



Microfluidics Automation Tool 18.0.0.2 User Manual



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1. Introduction

The Fluigent Microfluidic Automation Tool (or MAT) is a software solution for automating microfluidic based protocols. Built on a user friendly graphic interface, the MAT allows scientists to create protocols using the Fluigent LineUP™, ESS™, MFCS™ and FRP™ Series instruments. One can automate complex protocols with up to sixteen (16) pressure pumps (Flow EZ™), monitor or control up to 16 flow sensors (Flow Units™) and valving systems (M-SWITCH™, 2-SWITCH™ and L-SWITCH™).

This User Manual describes how to use MAT 18.0.0.2 for your day-to-day work. It explains all of the software's functionalities that will help you to control the flows in your microsystem(s). You will then be able to make the most of the Microfluidics Automation Tool performance and features.

2. MAT 17.1.0.0 introduced direct flow control

Pressure control provides very smooth flow-rates and provides for rapid settling times. However, the physical parameter users generally want to monitor and to control is the flow-rate. Indeed, flow-rate is related to fluid speed in the channel, the hydrodynamic resistance, and viscosity. A certain pressure can lead to different flow-rates in two different microfluidic channels depending on the variables.

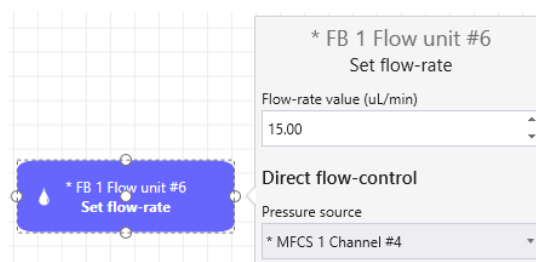
During an experiment, liquid levels in the reservoir change leading to modifications of the hydrostatic resistance. In a long-term procedure, a constant pressure can lead to slow flow-rate changes. Direct Flow Control is an algorithm which adjusts the pressure in the reservoir to reach the desired flow-rate and maintain it over long time period protocols. A "classic" algorithm would need the user to adjust some parameters in order to fit his/her set-up. Direct Flow Control does it automatically for extended ease of use and, of course, with the best performance.

DFC is only available for the Flow EZ with a Flow Unit connected to it and using A-i-O or MAT software.

3. MAT 17.2.0.4 introduced support for MFCS and FRP Series

MFCS™ pressure controllers were previously not supported. It is now possible to drive them using MAT 17.2.0. Each MFCS channel is visible, configurable and can be driven to output pressure to your microfluidic system. In addition, MAT 17.2.0 also supports FRP™ Series; i.e. you can now connect a Flowboard™ hardware and monitor any Flow Unit™ that is connected to it, thus dramatically increasing the number of flow measurement channels the software can monitor.

Both supports were added in order to allow the use of direct flow control algorithm (see §2) with a MFCS™ channel and a Flow Unit™ connected to a Flowboard™. An association between a flow channel and a pressure channel can be made in order to control the flow going through the flow channel.



4. System Requirements

This installation requires one of the following Microsoft operating systems:

- Windows 7 (32 and 64 bits)
- Windows 8 (32 and 64 bits)
- Windows 10 (32 and 64 bits)
- .NET framework: 4.6.1

Installation requires the MSI (Windows Installer) Engine to be installed on your computer. If you do not have the latest version of the MSI, the installer will prompt you to remove the old version and install the new one.

The Microfluidics Automation Tool software requires:

- A minimum of 512 MB of RAM (2GB recommended)
- Minimum processor Intel Pentium 1.6 GHz
- Minimum screen size 1024 x 768

5. Installation Instructions

Before installing the Microfluidics Automation Tool software, **log on as Administrator or as a user with Administrator privileges**. The Microfluidics Automation Tool software setup program must have Administrator privileges as the program modifies the configuration registry of your system. Complete the following steps to install the Microfluidics Automation Tool software:

1. Plug your Microfluidics Automation Tool USB key. The installer launches if your USB key plays data automatically. If the installer does not launch automatically, navigate into the USB key files using Windows Explorer and launch the setup.exe file from your Microfluidics Automation Tool software USB key.
2. The installation wizard guides you through the necessary steps to install the Microfluidics Automation Tool software. You can go back and change values where appropriate by clicking the **Back** button. You can exit the setup where appropriate by clicking **Cancel**.
3. When the installation is complete, click **Finish**.

6. How to start

6.1 Material needed

Microfluidics Automation Tool software can be launched without any instruments connected. The supported products are listed below:

- LineUP™ Link module with at least one (1) Flow EZ™ module. Optionally, a Flow Unit can be connected to each Flow EZ™ module for flow-rate monitoring.
- ESS Series.

Note: each LineUP™ Link module drives two configurable TTL ports allowing for external instruments synchronization.

