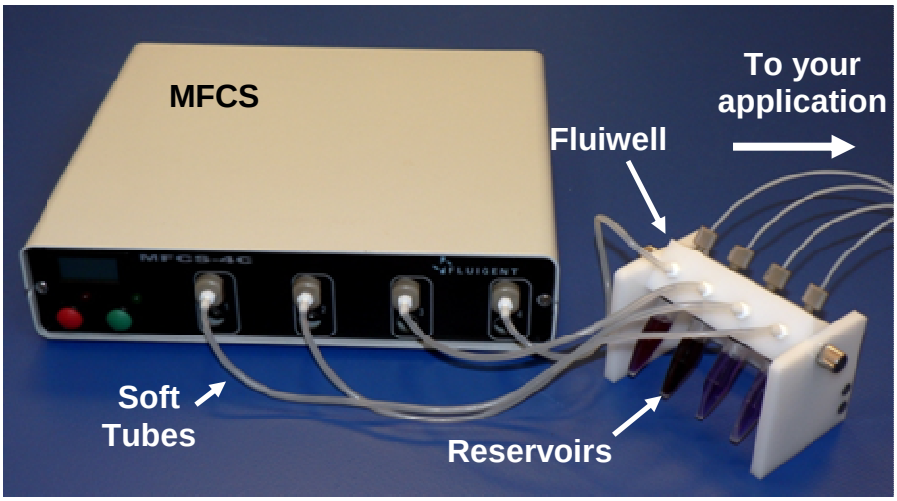
1. Introduction



The **M**icro**F**luidic **C**ontrol **S**ystem (MFCS) is a High precision pneumatic pressure controller designed to handle fluid in microfluidics systems (microchannels and nanochannels, capillaries, Lab-on-chips…).
It allows a stable and pulsation free flow with short response time (100 ms) and a stabilization time as low as 1s. With the MFCS it is also possible to control several independent channels (up to 16 cf Labiview VI) at the same time. The user friendly softwares allow you to create scripts for complex flow patterns or dynamic coupling for user-controlled dependence between channels.

Pressure Range / Channel Number	**0 to 25 mBar**	**0 to 69 mBar**	**0 to 345 mBar**	**0 to 1000 mBar**	**-25 to 0 mBar**	**-69 to 0 mBar**
4 channels	MFCS-4C-25	MFCS-4C-70	MFCS-4C-345	MFCS-4C-1000	MFCS-NEG-4C-25	MFCS-NEG-4C-70
8 channels	MFCS-8C-25	MFCS-8C-70	MFCS-8C-345	MFCS-8C-1000	MFCS-NEG-8C-25	MFCS-NEG-8C-70
Pressure type	**P>0**				**P<0**	

Figure 1. Available MFCS series

2. Package content and required materials

2.1. Package content

The MFCS package comprises following items:

- ☐ One MFCS unit,
- ☐ A power supply and a power line cable,
- ☐ A USB cable,
- ☐ A pneumatic Connection kit (4* soft tube adapters, 4* x 50 cm of soft tube (OD 3mm ID 1mm), a ¼ " spanner)
- ☐ A quick user guide.
- ☐ This user manual.

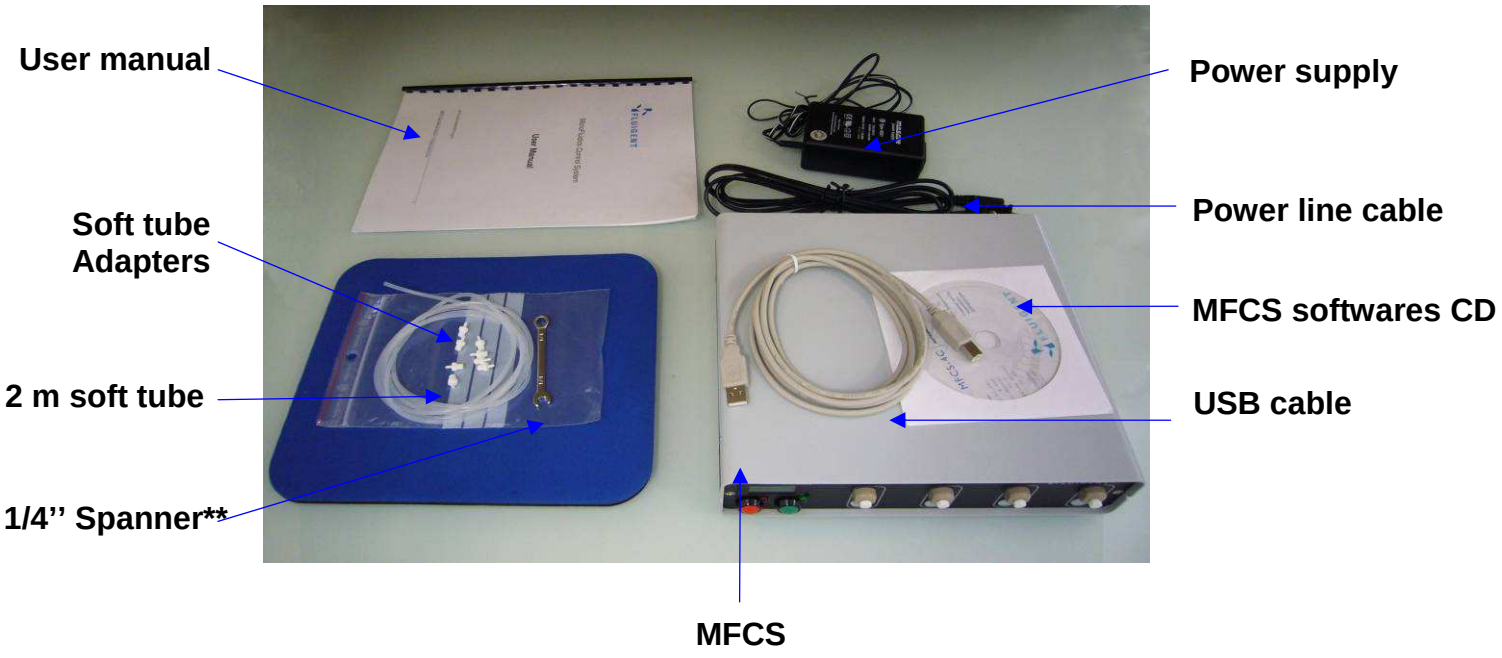


Figure 2 Package content

Optional Accessories:

A Fluiwell and a set of spare parts

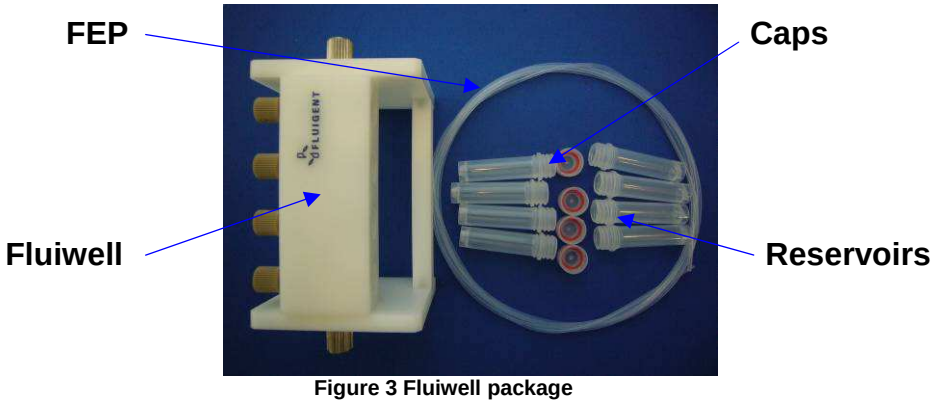


Figure 3 Fluiwell package

If any parts are missing or damaged, please contact your local dealer or Fluigent immediately.

* For a 8 channel MFCS, 8 adapters will be provided
** soon provided in the MFCS package

2.2. MFCS Description

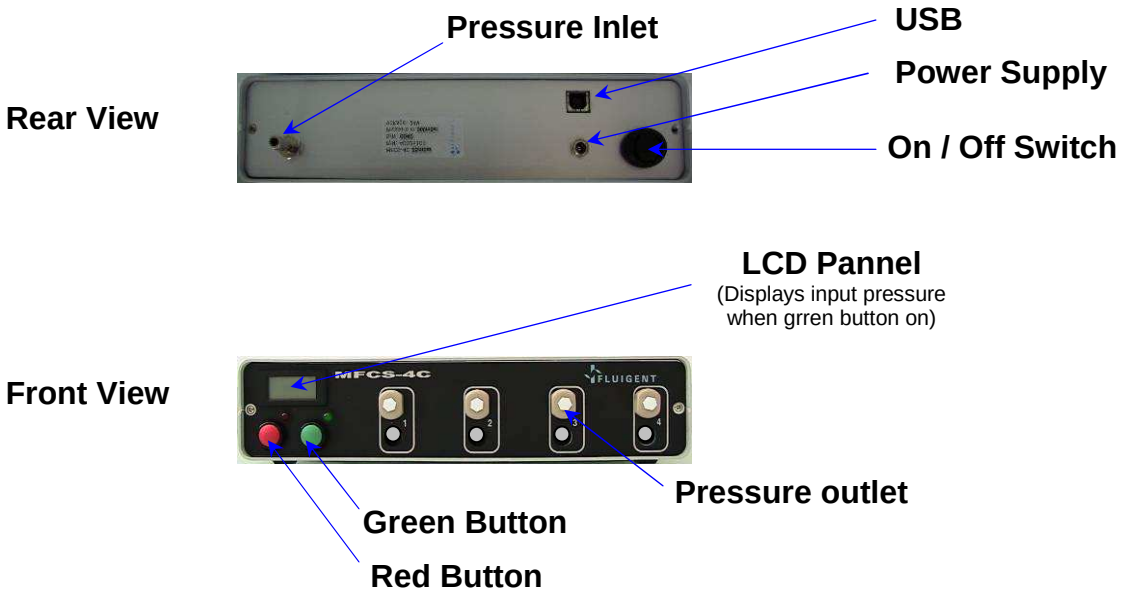


Figure 4 Front and Back views

2.3. Required Materials

Using the MFCS requires the following materials:

