Microfluidics Innovation Center

Flow Sensor Instrument User Guide

Wide range flow rate sensor with automatic clogging detection

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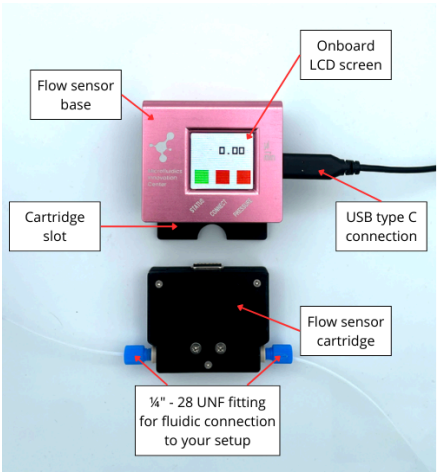
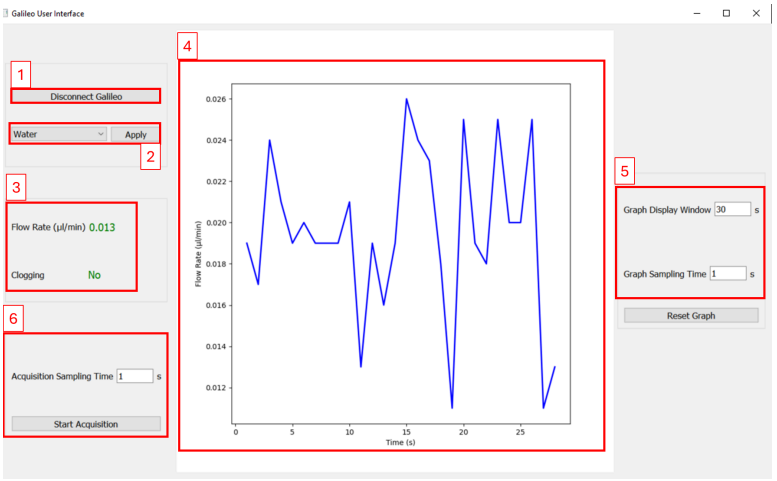
Base and cartridge



Software interface



A. Click the flow sensor cartridge into the flow sensor base.

B. Connect the base to a computer (USB type C-to-type C or USB type C-to-type A).

C. Open the Galileo software, click “Connect Galileo” (1) on the interface.

D. Select your working liquid from the dropdown menu and click “Apply” (2).

E. Select acquisition sampling time (6).

F. Click “Start acquisition” to select the log file name and location and start recording data (6).

G. Click “Stop acquisition” to stop recording data (6).

QUICK REFERENCE - ALERT ACTION GUIDE

The alerts on the sensor base indicate the state of function of the sensor:

Status: green = measurement OK; yellow/ red = potential air in sensor (if still filling); or drift from actual flow rate (if full of liquid): yellow = light fouling likely, red = moderate to full blockage

⇒ If yellow: Continue using sensor at the user's discretion. Clean the sensor at first convenience.
⇒ If red: Stop use and clean the sensor (see section 6)

Connect: green = cartridge properly inserted in the base; red = cartridge not properly inserted.

⇒ If red: re-insert cartridge to achieve a proper connection before continuing (green light)

Pressure: sensor pressure within limits (green); sensor over pressure (red)

⇒ If red: Stop use. Using while over pressure may damage the flow sensor and display erroneous flow rate (see section 6)

1. Introduction and Overview

The Microfluidics Innovation Center's Galileo Wide-range Flow Rate Sensor uses differential pressure technology to sense microfluidic flow rates. Its cartridge-based range configurability, measurement stability and automatic clogging detection make it a robust and versatile solution for microfluidic applications:

- Configurable sensing range from 0.1 to 10,000 µL/min
- Base & replaceable cartridge format for range configuration and flow path replacement
- <2% measured value flow rate accuracy over any given range
- Automatic detection of sensor clogging and measurement drift (e.g., biofouling)
- Bi-directional flow rate measurement (positive & negative)
- Software user interface and LCD screen for direct flow rate monitoring
- Response time under 20ms
- 0.01% full scale precision

This document will help get you started in using the Galileo flow sensor.

The Galileo flow sensor is a microfluidic flow rate sensor with a base + cartridge format.