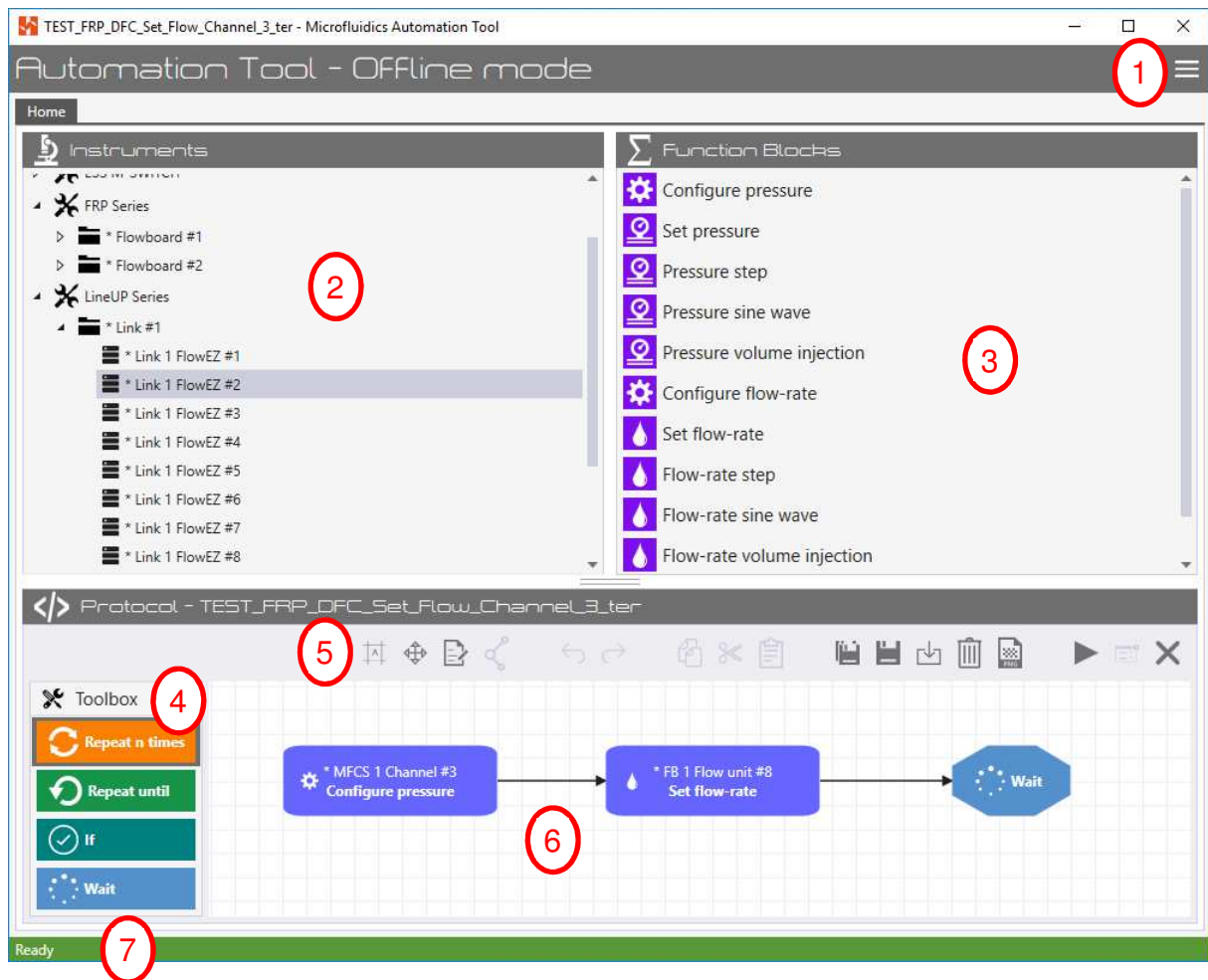
6.2 Starting The Microfluidics Automation Tool

Click on the MAT shortcut on your desktop to launch Microfluidics Automation Tool. The following splash screen should appear as the application loads.



Load instruments

7. Microfluidics Automation Tool Main View

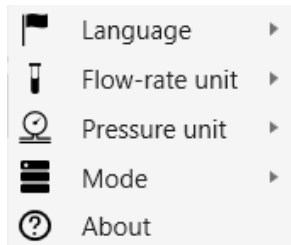


The Main Window is opened when you launch the application. It is divided into three main zones:

1. **Hamburger Menu:** for setting general parameters.
2. **Instrument window:** connected/simulated instruments appear in this window.
3. **Function Blocks window:** list of the functions the selected instrument can perform.
4. **Toolbox:** general functions and loops are listed here.
5. **Toolbar:** contains protocol management related features.
6. **Protocol editing area:** area where Function Blocks and Toolbox functions are dropped and managed.
7. **Status bar:** status information is displayed in this bar.

7.1 Microfluidics Automation Hamburger Menu

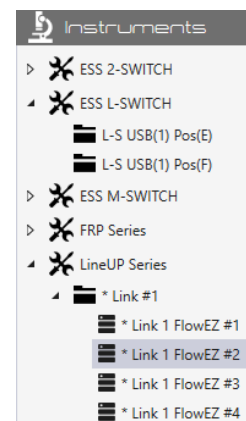
The menu icon is located top rightmost of the Home view:



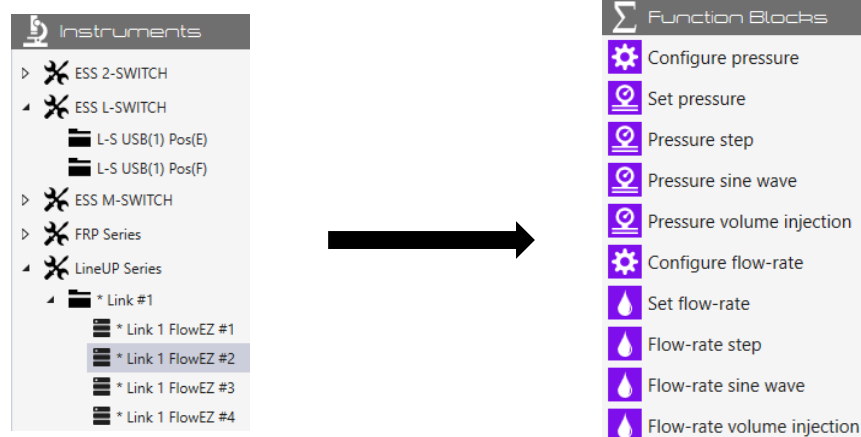
1. **Language:** Set your language preference
2. **Flow-rate units:** Display nL/min or $\mu\text{L}/\text{min}$
3. **Pressure units:** Choose PSI or mbar.
4. **Mode:** You could set-up experiment off-line with the mode set to Offline (see pictures below)
5. **About:** Click to open the about windows.

7.2 Instruments Window

Connected instruments are listed by category. Here is an example where two L-SWITCH valves are listed (in the ESS L-SWITCH folder). In the same way, all the Flow EZ's connected will be listed (in the LineUP).



