SENSIRION SFC5xxx High-precision, configurable, fast, multi-gas flow sensor User Guide

SENSIRION

Engineering guidelines for Mass Flow Controllers (SFC5xxx) and Mass Flow Meters (SFM5xxx)

Summary
This guide provides recommendations for evaluation, testing, and integration of Sensirion Mass Flow Controllers and Meters. It is applicable to SFC55xx, SFC54xx, and SFC53xx as well as SFM55xx, SFM54xx, and SFM53xx products.
For clarity, the document was written for Mass Flow Controllers, yet most guidelines are also valid for Mass Flow Meters.

Contents

How to choose your Mass Flow Controller (Mass Flow Meter)

Sensirion offers several families of Mass Flow Controllers and Meters.

- SFC5500 (SFM5500) is ideal for first testing and projects with yearly volumes of up to 50 pieces. It is available in fixed configurations with pre-configured multiple gas calibrations, different flow ranges, and exchangeable fittings, and is available via distribution.
- SFC54xx (SFM54xx) family is a make-to-order product that offers the highest configurability (flow rates, fluidic connectors, and communication interfaces), and is suitable for projects of various sizes.
- SFC53xx (SFM53xx) product family are Sensirion's OEM Mass Flow Controllers (Mass Flow Meters) best suited for projects with yearly volumes above 50 pieces.

To help you choose the right Mass Flow Controller, a "Selection Guide" is available on the Sensirion website. Please see the "Useful resources" section below.

How to operate your Mass Flow Controller

The evaluation method depends on whether your Mass Flow Controller has a digital or an analog interface.

2.1. Digital interface

Several different ways to operate Sensirion digital Mass Flow Controllers exist. They vary in complexity and implementation flexibilities.

The EK-F5x evaluation kit is the fastest way to start working with your Mass Flow Controller. It combines a power supply (adapters for most sockets worldwide are included) and a USB-A plug for your PC. It is a simple plug-and-play system to evaluate all digital Mass Flow Controllers with a DB9 plug (an adapter is available for other plugs – please contact Sensirion). EK-F5x is available from distribution. Please note, Mass Flow Controller is not included and has to be purchased separately.

- The quickest way to start working with your device is using the EK-F5x evaluation kit together with Sensirion Viewer Software. It is a plug-and-play solution, which will enable you to control and configure your device (e.g. choose the gas calibration). The Viewer Software can be used to control multiple Mass Flow Controllers by opening

  several instances of the program on a single PC.
- Another simple way to control your device is to use the evaluation kit together with the available LabVIEW drivers.

  This allows for more flexibility at an expense of some implementation effort. A LabVIEW implementation is suitable for most laboratory and prototyping applications. It is possible to control multiple Mass Flow Controllers with a single LabVIEW program, by giving the devices different addresses.
- Most OEM projects will require designing custom cabling (including a power supply) together with an implementation in the desired programming language. Sensirion provides ready-to-use libraries in C, C#, and Python (see Section 8.2.2 in Useful Resources). These libraries can be used to control multiple devices at the same time (please make sure the devices have unique RS485 addresses) or to add the Mass Flow Controllers to a measurement sequence. However, this also involves the highest implementation effort out of the options mentioned here.

It is also possible to use the LabVIEW library with custom cabling or to use C, C#, and Python libraries with the EK-F5x evaluation kit.