1.1 The cartridge

The replaceable cartridge houses all the fluidic components of the Galileo flow sensor. Each one is calibrated with a specific range of compatible flow rates, indicated on the cartridge casing. Both fluidic connections to the Galileo flow sensor (input and output) are made directly to the cartridge. These connections are made with **flat bottomed, male ¼"-28 UNF fluidic fittings**. Figure 2 shows these fittings used with 1/16" outer diameter microfluidic tubing, but the user may use their desired tubing (e.g., 1/32" OD tubing) as long as it is compatible with the flat bottomed ¼"-28 UNF fluidic fitting ports of the Galileo flow sensor cartridge.

1.2 The base

The Galileo flow sensor houses a cartridge slot, into which the cartridge is inserted for operation (described below), an onboard LCD screen for displaying real time data, and a USB type C port for connection to your computer. For best results during operation, the base should be placed on a flat stable surface.

2. Detailed User Guide: Galileo Flow Sensor

2.1 Operation of the sensor

In order to function, the Galileo flow sensor must be connected to your computer via USB cable (USB type C-to-type C or USB type C-to-type A).

To operate the sensor, the cartridge must be inserted into the cartridge slot of the Galileo flow sensor base. You should feel a light click as the magnetic connectors between the base and cartridge make their connection. If the magnetic connection is successfully completed, the "**Connect**" indicator on the LCD screen should turn green within a few seconds after connection. If connection is not properly established, the Cartridge indicator on the screen will remain red. If so, try to remove and replace the cartridge in the slot.

The fluidic connections to/from the cartridge can be made and manipulated both while the cartridge is outside of or inserted into the base. Figure 2 below shows the cartridge correctly inserted in the base, with the green "**Connect**" indicator displaying green.

While the Galileo flow sensor is best used with its dedicated software user interface (described in section 3), it is not mandatory, as the flow sensor displays key real-time data directly on the onboard LCD screen. Additionally, the sensor can be controlled using SDKs (software development kit–described in section 4).

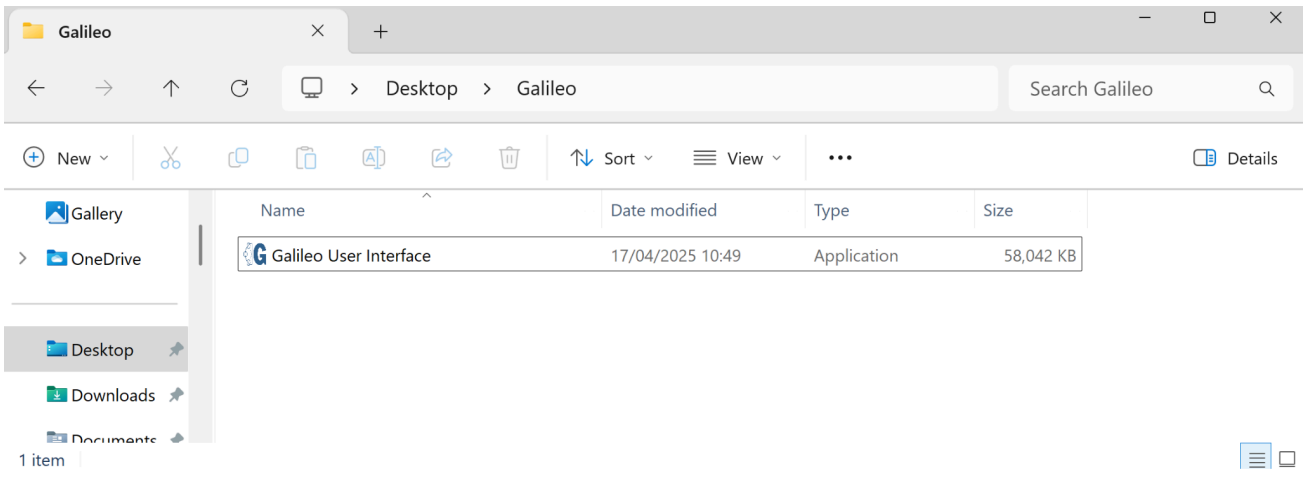
Figure 2. Galileo flow sensor with a successfully connected cartridge.The real time flow rate is displayed at the top. At the bottom of the screen, three indicators are displayed: "**Status**" indicating partial or full clogging or measurement drift detected inside of the flow sensor, "**Connect**," indicating the successful connection of a Galileo cartridge, and "**Pressure**," indicating an over-pressure (greater than 3 bar gauge pressure) occurring inside of the sensor. These are summarized in the table below.

