

# FS Series

User Manual

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## **WARRANTY TERMS :**

### More Information

This warranty is granted by Fluigent and applies in all countries.

Your Fluigent product is guaranteed for one year from the date of delivery at your laboratory for defects in materials and workmanship.

If found to be defective within the warranty period, your Fluigent product will be repaired or replaced free of charge.

### **What This Warranty Does Not Cover**

This warranty does not cover routine maintenance, or damage resulting from the failure to maintain the product in accordance with instructions provided by Fluigent. This warranty also does not cover damage that arises from accidental or intentional misuse or abuse, alteration or customization, or repaired by unauthorized persons.

### **How to Get Service**

If something goes wrong, contact the Fluigent dealer from whom you purchased your product. Arrange a mutually convenient time for a Fluigent service representative to discuss the problem and find a solution to fix the issue. In case more actions need to be taken, the system will come back to Fluigent offices (for no additional cost, if it is under warranty).

### **The warranty conditions are:**

- Only use cables provided by Fluigent
- Prevent foreign objects or liquids from being in contact with the F-OEM or FLOWBOARD OEM
- Prevent foreign objects from entering the Flow Sensor
- Do not place the product in an unstable location, place the unit in a location with a level surface and a strong and stable support
- Respect the temperature compatibility (from 5°C to 50 °C)
- Filter your solution, if possible add a filter in the fluidic path (§ 10) and clean your Flow Sensor after each use, especially the Flow Sensor XS (cf § 4.3). The diameter of the Flow Sensor XS capillary is small: 25 µm. Fluigent rejects any liability in the event of clogging or surface modifications.
- Do not allow the Flow Sensor to dry with media in the capillary tube without flushing clean first
- Fluigent advises the user to complete a cleaning procedure after use
- The Flow Sensor yellow plugs must be installed for storage
- Check the fluid compatibility with the Flow Sensor wetted materials before using it or ask Fluigent customer support
- The customer is responsible for fluid used with the Flow Sensor. Before use, the customer has to check the compatibility of the fluid with the Flow Sensor

For specific use, please contact our Support team at [\*\*support@fluigent.com\*\*](mailto:support@fluigent.com).

## 1. Introduction

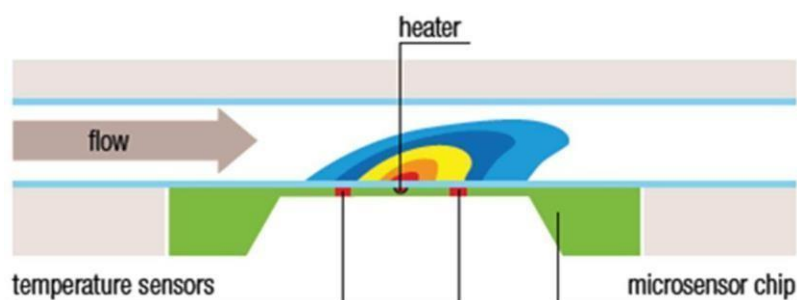
Our FS Series is dedicated to flow-rate control and monitoring. When combined with Fluigent pressure controllers, it permits pressure-based flow control. It enables precise and accurate measurements of dynamic liquid flow rates from 0 – 1.5  $\mu\text{L}/\text{min}$  and up to 40 mL/min bi-directionally.

This manual will show you how to assemble your FS Series. It will describe the product's functionalities and will teach you how to connect all the different Flow Sensor models and the FLOWBOARD. It will also convey how to use the product with its required equipment.

## 2. General information

The FS Series enables flow-rate measurements, in a wide range of flow rates thanks to the five models: XS, S, M, M+ and L+.

The flow-rate acquisition is based on thermal technology. A heating element on the microchip adds a minimal amount of heat to the medium for the thermal flow measurement. Two temperature sensors, symmetrically located above and below the source of the heat, detect even the slightest temperature differences, thus providing the basic information about the spread of the heat, which itself is directly related to the flow-rate.



It's possible to use the FS Series with any flow control systems, including pressure controllers to other types of flow sensors, provided that the flow-rate applied to a Flow Sensor does not go beyond its range. The FS Series allows one to measure the flow-rate and the volume of fluid introduced during the experiment. Five (5) different Flow Sensor models are available. They depend on flow-rate ranges and calibration.