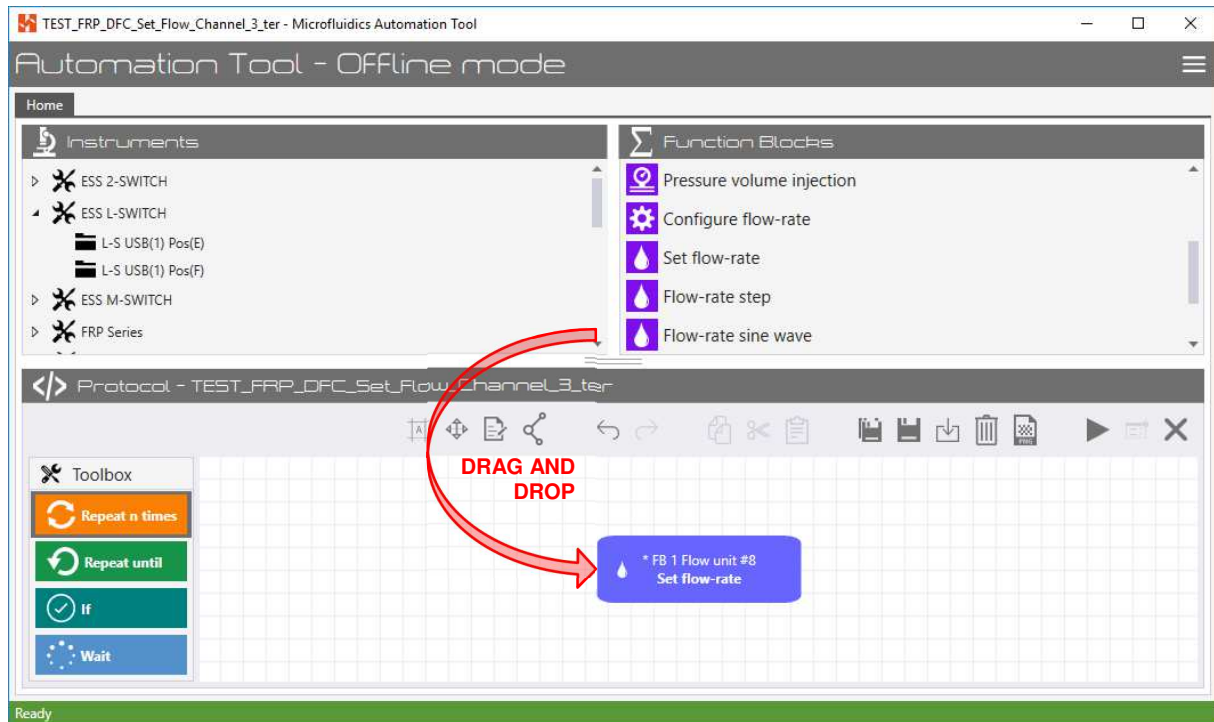
As shown in the picture below, clicking on one instrument will list all available functions (for this instrument) in the Function Blocks area.



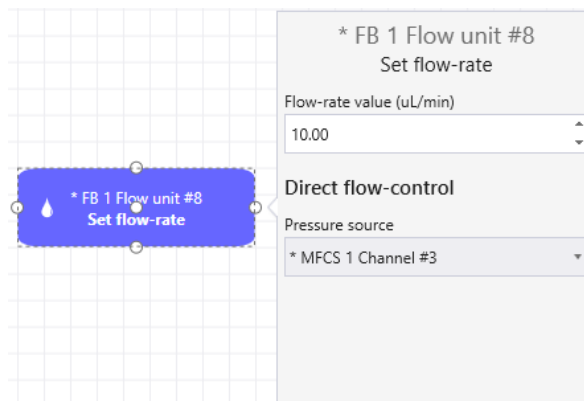
7.3 Function Blocks Window

7.3.1 General use

The list of functions in this window changes depending on the instrument the user has selected in the Instruments window. The function blocks have to be dragged and dropped on the Protocol editing area.



By selecting the function block, a parameter wheel appears providing access to the parameter(s) window (see picture below).



In this configuration window, the user can set the functions value. For example, in the picture above, in the "Set Pressure" function, the user can enter the pressure value to be applied in the reservoir.

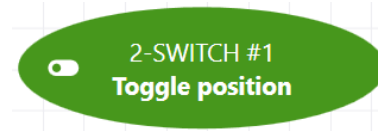
7.3.2 Function Block Descriptions

7.3.2.1 ESS Series

The EASY SWITCH SOLUTIONS™ series consists of a collection of three complementary bidirectional valves, connected to the computer via the SWITCHBOARD communication hub.

A. ESS 2-SWITCH

The 2-SWITCH is a 2-way bidirectional valve. A single function is available: **Toggle position**.



B. ESS L-SWITCH

The L-SWITCH is an injection valve (6 ports, 2 positions). A single function is available: **Toggle position**.

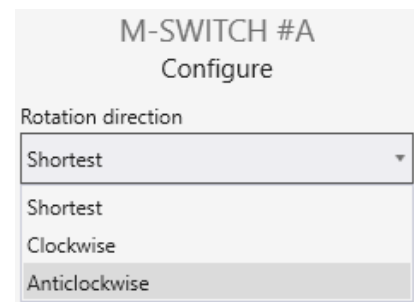
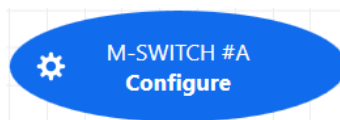


C. ESS M-SWITCH

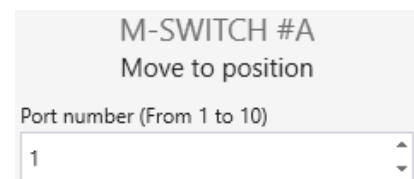
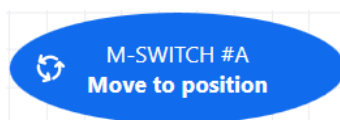
The M-SWITCH valve is a 10-way bidirectional valve. Two functions are available:

Configure: The user selects the rotating direction of the valve:

- Shortest path,
- Clockwise,
- Counterclockwise.



Move to position: The user enters the port number in the text box.