Status	No internal clogging or measurement drift detected	Partial internal clogging or measurement drift detected – flow rates displayed may be erroneous	Full internal clogging or measurement drift detected – flow rates displayed may be erroneous
Connect	Cartridge successfully connected		No cartridge connected
Pressure	Operation is within specified sensor pressure range		Operation is outside of specified sensor pressure range (3 bar) – inaccurate readings, leaks and/or damage to the sensor may occur.

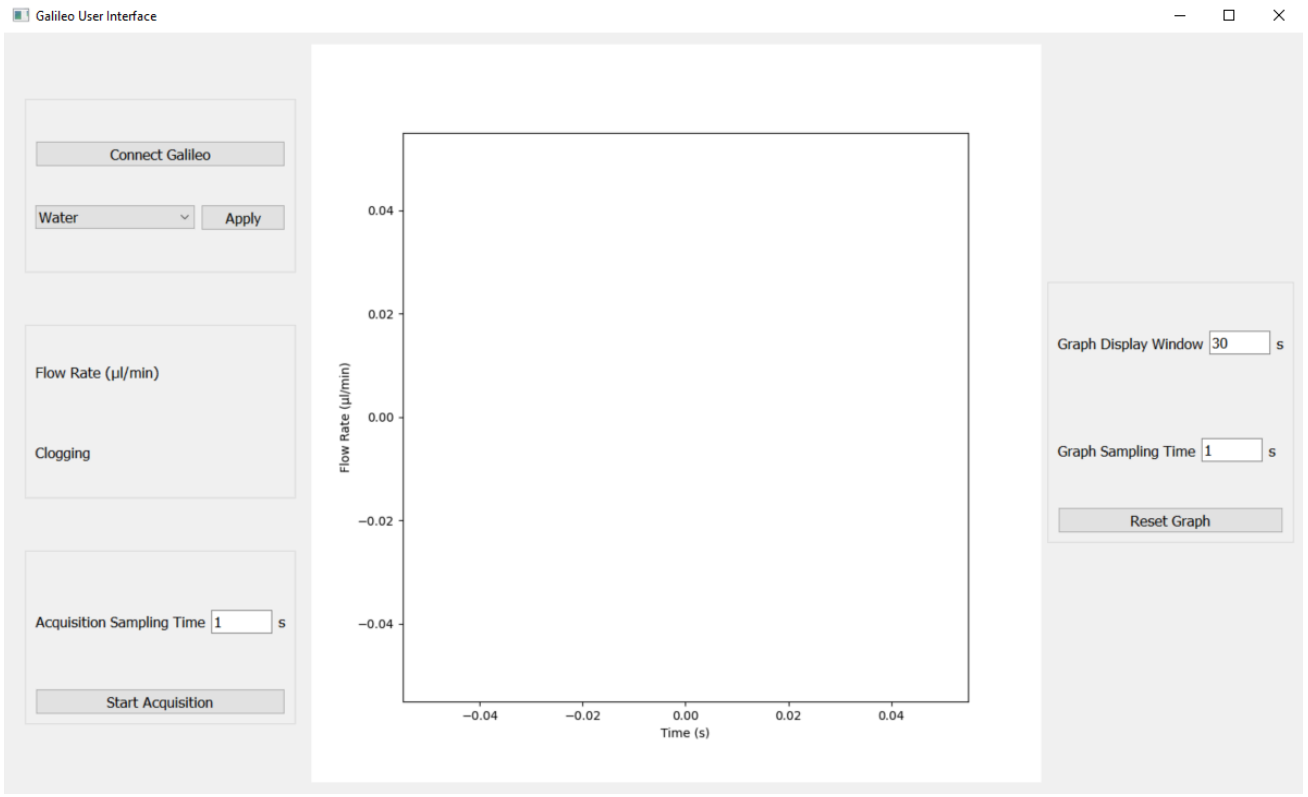
3. Galileo Flow Sensor Software Interface

The following section details, in instructional format, the use of the Galileo custom Graphical User Interface (GUI) software, or Galileo User Interface.