- ☐ A computer :
  - o USB 1.1 port or faster
  - o screen resolution of 1024x768
  - o Intel Pentium II 500 MHz or faster
  - o Windows2000, Windows XP.
  - o 5 Mo of Free Hard disk space

- ☐ A pneumatic pressure source :
  - o For positive pressure models :
    - ☐ dry and non corrosive (use an air drier)
    - ☐ dust and oil free
    - ☐ with a pressure regulator to tune the input pressure value
    - ☐ 0,01 µm filtered
    - ☐ The pressure range of the pump should suit your MFCS input pressure (see Figure 3)
  - o For negative pressure models:
    - ☐ Use a pump in aspiration mode

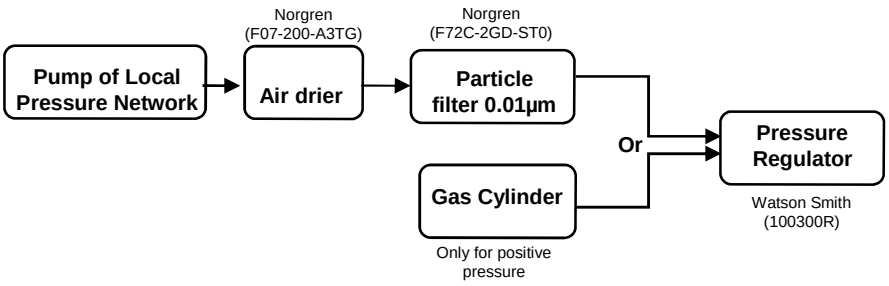


Figure 5 Suggested Pressure Source scheme

Pressure Range	0 to 25 mBar	0 to 69 mBar	0 to 345 mBar	0 to 1000 mBar	-25 to 0 mBar	-69 to 0 mBar
Input Pressure value	500 mBar	500 mBar	800 mBar	1300 mBar	- 500 mBar	- 500 mBar

Figure 6 : Input pressure value according to MFCS pressure range

Connection to the MFCS requires either:

- ☐ The Fluiwell, a microfluidic interface between the MFCS and your Microdevice that uses 1/16'' OD tube or smaller (see Figure **7**)
- ☐ Your own connection system.

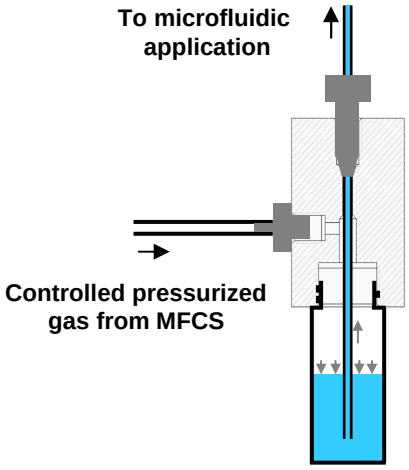


Figure 7 Fluiwell's working principle

3. Installation guide

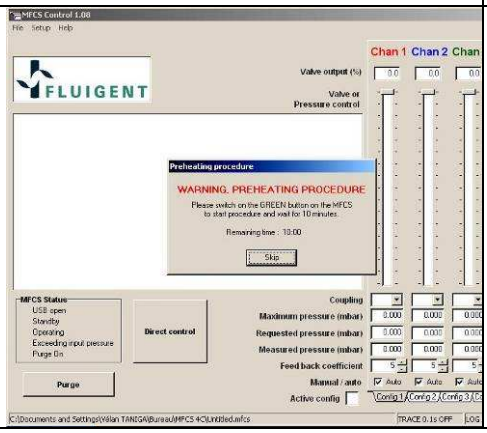
3.1. Warnings

- ☐ MFCS must be used in a clean and dry environment.
- ☐ No liquid should enter into the device otherwise this would void the warranty.
- ☐ The Pressure source must be dry, dust and oil free. Use a 0,01 µm filter and a pressure regulator to insure proper input pressure. (for positive pressure models)

3.2. Unpacking and preparation of the MFCS (with Fluiwell)

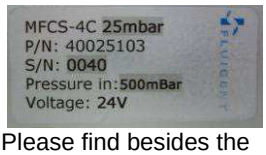
Please follow the next series of operation in order to set properly your MFCS.

Step	Indication	Photos	Remarks
1	Unpack the MFCS		Please check that all is in order.If any damage, please phone us or e-mail us (mfcssupport@fluigent.com).
2	Connect to the rear panel : - the usb cable - the power supply - the pressure source For positive pressure models: PLEASE USE CLEAN AND DRY GAS WITH A PRESSURE REGULATOR BEFORE THE MFCS (see section 2.3)		To avoid liquid back-flow, please use protection systems such as the FLUIWELL(see Figure 7).

3	Insert the MFCS softwares CD. Copy the MFCS-4C* folder to desired location on your hard drive		
4	Open the MFCS-4C* folder you just copied on your hard drive.		
5	Switch ON the MFCS (rear panel). The red light should be bright. If not, check the power supply and the USB cable.		
6	Double click on the MFCS control icon		
7	The software is ready to be used.		

* MFCS-8C for a 8 channel device

<table>
<tr>
<td>8</td>
<td>For positive pressure models: The pressure source should be CLEAN AND DRY and fixed to the input pressure value specified on the rear panel of your MFCS

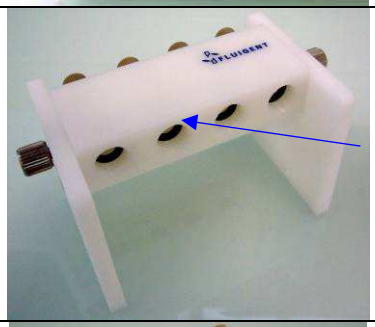
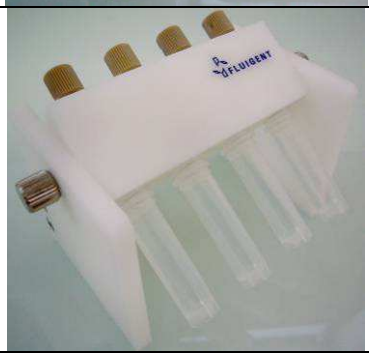
Please find besides the value of the input pressure MFCS.</td>
<td colspan="3">
<table>
<tr><td>Pressure Range (mBar)</td><td>25</td><td>69</td><td>345</td><td>1000</td><td>- 25</td><td>- 69</td></tr>
<tr><td>Input Pressure value (mBar)</td><td>500</td><td>500</td><td>800</td><td>1300</td><td>- 500</td><td>- 500</td></tr>
</table>
</td>
</tr>
<tr>
<td>9</td>
<td>Press the Green button and set the pressure source to the input pressure value of your MFCS. You can monitor the pressure source value on the front display.

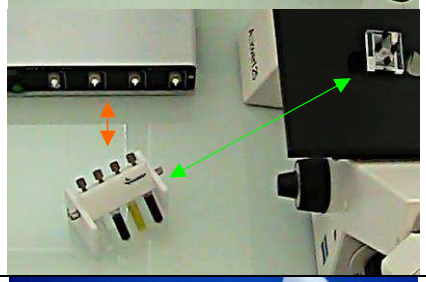
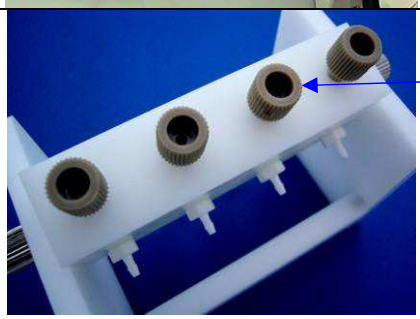
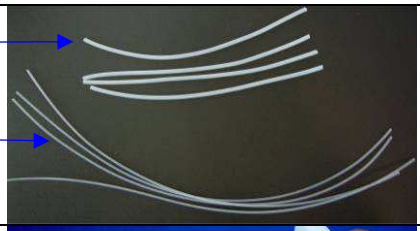
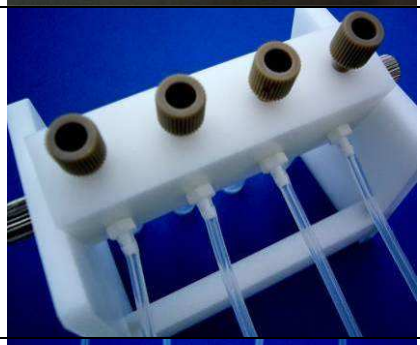
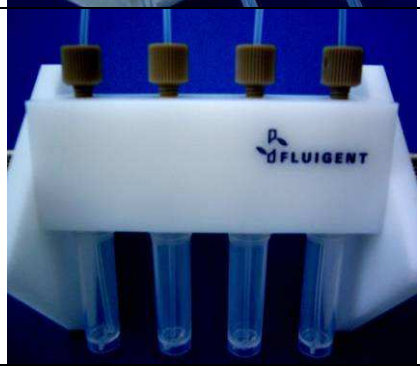
The preheating will start.</td>
<td> 

 
</td>
<td>A preheating procedure is necessary to warm up the MFCS (10min) meanwhile you can continue with the next step

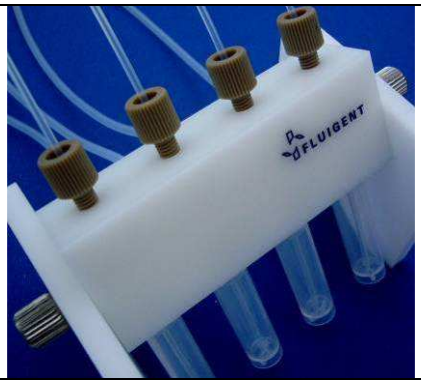
Avoiding this step can decrease the pressure control stability and accuracy.