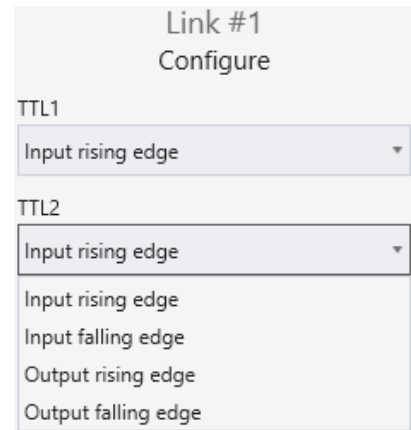
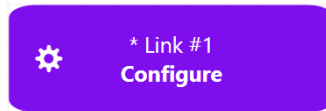
7.3.2.2 LineUP Series

A. LineUP Link

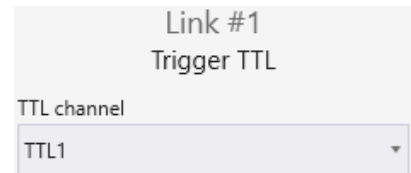
The link connects the Flow EZ and the computer and controls two TTL signals. With the Linkmodule, two functions are available.

Configure: configures the two TTL ports of the Link module

- Input rising edge,
- Input falling edge,
- Output rising edge,
- Output falling edge.



Trigger TTL: activates the configured TTL signal on the selected TTL channel



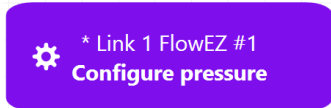
B. LineUP Flow EZ

The Flow EZ is a free-standing flow controller that regulates pressure in the fluid reservoirs. With this module, five functions are available. For more information concerning the functionalities see A-i-O user manual (www.fluigent.com).

a. Configuration blocks

Configure pressure: Allows one to:

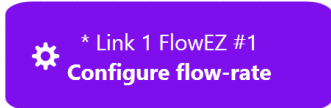
- Set the maximum pressure limit that will ever be applied to your system. This may prove useful to protect your system
- Set the way of imposing pressure: “Fast” or “Smooth”



Flow EZ #1 Configure pressure	
Pressure Max Limit (mbar)	7 000.00
Pressure Settling Time	Fast

Configure flow-rate: Allows to:

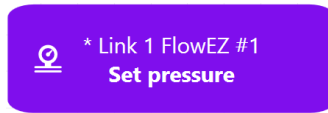
- Set the connected Flow Unit calibration table: Water or IPA calibration
- Set flow-rate custom scale factors
- Set the maximum flow-rate limit that will ever be applied to your system while using direct flow-control
- Set the flow sense
 - Nominal: flow follows the flow unit arrow
 - Inverse: flow goes against the flow unit arrow



Flow EZ #1 Configure flow-rate	
Flow unit	
Flow Unit Calibration Table	Water
Flow calibration parameter A	1.00
Flow calibration parameter B	0.00
Flow calibration parameter C	0.00
Direct flow-control	
Flow-rate Max Limit (uL/min)	100.00
Flow sense	Nominal

b. Basic Commands

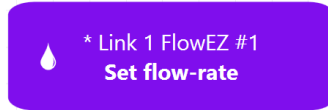
Set pressure: Sets the pressure value to be applied in the reservoir.



Flow EZ #1
Set pressure

Pressure value (mbar)

Set flow-rate: Sets the flow-rate value to be applied in the tubing.



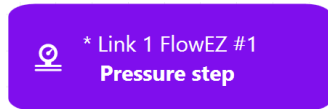
Flow EZ #1
Set flow-rate

Flow-rate value (uL/min)

c. Relative Commands

Pressure step: Allows to increase or decrease the pressure value in the reservoir by a specified pressure step.

Note: This function can be very useful to perform pressure ramps when used within a "Repeat n times" function (see in Toolbox section).



Flow EZ #1
Pressure step

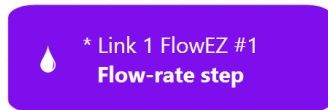
Pressure step(mbar)

Direction

Increase

Flow-rate step: Allows to increase or decrease the flow-rate value in the tubing by a specified flow-rate step.

Note: This function can be very useful to perform flow-rate ramps when used within a "Repeat n times" function (see in Toolbox section).



Flow EZ #1
Flow-rate step

Flow-rate step (uL/min)


Direction

Increase

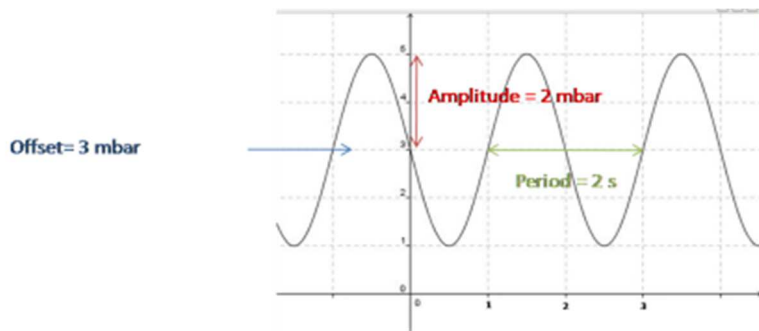
d. Sine waves

Pressure sine wave: performs pressure sine profiles.

Allows for pressure offset, pressure amplitude, signal period and number of period configuration.


 * Link 1 FlowEZ #1
Pressure sine wave

Flow EZ #1 Pressure sine wave	
Pressure offset (mbar)	3.00
Pressure amplitude (mbar)	2.00
Period (ms)	2 000
Number of periods	10



Flow-rate sine wave: performs flow-rate sine wave profiles.

Allows for flow-rate offset, flow-rate amplitude, signal period and number of period configuration.

 * Link 1 FlowEZ #1
Flow-rate sine wave

Flow-rate sine wave	
Flow-rate settings	
Flow-rate offset (uL/min)	1.00
Flow-rate amplitude (uL/min)	0.10
Period (ms)	2 000
Number of periods	10

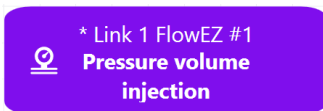
e. Volume injection

Pressure Volume injection:

Sets the pressure and waits for the specified volume to pass through the connected Flow Unit.