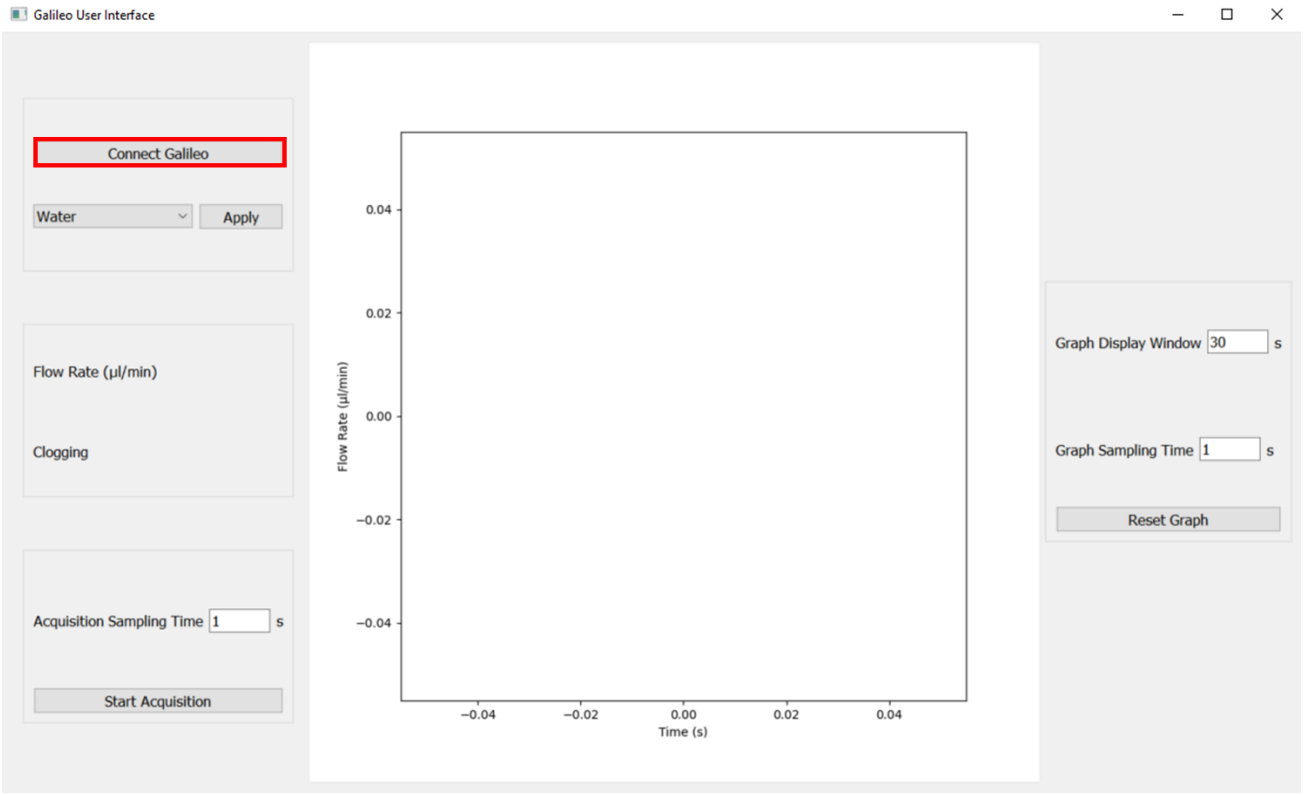
The Galileo User Interface is launched with an executable file, seen below. It is compatible with Windows 10 and Windows 11.



Double click on the .exe file to launch the software. You will see the interface below open.



Ensure the Galileo is connected via the provided USB cable to your PC, and the cartridge is properly connected to the base. Once the physical connections are made, you may click the “Connect Galileo” button on the interface, shown below.



Once communication is established, the interface will appear as below. The highlighted parts of working GUI are as follows, corresponding to the labels on the below image:

(1) This button terminates communication with the connected Galileo sensor.