When performing series of experiments, the preheating is only necessary once a day.

For negative pressure models LCD panel displays the absolute value of the pressure</td>
</tr>
<tr>
<td>10</td>
<td>Unpack the Fluiwell (optional accessory)</td>
<td>  </td>
<td>Please check that the 4 toric seals are in place, before mounting the reservoirs.</td>
</tr>
<tr>
<td>11</td>
<td>Screw the 2 mL reservoirs on the fluiwell</td>
<td>  </td>
<td></td>
</tr>
</table>

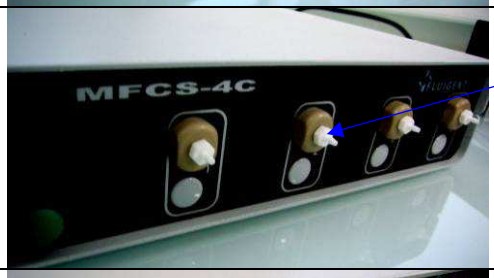
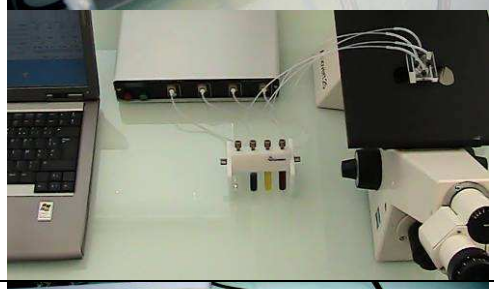
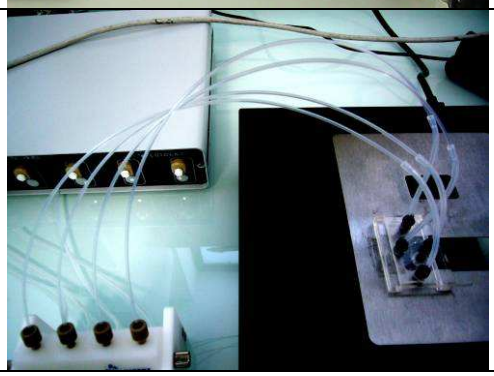
12	Prepare your experimental setup by placing all the devices and elements you might need. The lengths of the pieces correspond to the distance between the fluiwell and the MFCS.	 	
13	If you use different connectors, a list of compatible adapters is available in the appendices		
14	4* pieces of the soft tube. 4* pieces of the FEP tube.		You can find the references of the tubings in the appendices.
15	Connect the soft tubes to the fluiwell		
16	Connect the FEP tubes to the top outlets. In order to avoid leaks, the fitting should be tightly screwed.		The FEP tubes should be visible inside the 2 mL reservoirs.

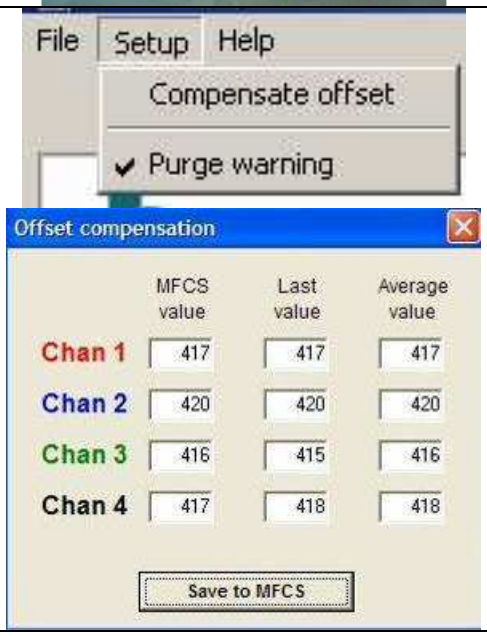
* 8 pieces for MFCS-8C with 2 fluiwells

17	Now your fluiwell is ready to be connected to your microfluidic chip and to the MFCS. Don’t forget to fill the reservoir with your sample !			

3.3. Starting the MFCS

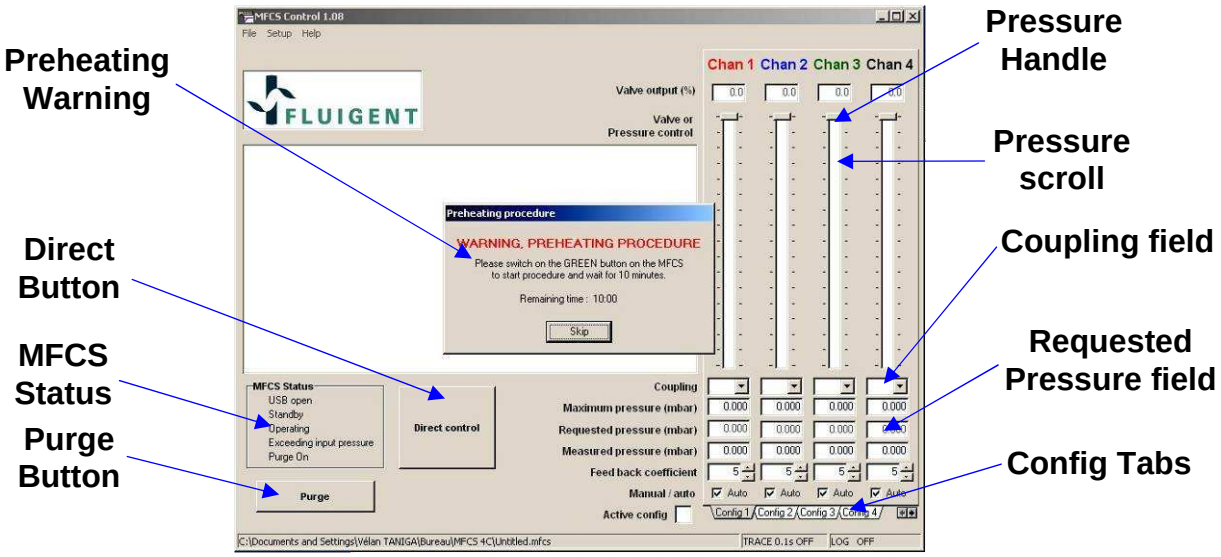
Please proceed as follow:

Step	Indication	Photos	Remarks
1	Remove the protection caps from the MFCS outlets.		Use the provided spanner or any ¼" tools* Protection cap Free outlet
2	Tightly screw the soft tube adapters on the outlets.		Soft tube adapters
3	Connect the soft tubes to the MFCS' outlets.	 	
4	Connect the fluiwell to your microfluidic chip, using the FEP tubes for example.		A list of adapters for smaller inner diameters tubes is available in the appendices.

5	Fill up the 2 mL reservoirs with the appropriate fluid corresponding to the inlets of your chip.		
6	At the end of the preheating countdown : - push the red button and - calibrate the MFCS by clicking on the Setup / Compensate offset. Click save to MFCS to load your calibration parameters into the MFCS and close the window.		In order to guarantee the accuracy of your measures we recommend you to calibrate the device every time you move it. Otherwise once a month is sufficient. The MFCS is ready to be used.

4. Basic Software Operations

Here you will learn how to operate the MFCS using the MFCS control interface.



For negative pressure models: the software displays the absolute value of the pressure

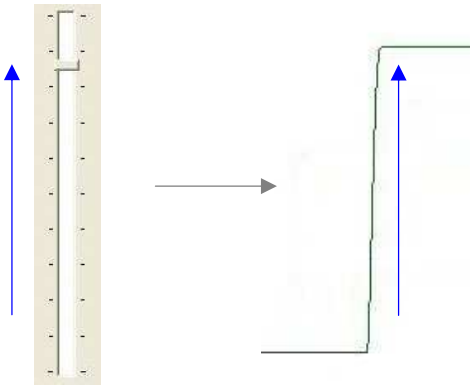
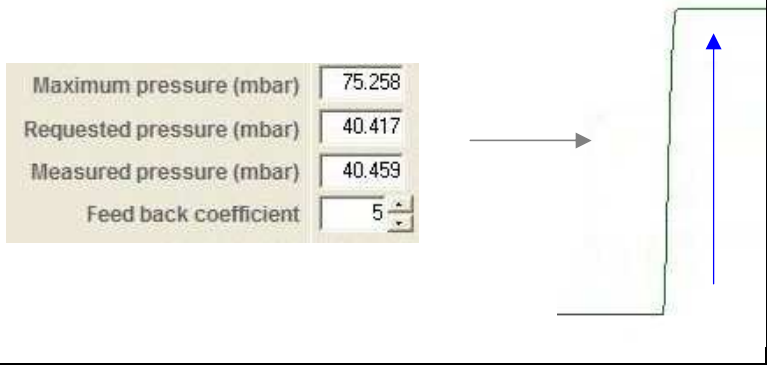
4.1. Purge

1	Click on the Purge button and valid the warning.		A purge feature is available in channel 1. It applies maximum pressure on this channel. It suits any filling or emptying purpose.
2	Disable the purge feature by clicking again on Purge button		The Purge on green indicator will appear until you stop the purge.