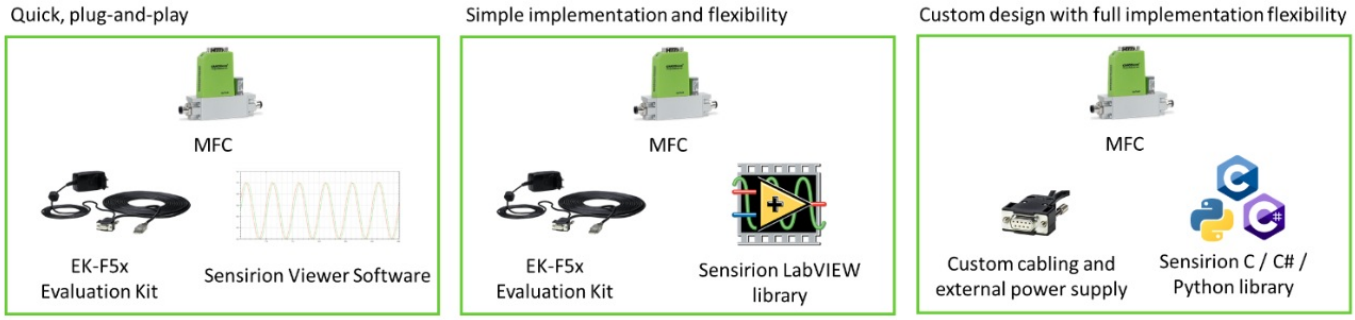


Figure 1 Different options for evaluating digital Mass Flow Controllers
Table 1 Software options for evaluating digital Mass Flow Controllers

SFC5xxx/SFM5xxx Viewer software	**LabVIEW**
for quick evaluation of plug-and-play software, no coding is required no custom cabling is required	for more fle custom cab

2.2. Analog interface

To operate a Mass Flow Controller with an analog interface (SFC54XX), you need:

- a tuneable power supply as a setpoint source, being able to deliver 0-5V, 0-10V, or 4-20mA, depending on the version of the analog Mass Flow Controller
- a DB9 cable to connect the Mass Flow Controller to a 15-24V power supply
- a multimeter or an oscilloscope to measure the flow signal

Testing recommendations

It is recommended to start by testing the communication with the device, using the EK-F5x Evaluation Kit and the Viewer software. The baud rate and address of the device with the viewer software can easily be changed if necessary.
As a second step, connect the device to a gas supply (or a source of vacuum). For best accuracy, mount the Mass Flow Controller horizontally and use the same pressure as during factory calibration (specified in the datasheet, by default for most products 3 bar inlet vs outlet).
If the Mass Flow Controller is mounted vertically, the chimney effect can adversely impact the accuracy at low flows and especially at zero flow. It is possible to use Sensirion calibration software to compensate for that effect. The “Recalibration software” can be downloaded from the Sensirion website and is also linked in the “Useful resources” Section 8.1. In this case, you will have to calibrate the mass flow controller yourself in the chosen orientation.
Try using different setpoint steps to test the Mass Flow Controller. If the chosen setpoint can’t be reached, try increasing the supply pressure, removing fluidic resistances like filters, or using tubes with a larger diameter. If the supply pressure used is significantly lower than the calibration pressure, the controller can be slower than expected. On the other hand, if the supply pressure is significantly larger than the calibration pressure, the Mass Flow Controller may become unstable. In these cases, lowering or increasing the ser gain to adapt the controller accordingly. This can be done conveniently with the Viewer Software. For detailed instructions, see the “Viewer Software Manual”, linked in “Useful resources” Section 8.2.1.

Common pitfalls

4.1. Flow appears to be off by several %

If the flow appears to be off by several % (especially around 7%) against your reference, there are good chances the flow units of the two devices are not the same. Sensirion’s ass Flow Controllers can be factory calibrated for different units: e.g. standard or norm liters. The conversion difference between the two is around 7%, due to the

different reference temperatures used for standard and norm liters. Please make sure that the Mass Flow Controller and your reference are using the same units when testing. Further information about the flow unit conversion can be found in a dedicated application note, “Reference and Flow Conversions between mass and volumetric flow”, in the “Useful resources” Section 8.1.
The most common cause for observing longer than expected settling time is trying to verify it from a position of a fully closed valve. Solenoid valves are commonly affected by the so-called “stiction effect”. To open the valve from a closed position (setpoint 0), a certain overvoltage is required to overcome the stiction effect. This can lead to a spike in the flow (especially for low setpoints) or a longer than expected settling time. By adjusting the “user gain” of the Mass Flow Controller, the behavior can be tuned to the specific requirements.

The settling time of Sensirion’s Mass Flow Controllers is specified for a step answer from 10% to 100% of full scale within 5% of setpoint. When testing the settling time, do not do so from a position of zero flow.