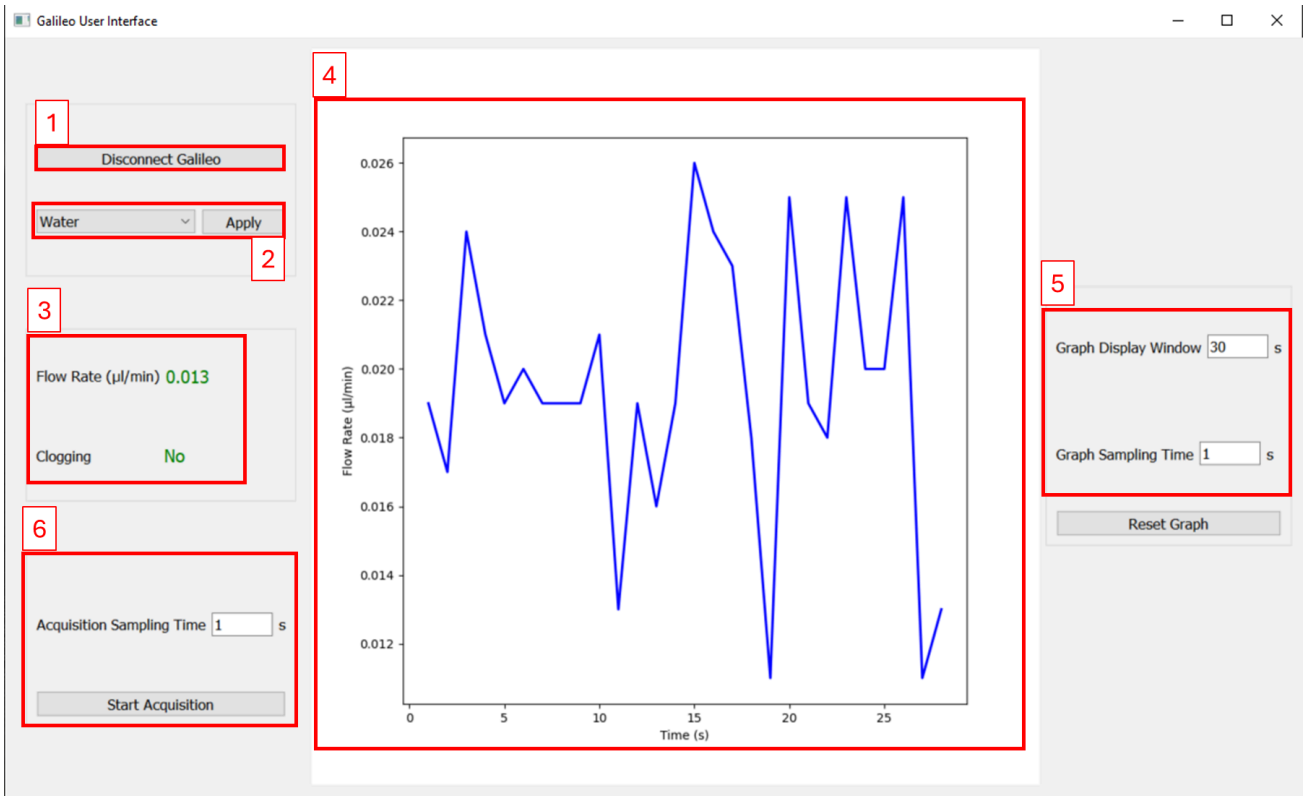
(2) This is where you can change your working liquid (flowing in your Galileo flow sensor). Select your working liquid from the dropdown menu and click apply before taking your flow rate measurements. This can also be changed during operation. By default, this is set to water.

(3) This box displays the real-time flow rate and clogging status being measured by the Galileo sensor.

(4) This central display is a live-updated graph of the measured flow rate over time.