4.2. Pressure control in the channels

For negative pressure models: the software displays the absolute value of the pressure

There are two different way to modify the pressure in a channel:

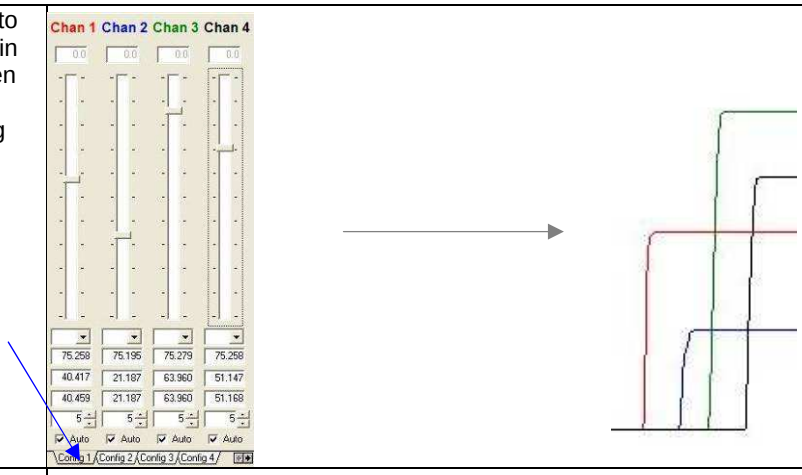
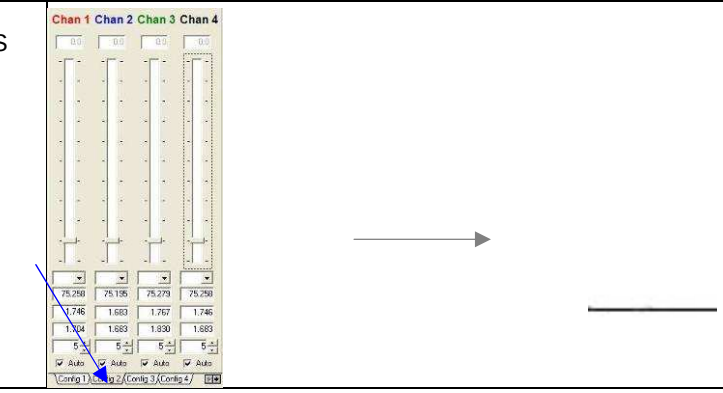
1	Press Direct Control button, to activate the control of the MFCS		Otherwise, orders will not be transmitted
2	Change pressure in the channels, using the corresponding handle		
3	Enter the numerical value of the pressure in the requested pressure field.		

Shortcuts:
It is possible to modify the positions of the handle using keyboard. Click on a handle, then:

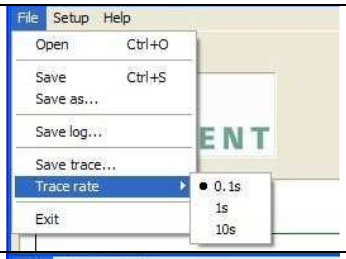
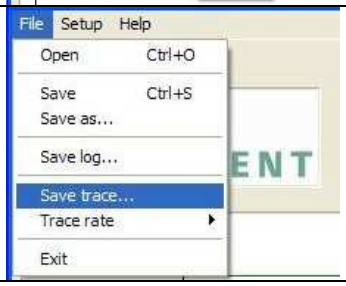
- Up arrow: Move the handle up by 1 steps
- Down arrow: Move the handle down by 1 steps
- Page up: Move the handle up by 10 steps
- Page down: Move the handle down by 10 steps
- Move to the top of the scale using home
- Move to the bottom of the scale using end

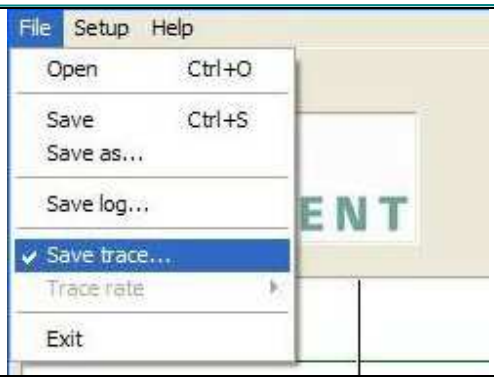
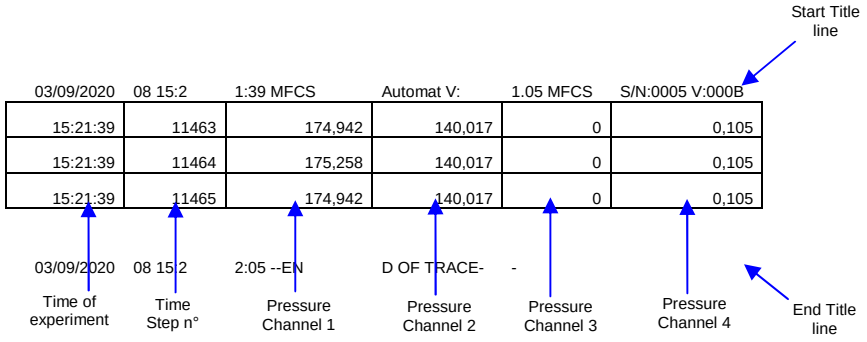
4.3. Tabs configurations

For negative pressure models: the software displays the absolute value of the pressure

1	You can use the config tabs to set different handle patterns in order to easily switch between several pressure sets by clicking on the corresponding tab.	
2	The curves will follow the pressure pattern. (See MFCS mat or labview VI for automated pattern setting)	

4.4. Save curves

1	To save a set of curves, first choose the desired trace rate		
2	Then start recording by giving a name to the curves file in save trace dialog box of the file menu. (a tick will appear)		

3	End the record by clicking on save trace (untick)		
4	The file is a text file that can be imported in any spreadsheet		
5	Curves File format (see section 6.7) **For negative pressure models: the software displays the absolute value of the pressure**		

5. Advanced Control of the MFCS

5.1. More about MFCS Control

5.1.1. Coupling

- The coupling is a feature that creates software driven dependence between channels. Thus it is possible to increase pressure in one channel while the pressure in a second one is decreasing with the same variation. Both parallel and antiparallel coupling are possible.
- To set a parallel coupling between channel 1 and channel 2 choose A + for both channel in the coupling field.
- To achieve an antiparallel coupling just choose A- for one of the two channels.
- To couple more than one channel set the coupling field of each channels in consequence.

.

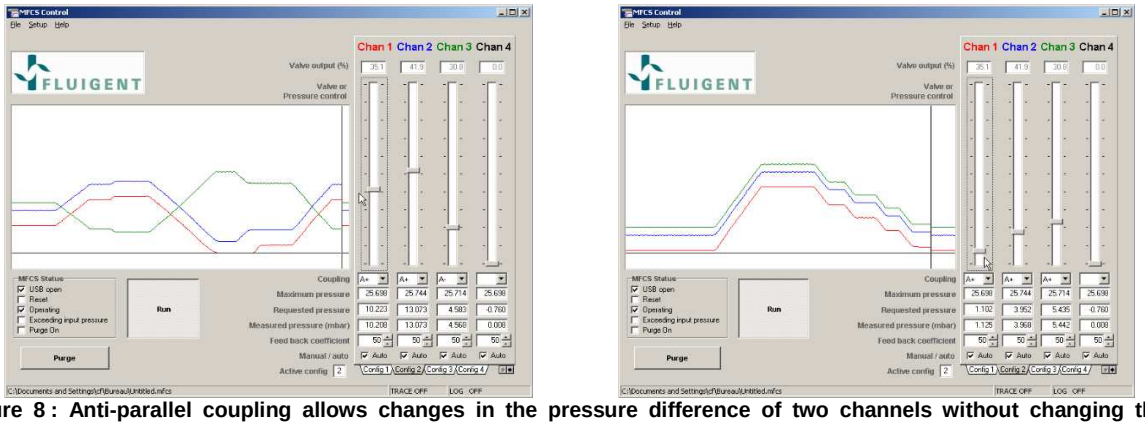


Figure 8 : Anti-parallel coupling allows changes in the pressure difference of two channels without changing the pressure sum. Parallel coupling keeps the pressure difference constant.

Shortcut :
It is possible to disable temporally the coupling feature of a set of channels by pressing the shift key. Then you are able to move the handles independently.