Note: The FS Series can work at its best performance with FLUIGENT pressure-based flow controllers (F-OEM, P-OEM and PX). More details on [www.fluigent.com](http://www.fluigent.com).

**Warning: Please note that the maximum pressure depends on the Flow Sensor model. Ensure that the pressure applied to a Flow Sensor does not go beyond this value. All maximum pressures are available on the datasheet.**

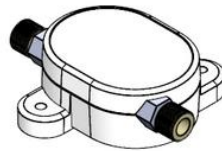
The FS Series can be used with other flow sensors. If you use a pressure regulator you may have to enter a maximum pressure below this value. If you use another flow sensor, be aware that pressure may go higher than 100 bar and may cause damage to your Flow Sensor.

### 3. Flow Sensor Description

#### 1. Flow sensor models

##### High flow rate applications: FS Series +

For applications that require flow rates ranging from 7  $\mu\text{L}/\text{min}$  to 40  $\text{mL}/\text{min}$ , we recommend our latest flow sensor series. It consists of a high-precision sensor and electronics integrated into a compact casing. Standard M3 sized screws can be used for fixing the device. Using these flow sensors, one can also monitor the liquid temperature and detect air bubbles that pass through the sensor.



Two references are available:

##### 1. FS Series M+:

H<sub>2</sub>O full-scale flow rate: 0 -  $\pm 2\text{mL}/\text{min}$

Accuracy :  $\pm 5\%$  of measured value if flow rate > 10  $\mu\text{L}/\text{min}$ ,  
0.5  $\mu\text{L}/\text{min}$  if flow rate < 10 $\mu\text{L}/\text{min}$

\*Additional specifications on the datasheet

##### 2. FS Series L+:

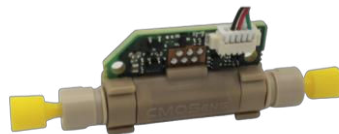
H<sub>2</sub>O full-scale flow rate: 0 -  $\pm 40\text{mL}/\text{min}$

Accuracy:  $\pm 5\%$  of measured value if flow rate > 1  $\text{mL}/\text{min}$ ,  
50  $\mu\text{L}/\text{min}$  if flow rate < 1  $\text{mL}/\text{min}$

\*Additional specifications on the datasheet

##### Low flow rate applications: FS Series

For applications that require flow rates lower than 10  $\mu\text{L}/\text{min}$ , we recommend our original flow sensor series.



Three references are available:

##### 1. FS Series XS:

H<sub>2</sub>O full-scale flow rate: 0 -  $\pm 1.5\ \mu\text{L}/\text{min}$

Accuracy:  $\pm 10\%$  of measured value if flow rate > 75  $\text{nL}/\text{min}$ ,  
7.5  $\text{nL}/\text{min}$  if flow rate < 75  $\text{nL}/\text{min}$

\*Additional specifications available on the specification table and on the datasheet

##### 2. FS Series S:

H<sub>2</sub>O full-scale flow rate: 0 - ± 7 µL/min  
Accuracy: ±5 % of measured value if flow rate > 0.42 µL/min,  
21 nL/min if flow rate < 0.42 µL/min

\*Additional specifications available on the datasheet

### 3. FS Series M:

H<sub>2</sub>O full-scale flow rate: 0 - ± 80 µL/min  
Accuracy: ±5 % of measured value if flow rate > 2.4 µL/min,  
0.12 µL/min if flow rate < 2.4 L/min