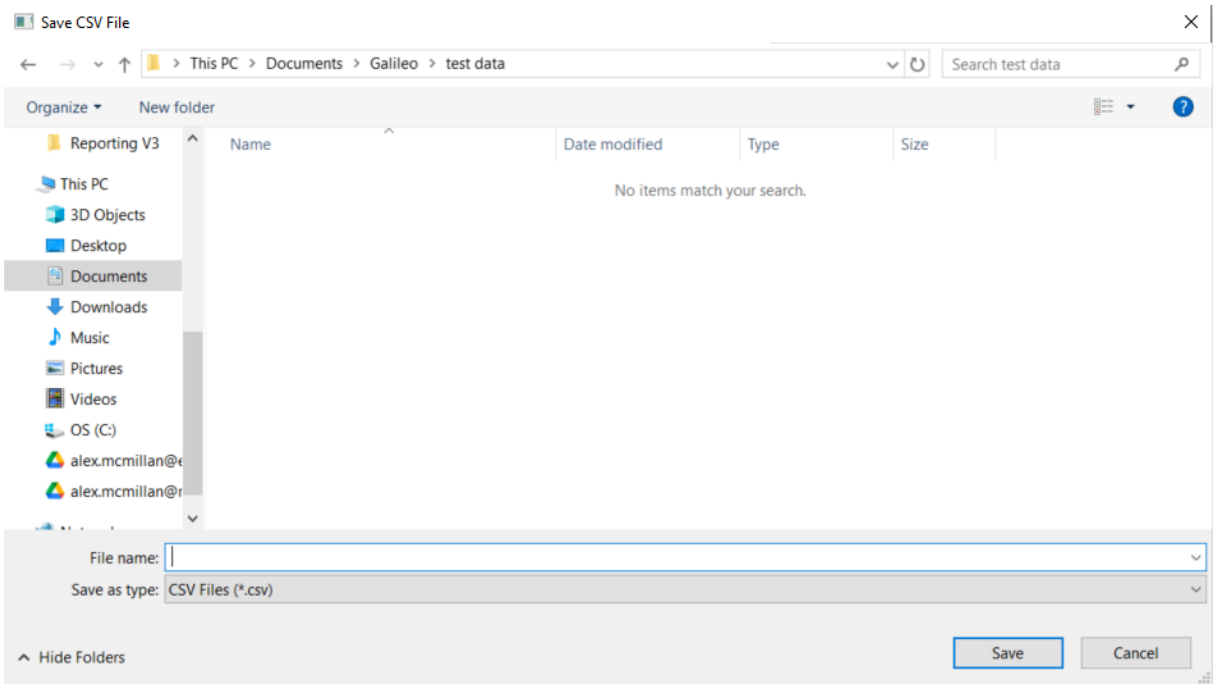
(5) This section allows the control of the graph sampling time and moving display window time. Changes are effective after clicking on the *reset* button. The minimum sampling time is 0.1s.

(6) This section allows the recording and saving of data at the user defined data acquisition sampling time. The minimum sampling time is 0.01s and can not be changed once the acquisition has started.



When clicking the “Start acquisition” button in the interface, you will be prompted to select a location and name of the log file, as seen below. Once a location and name are chosen and saved, you will find a CSV format file in the designated location, which will be logged with data constantly until you stop it. A second CSV file containing the parameters of the cartridge and base will be created at the same time. In order to finish data logging, you must click the “Stop acquisition” button found in place of the “Start acquisition” button in the interface. The CSV format file created may be opened in the preferred method of the user. An example of recorded data opened on Excel is shown in the figure below.

NOTE: your computer entering sleep mode may interrupt data acquisition. Please disable your computer’s sleep mode if long term data acquisition is required.



	A	B	C	D	E	F
1	Date	Time (s)	Flow Rate (ul/min)	Clogging	Liquid	
2	25/02/26_10:47:38.93	0	-0.034	No	Water	
3	25/02/26_10:47:38.94	0.01	-0.035	No	Water	
4	25/02/26_10:47:38.95	0.02	-0.035	No	Water	
5	25/02/26_10:47:38.96	0.03	-0.036	No	Water	
6	25/02/26_10:47:38.97	0.04	-0.035	No	Water	
7	25/02/26_10:47:38.98	0.05	-0.035	No	Water	
8	25/02/26_10:47:38.99	0.06	-0.035	No	Water	
9	25/02/26_10:47:39.00	0.07	-0.035	No	Water	
10	25/02/26_10:47:39.01	0.08	-0.035	No	Water	
11	25/02/26_10:47:39.02	0.09	-0.034	No	Water	
12	25/02/26_10:47:39.03	0.1	-0.034	No	Water	
13	25/02/26_10:47:39.04	0.11	-0.035	No	Water	
14	25/02/26_10:47:39.05	0.12	-0.036	No	Water	
15	25/02/26_10:47:39.06	0.13	-0.036	No	Water	
16	25/02/26_10:47:39.07	0.14	-0.036	No	Water	

4. Galileo Flow Sensor Software Development Kit

A Software Development Kit (SDK) was developed to communicate easily with the Galileo flow sensor with Python. This class-based interface called GalileoFlowSDK contains essential modules to read the flow rate and do other necessary operations. The currently available operations of the SDK are listed below:

read_flow()	*Returns the flow rate (µl/min)*
check_clogging()	*Returns the clogging status (« No », « Partial », « Yes »)*
read_liquid()	*Returns the liquid type set in the sensor*
update_liquid(liquid_type)	*Updates the liquid type of the sensor* *Argument : liquid_type: the liquid flowing through the sensor (0: water, 1: isopropanol, 2: DMEM with 10% FBS, 3: ethanol 70%, 4: ethanol 96%, 5: hexadecane, 6: light mineral oil)*
read_serial_number()	*Returns the serial number of the cartridge*
read_firmware_version()	*Returns the firmware version of the base*
update_firmware(file_name)	*Updates the firmware of the sensor* *Argument: file_name: path to the binary file of the firmware*

The GalileoFlowSDK is accessible on the Python Package Index (PyPI), where several example codes are also accessible. The GalileoFlowSDK can be installed as a simple package with the command « pip install GalileoFlowSDK ».