5.1.2. Manual/auto

The manual mode provides a proportional control on the valves. The handles directly control the valves opening, and no regulation occurs. This mode is only adapted for special use and it will be subject to intrinsic nonlinear characteristics, hysteresis and limited reproducibility of the solenoid-valves.
The auto mode provides a direct control on the pressure inside the channels. The handles set the requested pressure and the embedded regulation program will compute the order to give to the valves in order to have a stable, quick and reproducible response.

5.1.3. Feedback coefficient

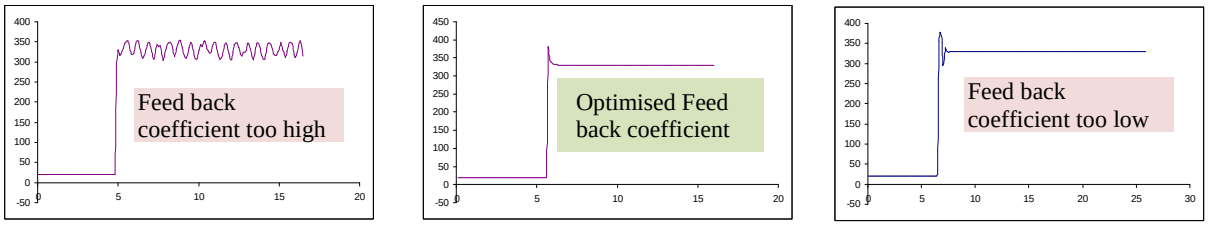


Figure 9 : effect of the « Feed back coefficient » value on the pressure stability and response time.

The MFCS Control software provides optimal pressure and flow regulation for a wide range of microfluidic applications, in particular those involving extremely low pressures and or volume flow rates (µl to pl/min). However when using large volumes, an adjustment of the feed-back

loop's reactivity can be necessary to achieve an optimal operation of the MFCS. This can be achieved, independently for each channel, by changing the "feed back coefficient".
The factory setting is 5, a smaller coefficient results in a slower reaction, a higher value gives a faster response.

If the feedback coefficient is to high, the regulation loop can become unstable and pressure control inside the channel is no longer possible.
The optimal response is obtained just below the critical damping situation between a monotonous return to equilibrium and oscillatory overshooting.

Please note that for high pressure versions of the MFCS, at the factory-setting initial value, operation is oscillation-free for small pressure changes but shows overshooting and transient oscillations for drastic pressure changes. If this overshooting is a nuisance to your application, it can be suppressed by decreasing the feedback coefficient, at the expense of the regulation speed for small pressure changes. A working compromise has to be found, the optimal value depends on several features of the connected system (volume and elasticity of tubing, hydrodynamic resistance and geometry of the microfluidic channels), and on the time constant of the phenomena under investigation.

5.2. MFCS mat (scripting software)

5.2.1.General description

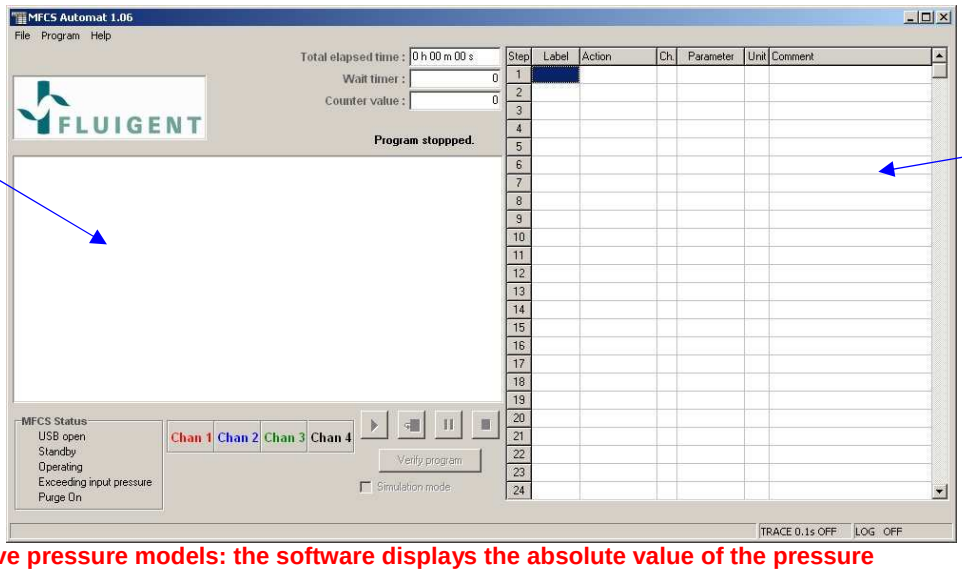


Chart
(here it is blank)

Table

MFCS Status

For negative pressure models: the software displays the absolute value of the pressure

MFCS mat is a script software that allows, to create automated pattern of pressure.

In the main window, you can find:

- A chart showing the pressure value of all the channels (here it is blank),
- Below the chart, the MFCS status is shown with the buttons 'play', 'pause', 'stop', et 'verify program', allowing one to play, pause, stop and verify the programme.
- On the right hand side, the user can fill in different actions in the table (script).

5.2.2.Description of the table

In this table, there are 6 rows :

- Label needs a string. It is where the action « Goto label » looks for.
- Action: define the type of action
- Ch: define the channel number where the action is applied.
- Parameter: define the parameter of the action if necessary,
- Unit: specify the unit of the parameter (automatically set)
- Comment: define a comment of the current action.

5.2.3.Descriptions of the Actions

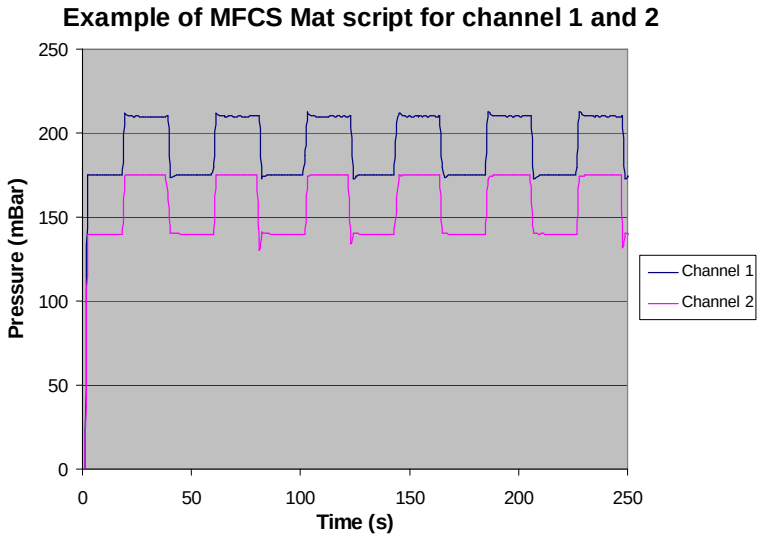
Actions	Parameters	Description
Alpha	Integer from 0 to 255 : n	This value is linked to the feedback coefficient for the pressure regulation. (default value 5)
Auto	Double : x	Send a pressure order in mbar to the specified channel
End		End programme
Goto label	String : s	Go to the line with the s string the label row
Manuel	Double : x	The channel is control manualy without feedback control. X is equivalent to the % of alimentation of the Electrovalve.
Purge off		Stop Purge on channel 1
Purge on		Start Purge on channel 1
Wait	Double : x	The programme waits for x secondes.

5.2.4.Script example

Here is an example of a script with the corresponding pressure chart.

Step	*Label*	*Action*	*Channel*	*Parameter*	*Unit*
1		alpha	1	5	
2		alpha	2	5	
3	start	auto	1	175	mb
4		wait		2	s
5		auto	1	210	mb
6		auto	2	175	mb
7		wait	2		s
8		auto	2	140	mb
9		goto label		start	

This is an endless loop generating a 4 seconds period square pressure signal.

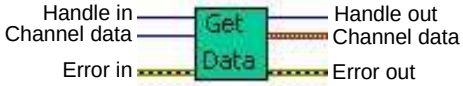
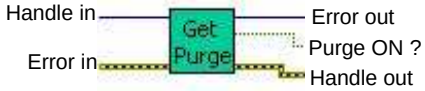
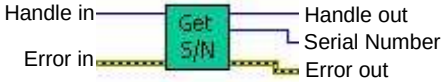
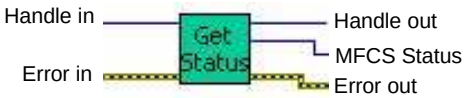
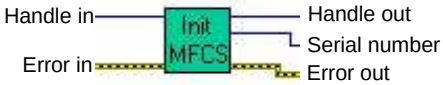
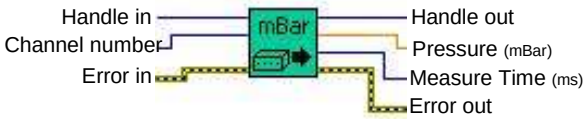


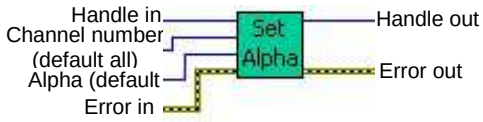
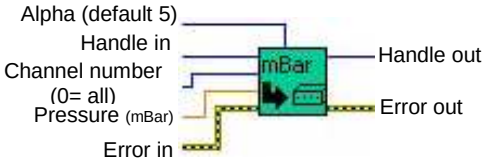
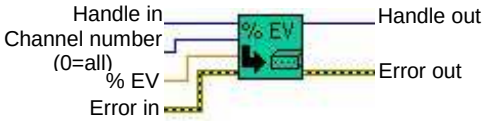
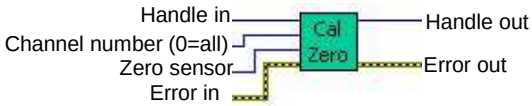
5.3. Labview

The Labview drivers are in the provided CD.