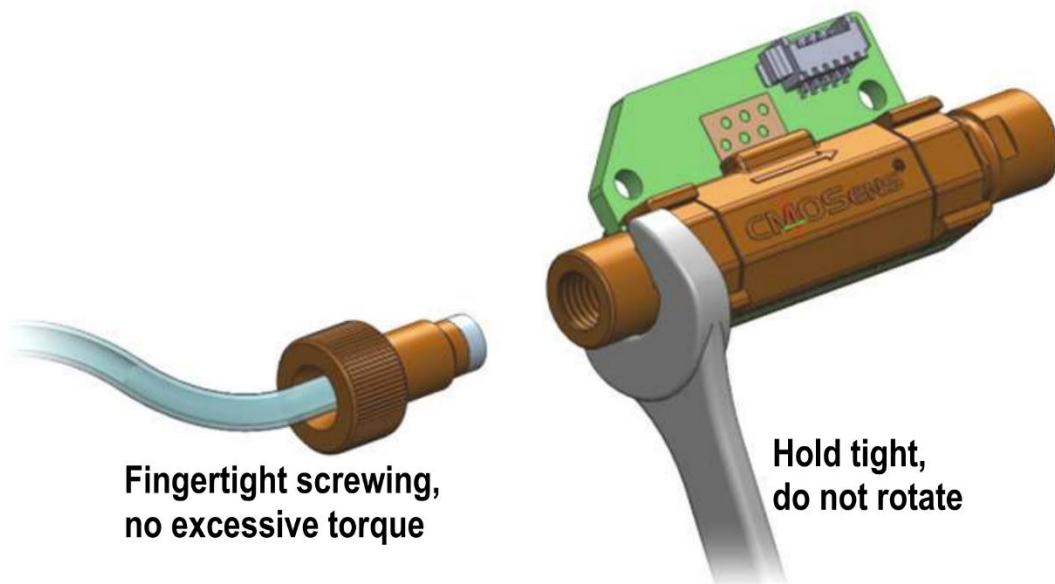
\*Additional specifications available on the datasheet

## Installation advice for FS Series

FS Series OEM Flow Sensors are highly sensitive measurement devices for ultra low flow rates. To assure precise and drift-free flow measurements, **mechanical stress needs to be avoided**. These OEM sensors are not made for stand alone usage. You should choose a protected location for reliable operation.

The model FS Series needs to be handled and installed with special care! Please make sure the following guidelines get respected:

- Connect the sensor to flexible tubings only. Rigid tubings cause mechanical stress.
- While tightening the fitting, fix the fluidic ports position with a wrench.



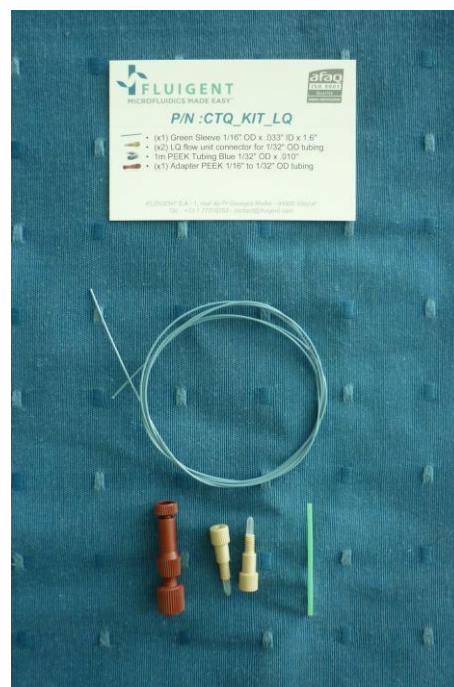
- FS Series sensors are equipped with fingertight fittings. Torques larger than fingertight are not needed for a tight connection and have to be avoided.
- Assure that the sensor gets not stressed temporarily or permanently by mechanical forces like bending or torque
- The cable length for digital I<sup>2</sup>C communication should be limited to 30 cm (12 inch)

## 2 Connection

### Fluidic connection for XS and S Flow Sensor models

The XS, S and M Flow Sensor models have two (2) fluidic ports.

- ▶ The characteristics of those two (2) ports are:
  - Thread-size: UNF 6-40.
  - Compatible with 1/32" tubing external diameter (1/32" OD).
- ▶ To get started, FLUIGENT can provide a "CTQ\_KIT\_LQ" kit including:
  - One (1) green sleeve 1/16" OD x 0.033"x1.6"
  - Two (2) LQ Flow Sensor connector for 1/32"OD tubing, One (1) meter of PEEK Tubing Blue 1/32" OD x0.010" ID One (1) adapter PEEK 1/16" to 1/32" OD tubing



**NB:** As there is a wide variety of tubing and fittings for different applications, FLUIGENT advises you to make sure that your fluidic connection system fits with the two (2) fluidic ports of the Flow Sensor. If not, please note that there is a large panel of adapters and unions to connect your tubing to ours. Visit [www.fluigent.com](http://www.fluigent.com) to learn more about materials and ID available with 1/32" or 1/16" OD tubing, nuts and ferrules from fittings suppliers to suit your application.