Note: Resets pressure when the volume has been injected

This function is suitable for precise injections and pipetting protocols. The user sets the volume to be injected.



Flow EZ #1
Pressure volume injection

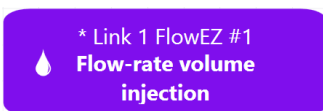
Pressure value (mbar)

Volume (uL)

Flow-rate injection: Sets the flow-rate and waits for the specified volume to pass through the connected Flow Unit.

Note: Resets pressure when the volume has been injected

This function is suitable for precise injections and pipetting protocols. The user sets the volume to be injected.



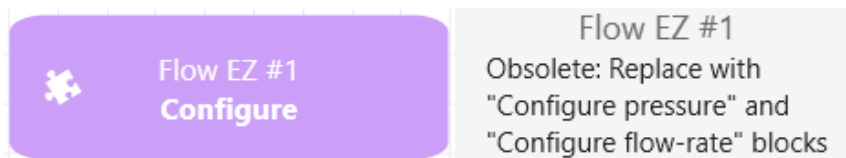
Flow EZ #1
Flow-rate volume injection

Flow-rate value (uL/min)

Volume (uL)

f. Obsolete blocks

Obsolete blocks appear in their original color, but lighter. You can still use protocols you wrote with previous MAT versions, even though they contain such obsolete blocks. Obsolete blocks are not available anymore when writing new protocols.



Here is a complete list of obsolete function blocks:

Name	Version of obsolescence	Comment
Flow EZ "Configure" function block	17.1.0.0	Split into two separate function blocks: <ul style="list-style-type: none"> Configure pressure Configure flow-rate
Flow EZ "Flow step" function block	17.2.0.2	Replaced by a new "Flow step" block. (Flow step value cannot be negative anymore)

C. MFCS and FRP

Function blocks available on MFCS channels and FRP/Flow Unit instruments cover all the features used by Flow EZ instruments' function blocks (see §B). Pressure related function blocks are available when selecting a MFCS channel, while flow-rate related function blocks are available when selection a FRP/Flow Unit instrument.

The following table lists all function blocks and their attached instrument

Function block name	Equivalent Flow EZ's function block	Attached to	Specific parameters
"Configure pressure"	"Configure pressure"	MFCS Channel	Response mode feedback coefficient: <ul style="list-style-type: none"> • defaults to 5, • ranges from 1 to 100. The higher the faster response. May cause instability when set too high
"Set pressure"	"Set pressure"	MFCS Channel	-
"Pressure step"	"Pressure step"	MFCS Channel	-
"Pressure sine wave"	"Pressure sine wave"	MFCS Channel	-
"Purge"	None	MFCS Flex/P-OEM instrument	Purge state <ul style="list-style-type: none"> • On/Off This block allows the activation/deactivation of the purge feature.
"Configure flow-rate"	"Configure flow-rate"	FRP Flow Unit	-
"Set flow-rate"	"Set flow-rate"	FRP Flow Unit	Pressure source <ul style="list-style-type: none"> • Drop down list of associable MFCS channels This parameter allows to choose which MFCS channel is used to pressurize the tubing
"Flow-rate step"	"Flow-rate step"	FRP Flow Unit	Pressure source <i>See description above</i>
"Flow-rate sine wave"	"Flow-rate sine wave"	FRP Flow Unit	Pressure source <i>See description above</i>
"Flow-rate volume injection"	"Flow-rate volume injection"	FRP Flow Unit	Pressure source <i>See description above</i>

Notes for MFCS/FRP Series:

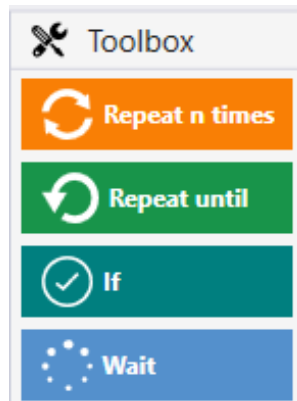
- MFCS sampling rate: MFCS pressure control rate is 100ms. By default, MAT sample period is 50ms. If you are using MFCS instruments only, you may want to change MAT's sampling period by editing *<install folder>/MicrofluidicsAutomationTool.exe.config* file as in the following screenshot.

```
<setting name="ReadPoolingMs" serializeAs="String">
  <value>100</value>
</setting>
```

- Legacy refurbished Flowell Series "Flow Unit" instruments are limited to 55uL/min and do not have IPA calibration table