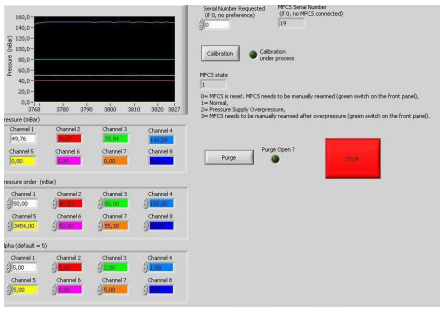
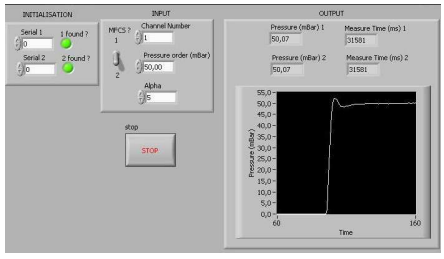
The Labview library provided is embedded with a set of functions that will allow you to control the MFCS in your own Labview program. Here are a few examples of what you can achieve with this library.

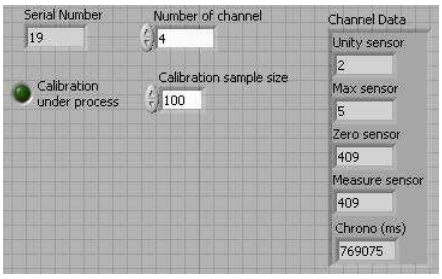
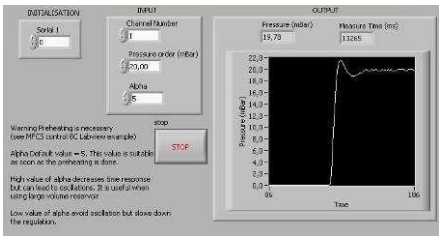
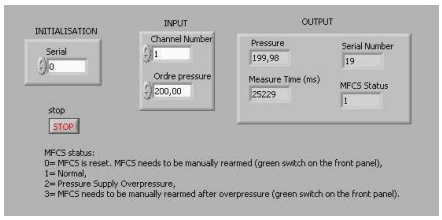
5.3.1.Labivew VI

Labview VI	Symbol	Description
mfcs_close.vi		Close the MFCS device and the allocated memory
mfcs_data_chan.vi		Get the characteristics of the specified channel: ☐ Pressure unity (0=no sensor, 1=water inch, 2=PSI) ☐ Maximum pressure range (in the specified unity) ☐ Zero pressure value of the sensor (unsigned 12 bits) ☐ Pressure value (unsigned 12 bits)
mfcs_get_purge.vi		Get status of the purge in channel 1: ☐ True= Purge ON ☐ False= Purge OFF
mfcs_get_serial.vi		Get the serial number of the MFCS (0 if no MFCS connected)
mfcs_get_status.vi		Get the status of the MFCS: ☐ 0= MFCS is reset. MFCS needs to be manually rearmed (switch on GREEN button) ☐ 1= Normal ☐ 2= Pressure Supply Overpressure ☐ 3= MFCS needs to be manually rearmed ater overpressure (switch on GREEN button)
mfcs_initialisation.vi		Initialize the MFCS device: ☐ If the serial number is not specified or equal to 0, the first MFCS device found will be initialized. ☐ If the serial number is specified, the corresponding MFCS device is initialized. Each MFCS has a unique serial number written on the back panel. ☐ The VI returns the handle and the serial number of the MFCS (0 if no MFCS found).
mfcs_read_chan.vi		Get the pressure value (mBar) and the measure time (ms) of the specified channel (from 1 to 4 or 8).

mfcs_set_alpha.vi		Set the alpha value (default =5) for the specified channel (from 1 to 4 or 8): ☐ If the specified channel is 0, the same is applied to all channels. ☐ Alpha is linked to the proportional value of the PID pressure regulation.
mfcs_set_auto.vi		Set the regulated pressure value (mBar) for the specified channel (from 1 to 4 or 8): ☐ If the specified channel number is 0, the same pressure is applied to all the channels. ☐ It is also possible to set the alpha value
mfcs_set_manual.vi		Set the electrovalve alimentation (%) for the specified channel (from 1 to 4 or 8): ☐ If the specified channel is 0, the same is applied to all channels. ☐ The manual control of the electrovalve is not recommended and the output pressure is no longer regulated
mfcs_set_purge_off.vi		Disable purge feature, channel 1 can be used normally.
mfcs_set_purge_on.vi		Enable purge feature, channel 1 is directly connected to the pressure supply. Please use with care in order to avoid any damage to your microsystem.
mfcs_set_zero.vi		Calibrate the zero pressure value of the specified channel. This value can be estimated with mfcs_data_chan.vi.

5.3.2.Labview examples

MFCS 8C control		This VI is a transposition of MFCS control. It integrates MFCS control software's functions in a Labview environment: ☐ Enter "serial number" ☐ Calibrate the MFCS if needed ☐ Set "pressure order"and "alpha" (feeback coefficient) in the channels of interests ☐ Press "purge" (channel 1 only) to fill or empty your device ☐ Press "STOP" to stop the pressure
Control 2 MFCS		Thanks to this Vi it is possible to control several MFCS at the same time: ☐ Enter the two serial numbers ☐ Select the MFCS of interest with the 1/2 switch of the "INPUT" box. ☐ Set channel number, pressure order, appropriate Alpha (feedback coefficient). ☐ Press STOP button to stop pressure

Calibration		The Calibration process can also be in operated from Labview interface
Set pressure and alpha analog		This example allows you to set an order (pressure and feedback coefficient) and then to read the result on an analog curve
Set pressure digital		This example allows you to set a pressure order and monitor the result on a numerical display

5.4. C++ and VBA

5.4.1.Function description (preliminary)

Here is a global description of the functions provided with the library.

mfcs_initialisation	Initialize the USB for the MFCS. If the Serial Number is not specified or equal to 0, the first MFCS device found will be initialized. If the Serial Number is specified, the MFCS device with this Serial Number is initialized. Each MFCS has a unique Serial Number written on the back panel. The vi returns the handle and a boolean that confirms that the USB initialized correctly.
mfcs_close	Close the MFCS device and the allocated memory.
mfcs_set_purge_on	Connect the channel 1 output directly to the pressure supply. This function should be used with care as it can cause damage to the microsystems connected.
mfcs_set_purge_off	Disconnect the channel 1 output from the pressure supply. Channel 1 can be used normally.
mfcs_get_purge	Get the status of the purge: - TRUE= purge ON, - FALSE= purge OFF
mfcs_get_status	Get the status of the MFCS: -1= Trouble in the MFCS connections (USB or electric alimentation) 0= MFCS is reset. MFCS needs to be manually rearmed (green switch on the front panel), 1= Normal, 2= Pressure Supply Overpressure, 3= MFCS needs to be manually rearmed after overpressure (green switch on the front panel).
mfcs_read_chan	Get the pressure value (mBar) and the measure time (ms) of the specified channel (from 1 to 4 or 8).
mfcs_data_chan	Get the characteristics of the specified channel: - Pressure Unity (0= no captor, 1= water inch, 2= PSI), - Maximum Pressure range (in the specified unity), - Zero pressure value of the captor (unsigned 12 bits), - Pressure value (unsigned 12 bits) - Chrono value (unsigned 16 bits).
mfcs_get_serial	Get the Serial Number of the MFCS.
mfcs_set_auto	Set the regulated pressure (mBar) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels.
mfcs_set_alpha	Set alpha value (default value =5) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels. Alpha is linked to the proportional value of the PID.
mfcs_set_manual	Set the electrovalve alimentation (%) for the specified channel (from 1 to 4 or 8). If the specified channel is 0, the same is applied to all channels. The manual control of the electrovalve is not recommended and the output pressure is no longer regulated.
mfcs_set_zero	Save in the EEPROM the zero pressure value of the specified channel.