### Fluidic connection for M+ and L+ Flow Sensor models

The L and XL Flow Sensor models have two fluidic ports.

- ▶ The characteristics of those two (2) ports are:
  - Thread-size: ¼-28.
  - Flat-bottom type (FB).
  - Compatible with tubings of 1/16" external diameter (1/16" OD).
- ▶ To get started, FLUIGENT can provide you the a kit including:
  - Two (2) Flow Sensor HQ connector ¼-28 Flat Bottom for 1/16" OD tubing
  - Four (4) ferrules for HQ Flow Sensor
  - 1 m FEP tubing 1/16" OD





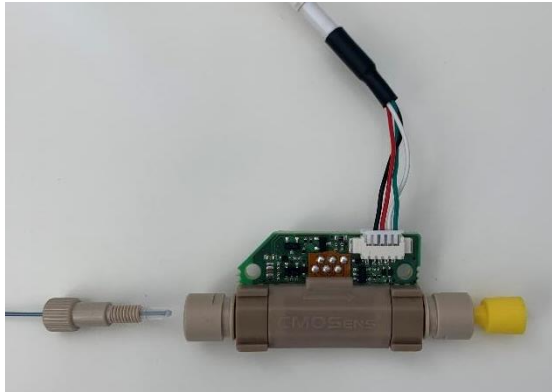
## How to connect tubing to the Flow Sensor models

The pictures below illustrate how to connect OD 1/16" tubing to M+ and L+ Flow Sensors



1. Cut the 1/16" OD tubing to the desired length, leaving a square-cut face.
2. Slide the nut over the tubing with the nut thread facing the tubing end being connected.
3. Slip the ferrule over the tubing, with the tapered portion of the ferrule facing the nut.  
NB: the nuts and ferrules are specifically designed to work together. FLUIGENT advises you to only associate the provided ferrules with the provided nuts and vice-versa.
4. Insert the assembly into the receiving port, and while holding the tubing firmly against the bottom of the port, tighten the nut finger tight.
5. To check the tightness of your connection, you may pull gently on the tubing: it must stay fitted in the ferrule and nut.
6. Do the same thing on the 2<sup>nd</sup> port

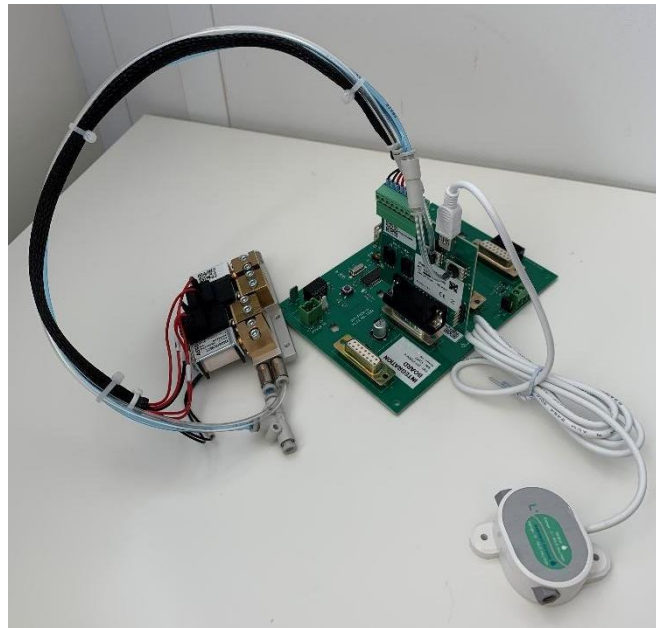
The pictures below show how to connect OD 1/32" tubing to XS, S and M Flow Sensor models.



1. Cut the 1/32" OD tubing to the desired length, leaving a square-cut face.
2. Slide the fitting over the tubing.
3. Insert the assembly into the receiving port, and while holding the tubing firmly against the bottom of the port, tighten the fitting finger tight.
4. To check the tightness of your connection, you may pull gently on the tubing: it must stay fitted in the ferrule and nut.
5. Do the same thing on the 2<sup>nd</sup> port.