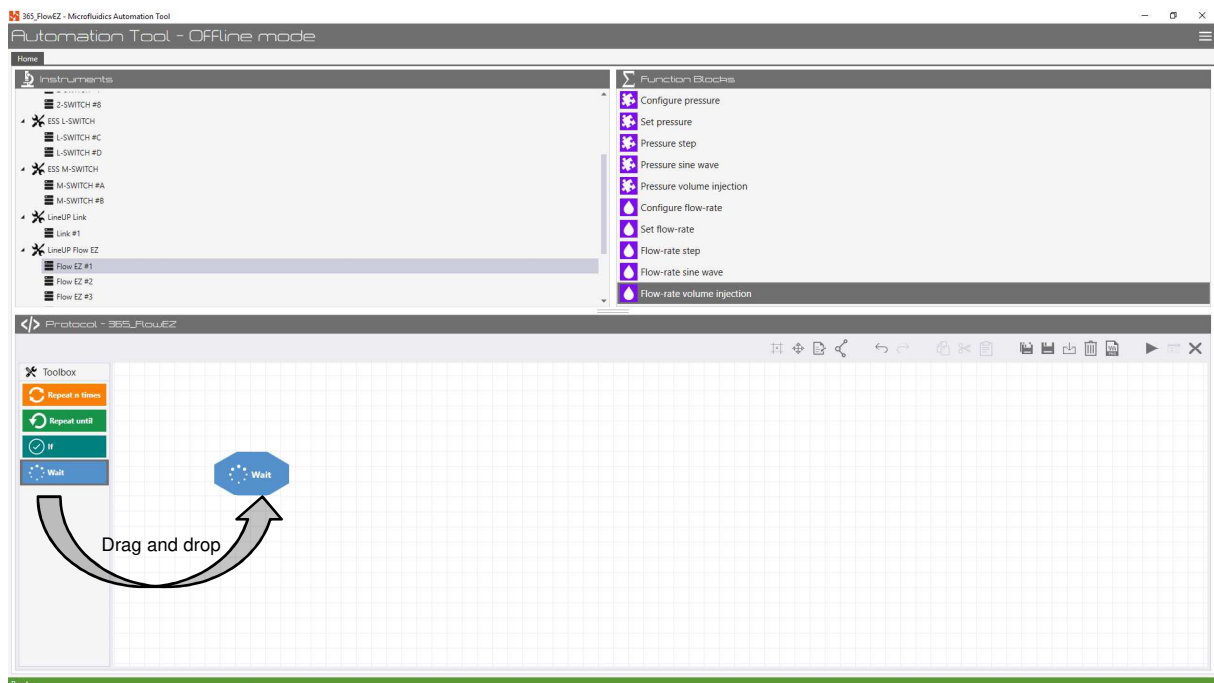
7.4 Toolbox

The toolbox is located bottom left of the Home view



The Toolbox contains two loops, a conditional structure and a wait function.

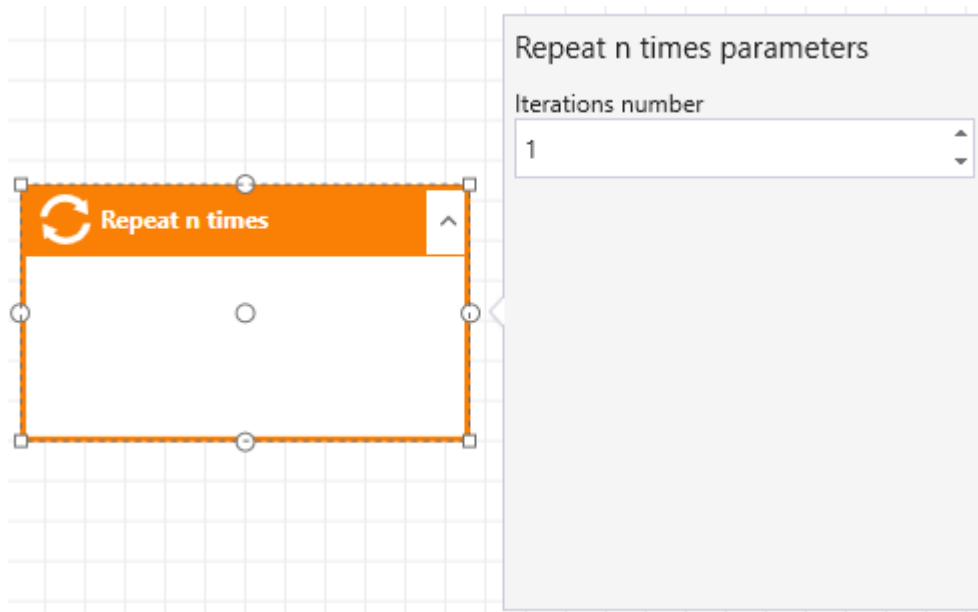
As for the Function Blocks, the user has to drag and drop the blocks to the protocol editing area.



These functions have also a parameter wheel for editing the function.

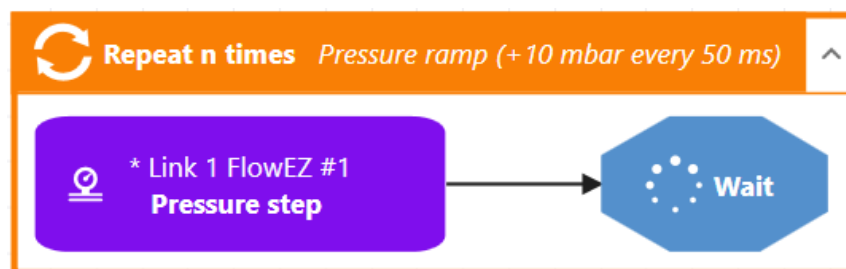
7.4.1 Repeat “n” times

The protocol inside this loop will be repeated “n” times. The user enters the iteration number and drags and drops function blocks to be repeated inside the loop square.



By double clicking the loop “Repeat n times” title, the user can set a comment.

In the example below, by repeating 100 times a pressure increase of 10 mbar, the user performs a pressure ramp. The Wait function allows controlling ramps speed.



7.4.2 Repeat until

The protocol inside this loop will be repeated while a condition is true. The condition has four parts:

- The time interval between each iteration of the loop,
- Selection of the function to be watched, for example “Read Flow Rate” on the “Flow EZ #1”,
- The condition operator: Equal, greater, less, greater or equal, less or equal,
- The condition value. (Examples: 100 μ L/min, 245 mbar, valve position 2)