The following array gives an algorithmic description of the previous functions.

function	return	parameter	Comment
mfcs_initialisation	UL handle	US serial number	Initialise USB connection and look for a MFCS with the specified serial number. handle = 0 if no USB connection
mfcs_close	B OK	UL handle	Close USB connection
mfcs_read	C error	UL handle	Read string on the interface
		S string	
mfcs_write	C error	UL handle	Write string on the interface
		S string	
mfcs_set_purge_on	C error	UL handle	Open purge on channel 1
mfcs_set_purge_off	C error	UL handle	Close purge on channel 1
mfcs_get_purge	C error.	UL handle	Get the purge state
		PB purge state	
mfcs_get_status	C error.	UL handle	Get MFCS status : 0 if the MFCS is reset 1 if normal 2 if overpressure 3 if MFCS needs to be rearmed.
		PC Status	
mfcs_read_chan	C error.	UL handle	Read the pressure value (mBar) of the specified channel with the timing (time unit 25ms).
		C channel	
		PF pressure	
		PUS chrono	
mfcs_data_chan	C error	UL handle	Read the sensor data : - sensor unit : 0 = no sensor, 1 = "H2O (2.4908 mBar) 2 = psi (68.946 mBar) - full scale in pressure unit - zero value sensor (U12) - direct pressure measure (U12) - chrono (time unit 25ms)
		C channel	
		PC sensor unit	
		PUS sensor max	
		PUS zero	
		PUS measure	
		PUS chrono	
mfcs_get_serial	C error	UL handle	Get the serial number of the MFCS
		PUS Serial	
mfcs_set_auto	C error	US handle	Regulate pressure (mBar) on the specified channel. (if 0, the same for all channel)
		C channel	
		F pressure	

mfcs_set_alpha	C error	UL handle	Set alpha value (U8). This value is linked to the PID performance. The recommended value is 50 for MFCS device sold with MFCS_Control V1.05. For more recent version (V1.06 and V1.07) the default value is 5 and a preheating of the electro-valves is necessary (45% alimentation for 10 min).
		C channel	
		C alpha	
mfcs_set_manual	C error	UL handle	Set electro-valve voltage (%) on the specified channel. (if 0, the same for all channel)
		C channel	
		F EV	
mfcs_set_zero	C error	UL handle	Save Zero sensor value on the firmware. To get this value, use mfcs_data_chan (PUS mesure)
		C channel	
		US Zéro	

Definition of [C error]:
- 0 = OK,
- 1 = USB closed
- 2 = Wrong channel

symbol	bits	C++	Labview	VBA
UL	32	unsigned long	(U32)	ByVal Long
US	16	unsigned short	(U16)	ByVal Integer
PUS	32	pointer on unsigned short	(U16) by address	ByRef Integer
S	32	char[]	(abc)	ByVal String
C	8	unsigned char	(U8)	ByVal Byte
PC	32	unsigned char *	(U8) by address	ByRef Byte
B	8	char for boolean result 1 = true, 0 = false	(U8)	ByVal Byte
PB	32	pointer on boolean	(U8) by address	ByRef Byte
F	32	float	(SGL)	ByVal Single
PF	32	pointer on float	(SGL) by address	ByRef Single

NB :
1) in Visual Basic, all values are signed
2) After calling mfcs_initialisation, a delay (0.5s) must be set before calling other functions,
3) A mfcs_close must be called before leaving the application, to avoid Windows error.

5.4.2.VBA declarations examples :

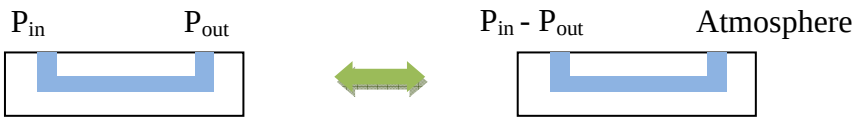
```
Public Declare Function mfcs_initialisation Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal i As Integer) As Long
Public Declare Function mfcs_close Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_read Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal S As String) As Byte
Public Declare Function mfcs_write Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal S As String) As Byte
Public Declare Function mfcs_set_purge_on Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_set_purge_off Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long) As Byte
Public Declare Function mfcs_get_purge Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByRef C As Byte) As Byte
Public Declare Function mfcs_get_status Lib "d:\mfcs\mfcs_vb.dll"
```

```
      (ByVal H As Long, ByRef C As Byte) As Byte
Public Declare Function mfcs_read_chan Lib "d:\mfcs\mfcs_vb.dll"
  (ByVal H As Long, ByVal Chan As Byte, ByRef P As Single,

   ByRef Chrono As Integer) As Byte

Public Declare Function mfcs_data_chan Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByRef Su As Byte,
       ByRef Sm As Integer, ByRef Zr As Integer, ByRef Ms As Integer,
       ByRef Chrono As Integer) As Byte
Public Declare Function mfcs_get_serial Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByRef Serial As Integer) As Byte
Public Declare Function mfcs_set_auto Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByVal P As Single) As Byte
Public Declare Function mfcs_set_alpha Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByVal Alpha As Byte) As Byte
Public Declare Function mfcs_set_manual Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByVal Ev As Single) As Byte
Public Declare Function mfcs_set_zero Lib "d:\mfcs\mfcs_vb.dll"
      (ByVal H As Long, ByVal Chan As Byte, ByVal Zero As Integer) As Byte
```

5.5. About output pressurization



In order to operate in an optimized range of the pressure full scale, it is recommended to work with differential pressure. Indeed, by pressurizing both input and output of a channel properly, the pressure inside the channel would be equal to the differential of the output and the input pressures.

6. APPENDICES

6.1. Technical Specifications MFCS

MFCS 25 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	500	600	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	23	-	µbar	
Max. output pressure	-	25	-	mbar	
Operation temperature range	-10	25	50	℃	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 70 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	500	600	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	63	-	µbar	
Max. output pressure	-	69	-	mbar	
Operation temperature range	-10	25	50	℃	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 350 mBar

Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	800	900	mbar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	0.32	-	mbar	
Max. output pressure	-	343	-	mbar	
Operation temperature range	-10	25	50	℃	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

MFCS 1000 mBar

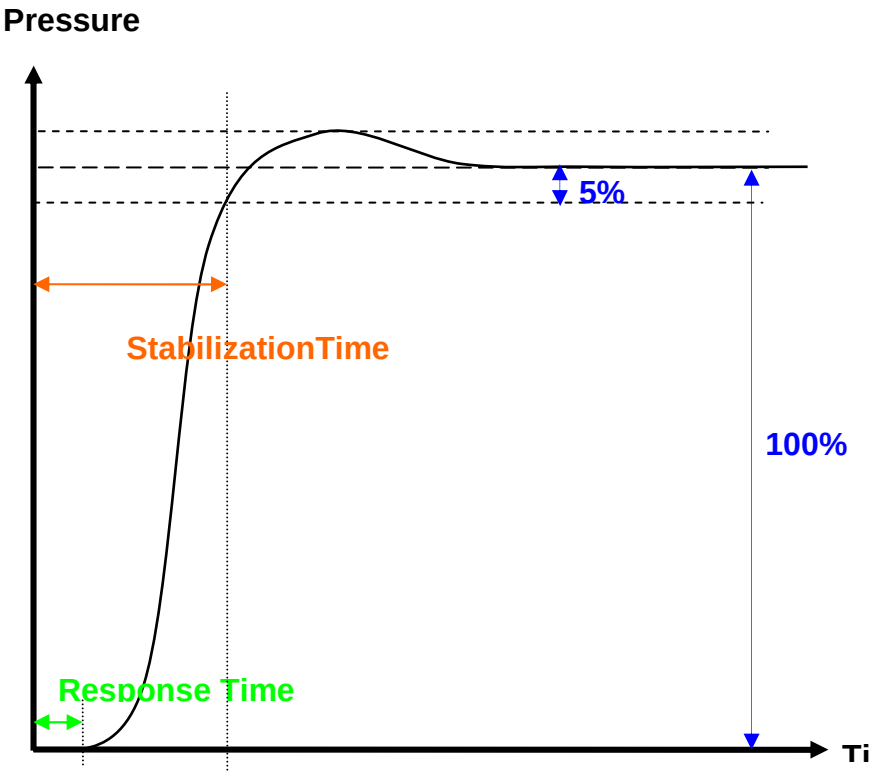
Characteristics	Min.	Typ.	Max.	Unit	Comment
Input pressure range	-	1.3	1.4	bar	
Output pressure precision	-	<2.5 %	-	full scale	Better if calibrated (see Quick start)
Min. output pressure step	-	0.95	-	mbar	
Max. output pressure	-	1033	-	mbar	
Operation temperature range	-10	25	50	℃	
Input voltage range	23	24	25	V	
Weight	1.9	-	2.25	kg	Depends on model
Power consumption	-	-	<16	W	

6.2. Accessories references and suppliers

Designation	Reference and Supplier	Remark
USB Cable		
CD Software		
User manual		
Blue tubing (OD=1/32'', ID=250µm)	Upchurch Scientific : 1581	
FEP tubing (OD=1/16'', ID=800µm)	Fisher : A28556	
Glass capillary (OD=360µm', ID=100µm)	Polymicro technologies : TPS100375	
Green Sleeves (1/16˝ to 360µm)	Upchurch Scientific : F-242X	
Green Sleeves (1/16˝→ 1/32˝)	Upchurch Scientific : F-247X	
10-32 Peek Fitting Nuts	Upchurch Scientific : F-120	
soft tubing (1x3mm)	Fisher : A31309	
Micrew reservoir 2 mL	Fisher : W14437	

6.3. Response and Stabilization Time

Here are the graphic definition of response time and stabilization time.



6.4. Unit Conversion Table

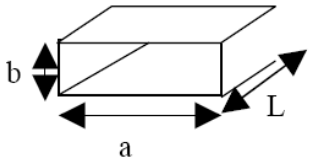
value (↓) = *factor* xunit (→)	kPa	bar	psi	inch H_2O
1 kPa	*1*	*0.01*	*0.145*	*4.016*
1 bar	*100*	*1*	*14.5*	*401.6*
1 psi	*6.895*	*68.95x10^{-3}*	*1*	*27.68*
1 inch H_2O	*0.249*	*2.49x10^{-3}*	*3.612x10^{-2}*	*1*

Example: 10 kPa = 10 kPa x *0.01* bar/kPa = 0.1 bar

6.5. Hydrodynamic Resistance of Rectangular Channels and Networks

Pressure difference □p, the volume flow rate Q, or the averaged velocity u and the friction coefficient C are related through

$$Q = C\frac{ab^3}{L\mu}\Delta p = abu$$



with channel dimensions a and b with a/b>>1, channel length *l* and viscosity μ (= 9.5 □10^{-4} Pa s for H_2O at 25℃).