## 5. Using the FS Series with Fluigent F-OEM

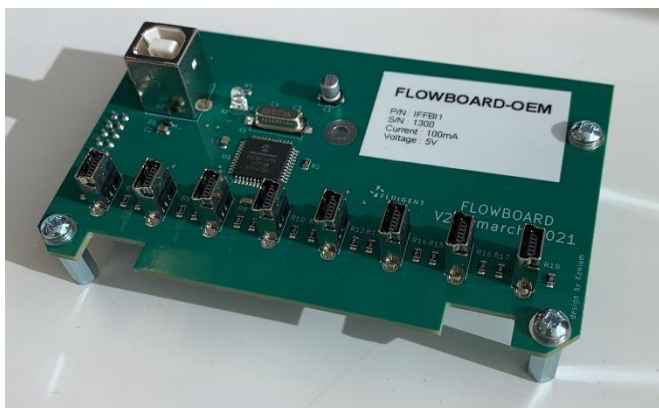
If using Fluigent F-OEM, one can directly connect the sensor to the pressure module using the mini-USB port of the electrical sub-module. Connect the type B plug of the USB cable provided into the type B USB port on the integration board of the F-OEM. Connect the other end of the USB cable (type A standard plug) to the computer. The flow sensor will automatically be detected by Fluigent software (SDK and OxyGEN).



## 6. Using the FS Series with Fluigent PX and P-OEM

If using Fluigent PX or P-OEM pressure controllers, one needs an OEM FLOWBOARD to operate the FS Series. This device hosts up to eight (8) Flow Sensor models and provides power supply.

### 6.1 Description



A green indicator (power LED) lights up when the FLOWBOARD is connected.

- ▶ A USB port (type B) links the FLOWBOARD to a computer for software control.
- ▶ There are eight (8) mini-USB ports (to connect up to eight (8) Flow Sensor devices).

## 6.2 Connection

### 6.2.1 USB connection

Connect the type B plug of the USB cable provided into the type B USB port on the front of the FLOWBOARD OEM. Connect the other end of the USB cable (type A standard plug) to the computer.

### 6.2.2 Flow Sensor connection

To connect a Flow Sensor to the FLOWBOARD OEM, plug the end of the mini-USB plug fixed with the Flow Sensor to one of the eight (8) mini-USB ports on the FLOWBOARD OEM.



## 7. Fluigent SDK and software

### SDK (software development kit)

The Flow Sensors Series is fully supported by Fluigent SDK. It has been ported to the most popular programming language within the instrumentation field (LabVIEW, C++, C#.NET, Python and MATLAB). This SDK merges all Fluigent pressure controllers and sensor instruments and provides an advanced regulation loop. A specific function has been implemented for the FS Series +, which allows it to read the flag indicating whether the flow rate sensor detects an air bubble. Only available on Flow Unit sensor ranges M+ and L+.

fgt\_get\_sensorAirBubbleFlag: see page 29 of the SDK user manual

For all the functions and the user manual, visit the following webpage:

<https://github.com/Fluigent/fgt-SDK>

### OxyGEN

Fluigent OxyGEN software supports the FS Series. The sensors will be identified and the same level of features of our end-user products are available. For more information, visit OxyGEN webpage available here: <https://www.fluigent.com/research/software-solutions/oxygen/>

## 8. Start working with the FS Series

### 8.1 Quick start procedure

Here is a quick setup guide to remind you of the main steps to get your FS Series up and running.

1. First, you may want to connect the Flow Sensor to your microfluidic system, with the right fittings.
2. Connect the Flow Sensor models to the F-OEM directly or to the FLOWBOARD OEM if you are using Fluigent PX or P-OEM (see §5 and §6). Connect the F-OEM or the FLOWBOARD OEM to the computer using the USB cable.
3. You can now use your FS Series for your application.



**CLEAN AND RINSE YOUR Flow Sensor AFTER USE** (See §8)

### 8.2 Use at high temperature and high flow-rate

The Flow Sensors can be used in a large range of temperature, but some elements need to be taken into account:

- The Flow Sensors include temperature compensation between 10°C and 50°C. However, as the temperature deviates from 20°C, the absolute accuracy may acquire an additional error of typically 0.1% of the measured flow rate per °C.
- Between 50°C and 80°C the Flow Sensor will still be operational and the performances optimal. However, the absolute accuracy will depend on the temperature.