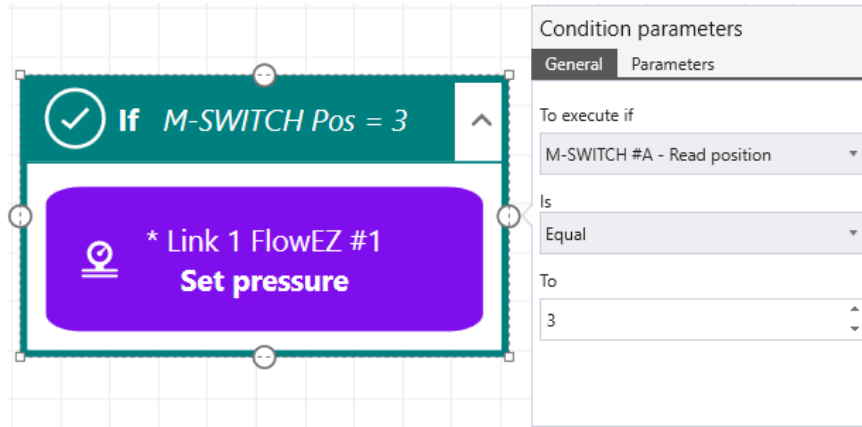
The image shows a software interface for configuring a 'Repeat until' loop. The loop is represented by a green box with a circular arrow icon and the text 'Repeat until Flow-rate is lower than 100uL/min'. Inside the loop is a purple box labeled '* Link 1 FlowEZ #1 Pressure step'. To the right is a 'Repeat until loop parameters' panel with 'General' and 'Parameters' tabs. The 'Parameters' tab is active, showing: 'Iterations period (milliseconds)' set to 50; 'To execute while' set to '* Link 1 FlowEZ #1 - Read flow-rate'; 'Is' set to 'Less'; and 'To' set to 100.00.

In the example below, the loop is set to repeat an increase pressure operation until the flow-rate on the Flow EZ #1 is equal or lower than 100 μ L/min.

Note: by double clicking the loop “Repeat until” title, the user can set a comment

7.4.3 If (condition structure)

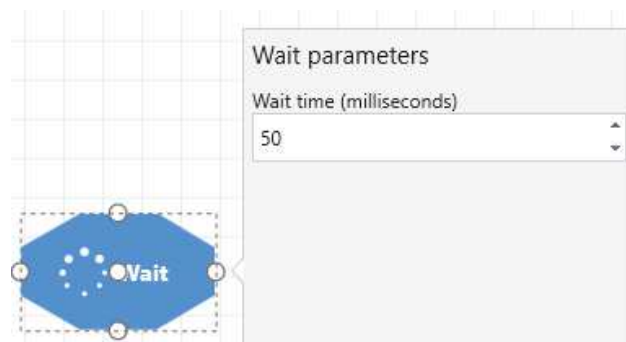
The protocol inside the “If” structure is executed only if a specified condition is fulfilled. This condition is selected in the “to execute if” list. The conditions proposed are related to the connected instruments. For example, below, we will set a pressure (purple function block inside their loop square) if the M-Switch 1 position is 3. If not, the protocol will proceed to the next step.



Note: by double clicking the structure “If” title, the user can set a comment

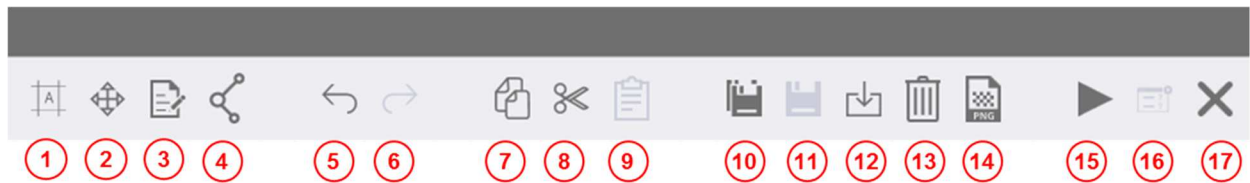
7.4.4 Wait

Wait function allows a pause for an amount of time set by the user.



7.5 Toolbar

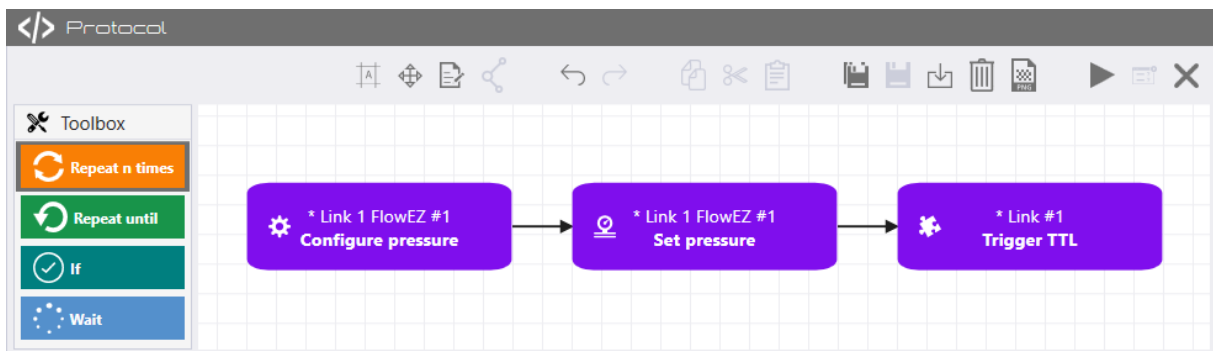
This area allows you to interact with the protocol editor; each function has a tooltip to guide you.



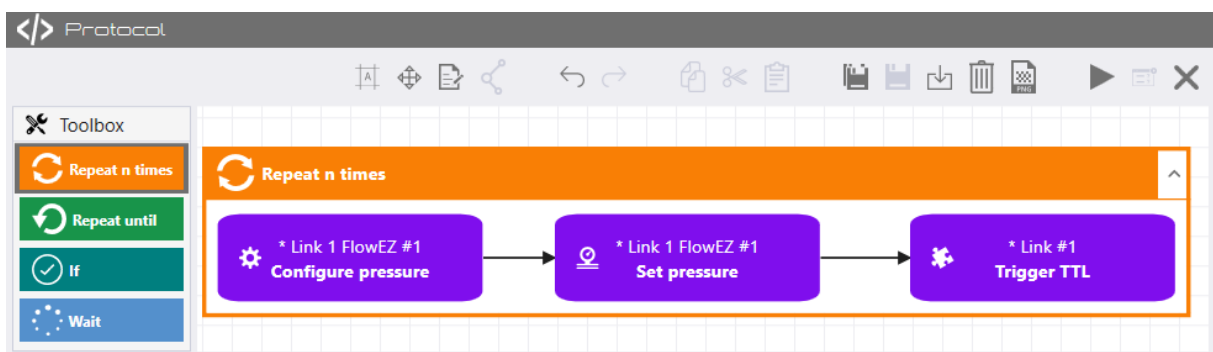
1. Arrange the diagram automatically
2. Center all protocol elements
3. Comments
4. Wire diagram blocks automatically
5. Undo
6. Redo
7. Copy
8. Cut
9. Paste
10. Save as: save a *.fmat protocol
11. Save: save the current protocol
12. Load: load a protocol
13. Delete: clear the protocol editor
14. Export to PNG: export the protocol to PNG image.
15. Play: Start the protocol and open the Dashboard view
16. Open Dashboard view
17. Close file