Design recommendations

To achieve the best accuracy, it is recommended to use a design where the Mass Flow Controller is mounted horizontally.
The valve used in the Mass Flow Controllers (proportional valve) is an oscillating system. Try to avoid sources of vibrations or decouple these sources mechanically from the Mass Flow Controller. They can interfere with the proper function of the valve.
The operation of the valve produces a significant amount of heat. The Mass Flow Controller should therefore not be placed in a hermetically sealed space. It is recommended to design a cooling flow over the Mass Flow Controller in order to counteract the heating from the valve. A large temperature gradient between the Mass Flow Controller and the gas it is used to control may adversely influence the accuracy of the device.

5.1. Pressure drop and input pressure

Pressure drop is generated when gas passes through the valve of a mass flow controller. The magnitude of the pressure drop is proportional to the flow rate and the density of the gas.
It is important to verify that at the maximum required flow rate, for a given gas, the inlet pressure is higher than the pressure drop. If this cannot be achieved, contact ensuring – it might be possible to order a similar mass flow controller with a larger-sized valve. Larger valves offer a lower pressure drop at the cost of a decreased accuracy/resolution at low flows.

Fluidic and electrical connectors

Table 2 Fluidic and electrical connectors

Product reference	Fluidic connector	Electrical connector
SFC5500/ SFM5500	Factory fitted with Legris G 1/4″ flange (exchangeable fittings) Compatible with Legris, Swagelok, Festo, Serto fittings (and others)	DB9
SFC5400/ SFM5400	Swagelok, VCO, VCR, Downmount	DB9
SFC5460/ SFM5460	Swagelok, VCO, VCR, Downmount	JST 4-pin*
SFC5300/ SFM5300	Downmount	DB9
SFC5330/ SFM5330	Downmount	JST 4-pin*

*Please ask Sensirion for an adapter, if used with the EK-F5x evaluation kit.

6.1. Downmount interface

When using products with down mount connectors, a specific manifold must be designed and manufactured by the user.
In Table 4 in the “Useful resources” Section 8.1, CAD models for suggested manifold designs for SFC54xx / SFM54xx and SFC53xx / SFM53xx can be found. They can be used as a starting point for a custom design.
The required O-rings for sealing are not provided by Sensirion. Suggestions are provided in Table 4 in “Useful resources” Section 8.1. It is recommended to use the same sealing materials as inside the Mass Flow Controller (see datasheet) to ensure material compatibility with the used gasses.

Description of the manifolds:

- SFx54xx: 4 screws can be used for mounting. The O-rings must be placed on the mass flow controller side. The manifold pictured below can be used as a starting point for the design. A Mass Flow Controller is placed on top of the manifold.

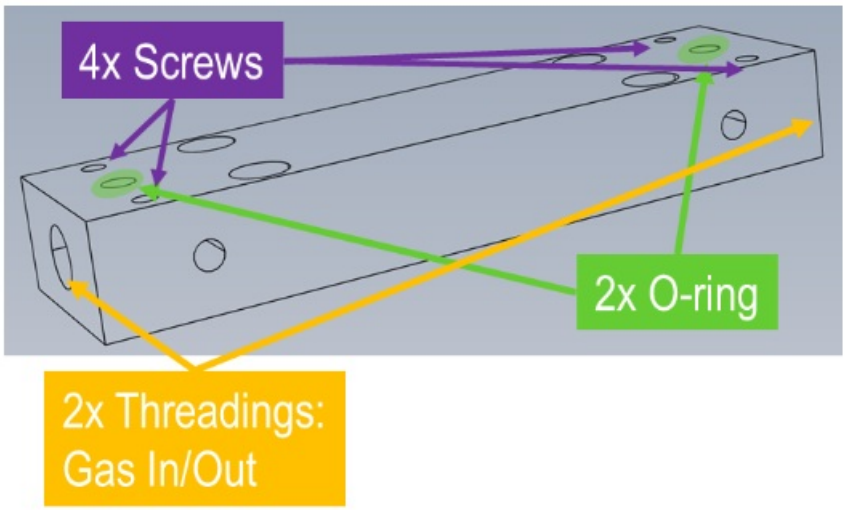


Figure 2 Suggested manifold design for SFC54xx / SFM54xx

- SFx53xx: for the short body type (see datasheet) 2 screws are needed for fixation from the bottom side. For the long body, 4 screws can be used from the top. The O-rings must be placed on the manifold side. The design pictured below is compatible with both “short” and “long” body designs.