In order to get a correct reading from the sensor, it is important that liquid temperature and ambient temperature are identical (within  $\pm 3^\circ\text{C}$ ). At low flow rates this will not be an issue, but for higher flow rates (for M+ and L+ Flow Sensor models) this is important.

## 9. Cleaning Procedure

Flow Sensor models are highly sensitive and should be properly cleaned to always maintain a high performance. With proper care and maintenance, the Flow Sensors can last many years. No cleaning or improper cleaning may leave deposits on the internal capillary wall which could result in measurement deviations and even clogging. Cleaning the sensor after use and before storing the device for a long period of time should prevent the sensors from any damage.

### 9.1.1 Explanation

Inside the liquid flow sensors, the sensor chip measures the flow through the wall of a thin walled glass capillary. Because the measurement uses the heat propagation through the glass wall and the heat exchange with the medium, it is critical that the coupling of the chip with the medium is not altered. Formation of deposits on the glass wall inside the capillary may block the heat transfer.

### 9.1.2 General Handling

Do not allow the sensor to dry with media in the capillary tube without flushing it clean first. Also try to avoid letting the filled sensor sit for extended periods (depending on your liquid).

Before storing the sensor, always drain fluid, flush with a cleaning agent, blow out, and dry the capillary.

**For the XS Flow Sensor model, filter the solution through a 5µm (or lower) membrane filter.**

### 9.1.3 Cleaning Procedure

Cleaning and flushing of the Flow Sensors should consider the nature of the materials that were being pumped through them. Typically, one should select a cleaning solution that is safe for the Flow Sensor (the inside surface) and the rest of the set up will dissolve the type of samples that were in contact with the surface.

For Flow Sensor XS, S and M, fluids have to be compatible with PEEK & Quartz glass.

For Flow Sensor M+ and L+, fluids have to be compatible with PPS, stainless steel (316L) and PEEK/ETFE.

The following steps are recommended for water-based solutions, in the right order:

- Rinse all of your system with water. Clean the
- Flow Sensor with a non-foaming detergent.  
The detergent needs to be compatible with the Flow Sensor, the rest of your set-up (microfluidic chip, especially) and fluids used before and during your
- experiment. Remove all the contaminants thanks to a disinfectant (for
- example, bleach). Rinse the bleach (or the selected disinfectant) with water.
- Rinse the system with isopropanol. This will eliminate any residues from being left behind. Then, the sensor's yellow plugs must be installed for storage.

## 9.1.4 Recommendations for Fluids

### Working with Multiple Liquids

Switching between multiple liquids can leave transient deposits in the form of liquid layers inside the glass capillary. This is especially common for insoluble liquids, but can happen even with miscible liquid combinations. For example, when IPA is followed by water in a sensor without drying in between, large offsets can be observed for hours after switching to water.

If possible, dedicate a separate sensor for each different liquid to be measured. If not possible, use caution when switching media and clean properly.

### Working with Water

When working with water, **do not** let the sensor dry out. All salts and minerals in the water will deposit on the glass and are difficult to remove. Although salt solutions are particularly prone to problems, even clean water can still contain enough dissolved minerals to form a deposition layer. Flush with DI water on a regular basis to prevent build-up. If you still encounter problems, occasionally flush the sensor with slightly acidic cleaning agents.

When working with water containing organic materials (sugars, etc.) microorganisms often grow on the walls of the glass capillary and form an organic film that can be difficult to remove. Flush on a regular basis with solvents such as ethanol, methanol or IPA, or with cleaning detergents to remove organic films.

### Working with Silicone Oils

When working with silicone oil, do not let the sensor dry out. Silicone oils can be cleaned out using special cleaners. Check with your silicone oil supplier for cleaning agents compatible with glass surfaces.

### Working with Paints or Glues

When working with paints or glues, do not let the sensor dry out. Often, depositions of paints and glues cannot be removed after they have dried. Flush the sensor with cleaning agents recommended by your paint or glue manufacturer that are compatible with glass. Ensure that you have found a good cleaning procedure before performing the first tests, and always clean shortly after emptying the sensor.