The relation between the friction C and the aspect ratio a/b can be calculated [*Stone, Stroock, Ajdari, Ann. Rev. Fluid. Mech., 2004*]:

$$C = \frac{1}{2}\xi^2 \sum_{n=1}^{\infty} \frac{1}{\beta_n^4}\left[1 - \frac{1}{\beta_n}\tanh(\beta_n \xi)\right],$$

with

$$\beta_n = \frac{(2n-1)}{2}\pi, \xi = \frac{a}{b}$$

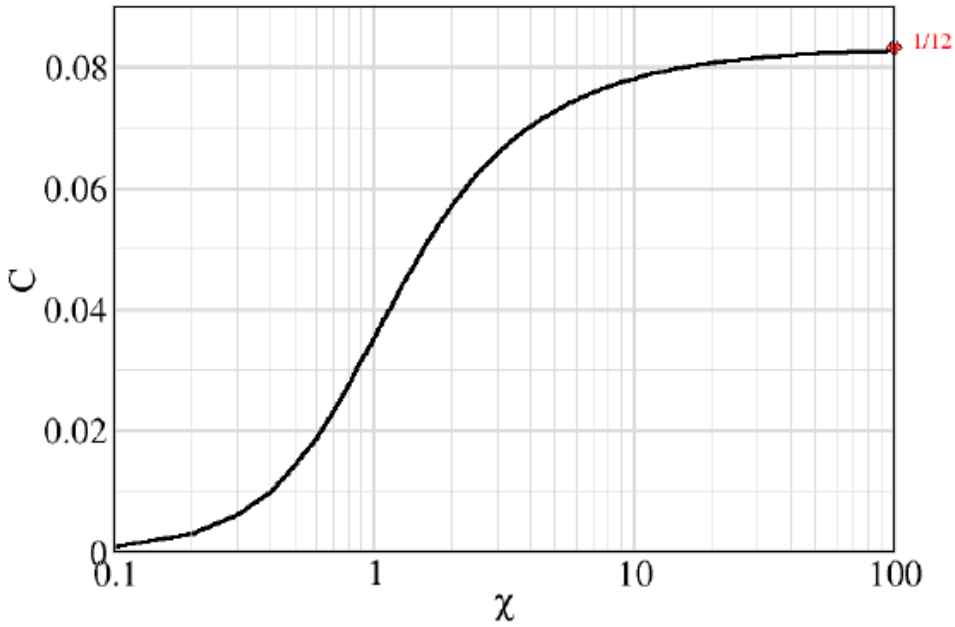


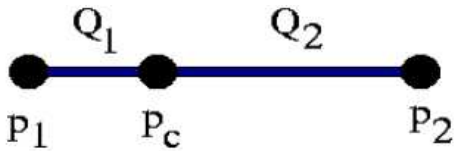
Figure 6: This graph shows the friction coefficient as a function of the aspect ratio of the channel and can be used to estimate the flowrate due to a given pressure difference. Typical values are: □=1 -> C=0.03512; □□□□C=0.05708; □=10 -> C=0.07688.

Example: A channel of 10x100µm with a length of 10mm contains 0.01 µl. Applying a pressure difference of 10 Pa (=100 µbar) gives a volume flow rate of about Q=0.0005 µl/min and an averaged flow velocity of u = 5 µm/min. A pressure of 100'000 Pa (=1 bar) is 10'000 times higher thus the flow rate and velocity are also 10'000 times increased.

Since Ohm's law also applies to flow of other particles than electrons (e. g. water) we can transfer the formulas.
For one single channel we have for the volume flow Q as a function of the externally applied pressure difference p and the resistance R: Q=p /R, Q=abu.

The pressure pc at an arbitrary position in a single channel with partial resistances R1 and R2 of the two halves of the channel is:

$$p_c = \frac{(p_1 R_2 + p_2 R_1)}{(R_1 + R_2)}$$

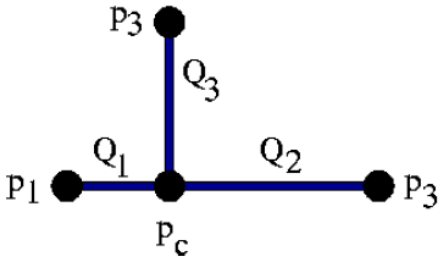


The total resistance is R=R1+R2, the flow yields Q=(p1−pc)/R1, R2 is equivalent.

If the two parts are of equal resistance (equal length and diameter) we find the well known average value: pc=(p1+p2)/2.

For three channels (p1, p2, p3 and R1, R2, R3) joining in one point with pressure pc we find using the continuity equation (the sum over all Qs going into one knot vanishes)

$$p_c = \left[\frac{p_1}{R_1} + \frac{p_2}{R_2} + \frac{p_3}{R_3}\right] \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3}$$



The corresponding flow in channel 1 as an example can be obtained with Ohm's law:
Q1=(p1−pc)/R1, the other values are equivalent.

To obtain the corresponding formulas for n channels joining in one knot, the latter formula can be generalized:

$$p_c = \frac{\sum_i^n \frac{p_i}{R_i}}{\sum_i^n R_i^{-1}}$$

More complex geometries can be calculated using well-known methods in analogy to electrical resistor networks (pressure is equivalent to the electric potential, flow is equivalent to the current, and flow resistance of a channel plays the same role as the Ohm's resistance).

6.6. Maintenance

The MFCS is designed as a very robust device for usage in laboratory and industrial environment and easy to maintain. For optimal accuracy, calibration should be performed regularly (typically every month) or after the MFCS has been displaced, in order to maintain optimal accuracy of the results and compensate for offset drift of the pressure sensors. The housing can be cleaned with a moisty soft tissue, iso-propanol or window-cleaning products.
Avoid aggressive organic solvents as acetone or chloroform or abrasive cleaning products.

Please use the following form if you have problems or suggestions with your MFCS device or software and send it to us by fax or e-mail.

6.7. Trace and Log files format

MFCScontrol allows a complete real time recording of all settings and measured pressure values during operation.

```
11.07.2005 17:39:03 MFCS S/N:0003 V:000.011
 15885   18.424    0.426    5.146   20.560
 15886   18.424    0.426    5.100   20.477
 15887   18.386    0.395    5.100   20.454
 15888   18.371    0.426    5.123   20.583
 15889   18.485    0.395    5.100   20.583
 15890   18.462    0.426    5.100   20.500
 15891   18.402    0.426    5.146   20.500
  15892   18.333    0.395    5.123   ...
```

Figure 10: an example of a Trace file.

The trace file format consists of a header line and a data block. The header line is composed of the starting date and time, serial number of the connected unit and version number of the MFCScontrol software. The data block is composed of lines carrying a time stamp (absolute time and the internal step number) and the 4 (8) pressure values. '#N/A' means information lost (e. g. transient transmission failure). When using this option, avoid the creation of oversized data files. Adjust the storage frequency according to the needs (see pull down menus).

```
11.07.2005 17:27:38 --BEGIN OF LOG--
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2196
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2221
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2246
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2283
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2332
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2381
11.07.2005 17:27:43 AUTO.      Chan. 1 :  2406
11.07.2005 17:27:45 AUTO.      Chan. 1 :  2715
11.07.2005 17:27:45 AUTO.      Chan. 1 :  2727
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:27:46 AUTO.      Chan. 1 :  2739
11.07.2005 17:39:27 --END OF LOG--
```

Figure 11: an example of a Log file.

ALPHA Chan. X : YYYYY	Order: set □ value to *YYYYY* in Channel *X*
AUTO Chan. X :YYYYY	Order: set value *YYYYY* in Channel *X* in feed back mode
--BEGIN OF LOG--	Order: start logging
--END OF LOG--	Order: stop logging
MANUAL Chan. X : YYYYY	Order: set value *YYYYY* in Channel *X* in manual mode
PURGE OFF	Order: open purge valve
PURGE ON	Order: close purge valve
USB OFF	Order: close USB channel
USB ON	Order: open USB channel
ZERO Chan. X : YYYYY	Order: set zero value *YYYYY* on channel *X*

Table 2: commands sent from the computer to the MFCS.

mfcs exceeding input pressure	Message: input pressure exceeds threshold value
mfcs operating	Message: system is operating normally
mfcs purge off	Message: purge is switched off
MFCS S/N:---- V:----	Message comprising serial and version number
mfcs purge on	Message: purge is switched on
mfcs reset detected	Message: system has realized activation of reset signal (button, processor reset line)

Table 3: commands sent from the MFCS to the computer.

.

Fluigent tel. : +33(0)15373-1551 fax. : -1552 e-mail : support@fluigent.com	**MFCS**	**date** :

SUGGESTIONS /DYSFUNCTIONS

Name : _____ **Urgent** : **yes**

☐ **Suggestion** ☐

Society : _____ **Dysfunctions**

☐

Device/Version : _____

Software/Version : _____

_____

Menu or concerned function :

_____

_____

Error code, if available :

DESCRIPTION *(please cite error messages, operation before error, operation to quit error message, add screen shots if possible)*

Don't write in this field, please.

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