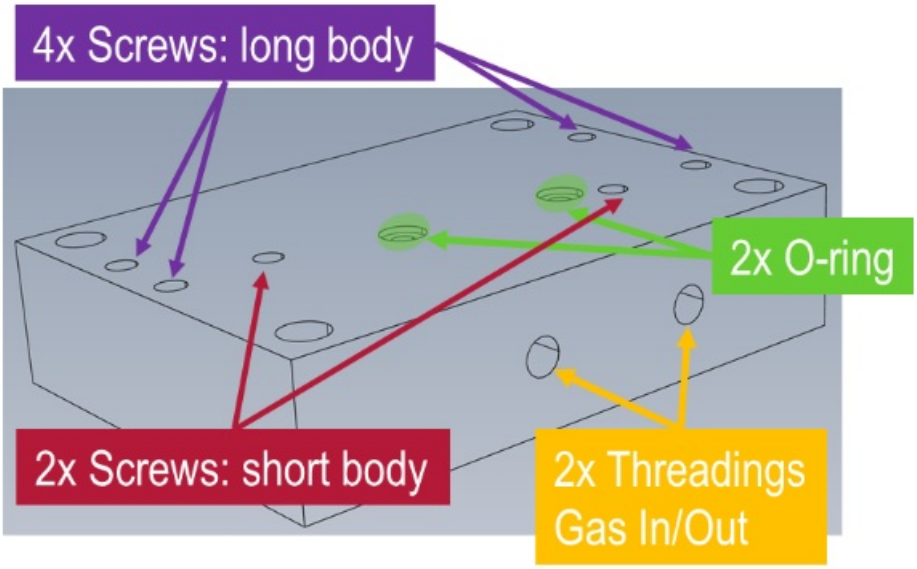


Figure 3 Suggested manifold design for SFC53xx / SFM53xx

Recalibration Tool

Sensirion's MEMS-based Mass Flow Controllers are shipped fully calibrated for the gasses specified when ordering. Unlike traditional, capillary-type Mass Flow Controllers, they do not drift and do not require regular re-calibration.
However, it is also possible to create and save a custom calibration for special use cases. A dedicated tool is available for this purpose. Possible scenarios, where user re-calibration might be helpful are:

- calibrate the Mass Flow Controller for gases, for which the controller was not factory calibrated
- calibrate the Mass Flow Controller at a pressure significantly different than factory calibration conditions (typically 3 bar differential pressure: 4 bar at the inlet and atmospheric pressure at the outlet)
- any situation which leads to the factory calibration requiring adjustments due to the accuracy requirements, e.g. vertical instead of horizontal implementation, …

To recalibrate your Mass Flow Controller, you need a source of pressurized gas with a defined flow rate and the Sensirion recalibration software. To precisely measure the flow through the Mass Flow Controller, it is recommended to set up the Mass Flow Controller in series with a Mass Flow Meter as a reference (see picture). The number of calibration points will impact the accuracy of the calibration. Generally, fewer points are needed when the new calibration gas has similar properties (density, thermal conductivity, and heat capacity) compared to one of the gasses the mass flow controller has already been factory calibrated for. An example would be re-calibrating a device for O_2 which has already been factory calibrated for Air.