### Working with Alcohols or Solvents

Unlike most other fluids, alcohols and solvents are not critical and a short flush of isopropanol (IPA) is sufficient to clean the capillary walls.

### Other Liquids or Applications

If uncertain about your application and how to clean the flow sensor, please contact FLUIGENT for additional support at [support@fluigent.com](mailto:support@fluigent.com).

### Identified Cleaning Solutions

Sample liquid	Cleaning solution	Supplier
Biofilm/cells	<ul style="list-style-type: none"><li>● Biofilm remover</li><li>● Sodium dichloroisocyanurate (1 ppm HClO; ref : 218928)</li></ul>	<ul style="list-style-type: none"><li>● Umweltanalytik</li><li>● Sigma Aldrich</li></ul>
1% micro-beads of polystyrene in DI Water	Toluene 99.8% (ref : 244511)	Sigma Aldrich

Mineral oil (Sigma cat no. 5904)	RBS 25 (ref : 83460)	Sigma Aldrich
Blood	<ul style="list-style-type: none"> <li>● BD FACS Clean</li> <li>● RBS 25 (ref : 83460)</li> </ul>	<ul style="list-style-type: none"> <li>● BD</li> <li>● Sigma Aldrich</li> </ul>

### 9.1.5 Cleaning Methods That Are Not Recommended

In general, **any cleaning by mechanical means should be avoided**. Never enter the sensor's flow path with sharp objects that could scratch the glass surface.

Furthermore, no abrasives or liquids containing solids that can grind the surface clean should be used. Anything that affects the glass wall will cause deviations in the measurement performance or permanently damage the sensor.

**Strong acids and bases should also not be used to clean the sensor.** Acids can sometimes be used in low concentration and at low temperatures. Before using the acid check how compatible it is with borosilicate 3.3 glass (Pyrex® or Dur



## 10. Frequently Asked Questions

How can I clean the Flow Sensor after use?

See §9 to see how.

What's the accurate range of the temperature sensor?

The Flow Sensor sensors are already temperature compensated, so they work in a range of 10°C to 50 °C. This can be useful if your device needs to be contained within an incubation chamber.

Will the size of the capillary of the XS Flow Sensor model have an influence on my system?

Yes, the diameter of the capillary is small: 25 µm, so depending on the size of your system, you may need to push your fluids harder to obtain a given flow-rate. The maximum pressure drop between the sides of the XS Flow Sensor model at maximum flow-rate is 0.8 bar.

Is there a specific way of washing the XS Flow Sensor?

You can find cleaning procedures in §9. Regarding the XS Flow Sensor, it may withstand pressures up to 200 bar, so it is possible to use high pressure or flow-rate pumps in case of clogging.

Is there a specific way to prevent clogging in the XS Flow Sensor?

It is possible to add a filter in the fluidic path. For example, you can find among IDEX products, biocompatible precolumn filters (references A-355, A-356). These filters are designed for use with 1/16" OD tubing. You can choose either 0.5 µm (A-700) or 2 µm (A-701) frit to filter particles from the flow path.

Why is the flow-rate measured by the Flow Sensor not stable?

Some fluid controllers will exhibit pulsatility around a mean value as they are mechanically actuated. Therefore, the flow-rate within a system can vary depending on the controller used. Visit us on [www.fluigent.com](http://www.fluigent.com) for further information.

Why will the measured flow-rate not reach a steady state?

For some fluid controllers, the settling-time may be long. For this reason, the transition phase after an order change in the fluid controller takes much longer, depending on the nature of the fluid controller. Visit us on [www.fluigent.com](http://www.fluigent.com) for further information.

Why does the flow-rate measured by the Flow Sensor not match the ordered flow-rate on my fluid controller?

- ▶ The flow-rate calculated by the Flow Sensor is based on a temperature diffusion-advection measurement with the glass capillary. If your fluid is not pure water (or isopropanol) you first need to add a scale factor to calibrate your Flow Sensor. See section 8 for more details on the calibration of the Flow Sensor.
- ▶ There might be a leak within your system. Please check if your system is completely tight before going any further. See §4.2 on how to connect your Flow Sensor.
- ▶ The settling time may be long. Check your fluid controller supplier for more information.



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