5. Galileo Flow Sensor Cleaning and Storage Recommendations

For best sensor performance and lifetime, it is recommended that the Galileo flow sensor is cleaned after each use, especially if being placed in storage for a significant amount of time after a flow experiment. Depending on the working fluid being used, the Galileo flow sensor may be cleaned by flushing one or a combination of the following liquids:

- Pure, deionized water
- Pure isopropanol
- Pure ethanol
- Hellmanex® III 2% v/v in water solution (especially if working with biological media)

Regardless of the cleaning liquids applied, the Galileo flow sensor should be stored dry. Thus flushing the Galileo flow sensor with air should be done after any liquid cleaning step.

Important: as with normal operation, ensure that cleaning flushes are not being applied with too great a pressure that may damage the sensor (over 3 bar gauge pressure). If uncertain, this can be verified by leaving the Galileo flow sensor connected to the

computer while cleaning and ensuring that the “**Pressure**” indicator remains green during cleaning flushes. If it turns red, reduce the pressure or flow rate being used to flush.

6. Troubleshooting reference guide

This section describes potential problems you may encounter and what actions can be taken to overcome them.

Filling

For sensors with high internal resistance, we recommend to always fill the sensor first with a liquid that has good wetting properties on PEEK surfaces (for example ethanol 96% or more), and then to replace ethanol with your liquid, if possible. This reduces the possibility of bubbles or particles that could stay trapped in the sensor.

A filling issue may manifest as a difficulty or inability to see liquid exiting from the outlet of the Galileo flow sensor while purging air from the sensor. This may occur at the start of an experiment (i.e. the sensor was previously dry) or any time after air has entered the sensor (intentionally or unintentionally) during an experiment and it must be removed.

Air in the Galileo flow sensor:
i. Filter all solutions first to remove small particles
ii. Disconnect the sensor from the flow path and fill the tubing up to the sensor inlet. Then connect the sensor and use your maximum flow rate (or up to ~3 bar) to flush out all air.
Note: the Galileo flow sensor has less than 20 µL internal volume, filling it could take several minutes depending on the flow rate being applied.

If the issue persists, it may be that the sensor is blocked, e.g. with a small particle. Move to status resolution tips below.

Status alert appears

- Orange alert: The flow sensor is experiencing slight fouling. If the clogging event is brief, e.g. seconds to minutes, this may indicate that a small particle became temporarily stuck and then dislodged. A sustained orange alert indicates a likely drift in measurement accuracy. In either case, sensor use may be continued at the discretion of the user and their application.
- Red alert: The flow sensor is likely clogged fully or badly. In this case, the flow may be completely stopped, substantially slower than expected, or only occur with

priming using higher pressure. It is recommended to clean the sensor before continuing with its use.

Recommendations are (use one or a combination of these):

i. Filter all solutions to remove small particles;
ii. Flush at your maximum flow rate (or up to ~3 bar) for 10-15 min. If your setup allows it, you can alternatively use square impulse of pressure up to 3 bar (every 1 to 10 sec). You can also use a manual syringe, while taking special care to remain below the maximum operating pressure (Pressure flag should stay green).
iii. Flip the sensor around and push in the direction from outlet to inlet
iv. Flush in reverse with appropriate clean solvent (e.g. ethanol or isopropanol),, then switch to your working liquid
v. Clean the sensor with Hellmanex® III 2% v/v in water solution (especially if working with biological media).

If those operations do not resolve the clogging indication, use a new cartridge with a brand new flow path.

Overpressure warning

Reduce flow rate or pressure being applied to pump liquid into your microfluidic circuit.

Software is not responding when trying to connect to my Galileo flow sensor

Try turning off your computer's Bluetooth and attempt connection to the software again. If the connection is then successful, your computer's Bluetooth may be re-activated.

If you have multiple devices connected to your computer, the Galileo flow sensor may be very slow to connect to the software. Try to physically disconnect the other devices from your computer, connect your Galileo flow sensor and start the software. If the connection with the Galileo flow sensor is successfully established, reconnect your other devices.

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