7.6 Protocol Editing Area

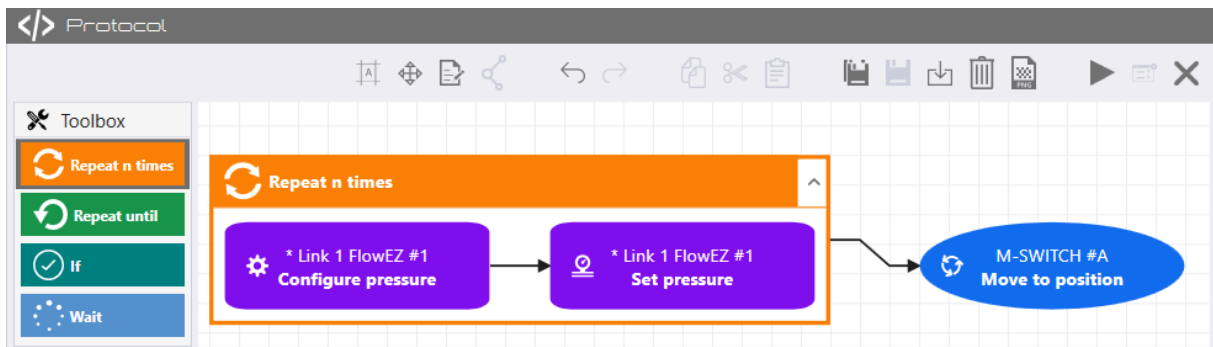
To start creating a protocol, the user drags and drops desired function blocks and has to link them in chronological way.



When using loops, the user has to drag and drop the function blocks inside the loop.



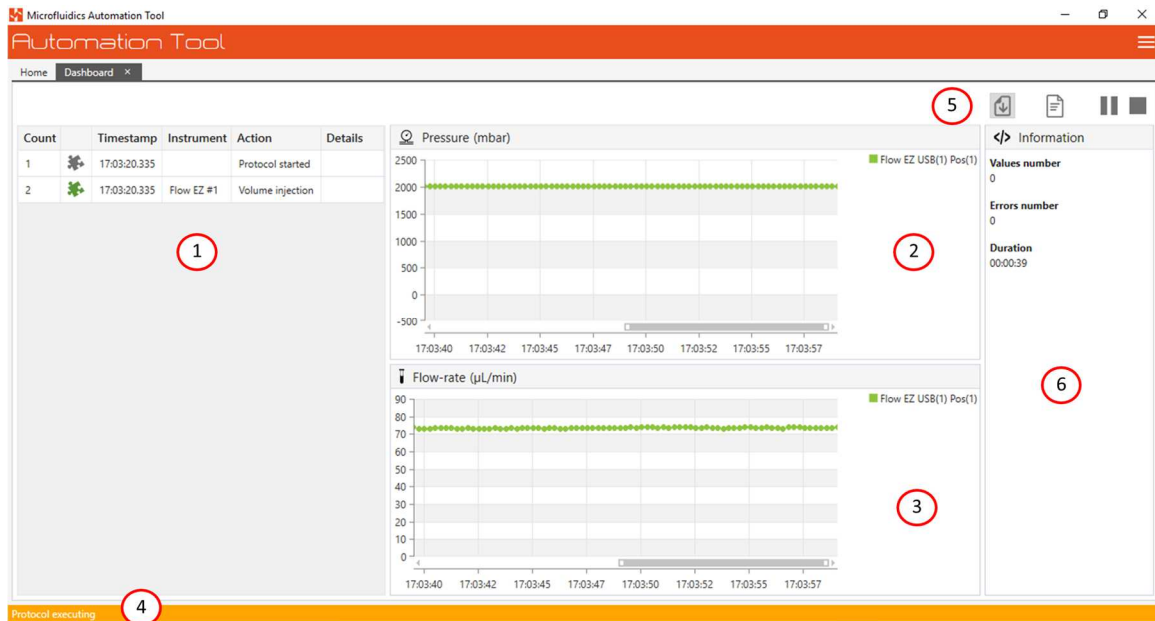
Using the same principle, one can link loops inside loops and connect function blocks to loops.



To start executing a protocol, the user has to click on the play button. A new tab (the dashboard) will appear to follow the operations, flow-rates and pressures.

8. Microfluidics Automation Tool dashboard view

When you have finished editing your protocol, click on the Start button; the protocol starts and the Dashboard view is displayed:



1. **Action list:** this view allows you to know the step of execution method protocol
2. **Pressure graph:** you can view the pressure graphs
3. **Flow rate graph:** you can view all your flow rates graphs
4. **Status bar**
5. **Dashboard function**



1. **Auto scroll function:** allow the Execution list to be always at the end
2. **Open the data log folder:** MAT logs all pressures and flow-rates periodically in csv files with the experiment date
3. **Stop the protocol**
4. **Information:** Displays information, as the duration of the step for example.

Note: by default, charts do not display latest values. Set scroll bars to the right to have charts show latest values.

9. List of Keyboard Shortcuts

The Following table lists keyboard shortcuts of the Microfluidics Automation Tool Software Home view:

Keyboard Shortcut	Description
Ctrl-C	Copy a block function
Ctrl -V	Paste a block function
Ctrl-Z	Undo the last action
Ctrl-Y	Redo the last action

10. Exit the Software

When exiting the Software, pressures will be reset to 0. Make sure to save your protocol before closing MAT.



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