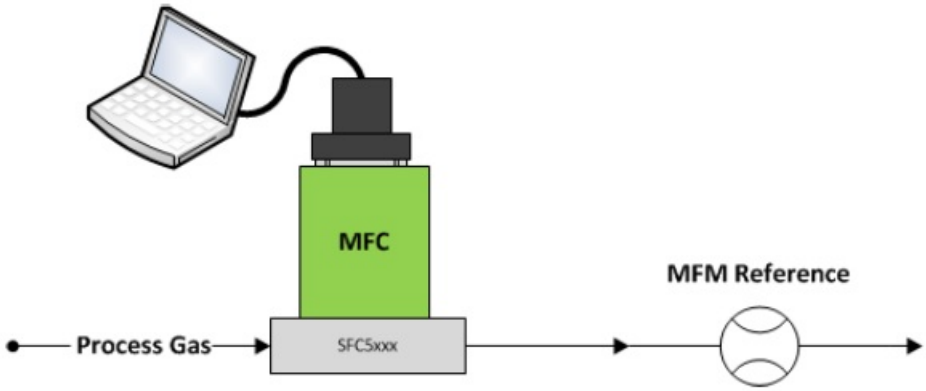


Figure 4 Recommended configuration for re-calibration of Mass Flow Controllers

The software tool and its manual can be downloaded from the Sensirion website. A link to “SFC5xxx/SFM5xxx Viewer software” is provided in the “Useful resources” Section 8.2.1.

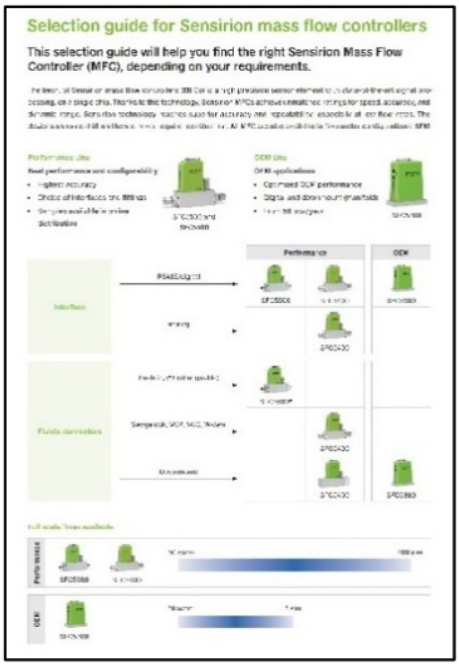
Useful resources

8.1. Documentation

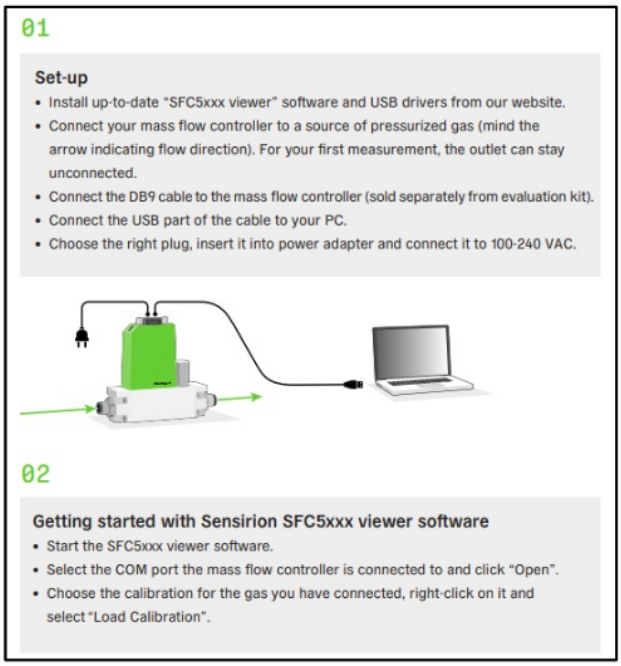
Various guides and application notes are available on the Sensirion website.
Mass Flow Controllers (SFC): **sensirion.com/products/product-categories/mass-flow-controllers/**
Mass Flow Meters (SFM): **sensirion.com/products/product-categories/gas-flow-sensors/**
General technical download section: **sensirion.com/products/downloads/**

The most relevant resources are linked below.

Selection guide



Quick start guide



SFC5500 gas fittings guide

SHDLC Communication Interface Reference

SFC5500 Mass Flow Controller
Application Note – Fittings

1 Exchangeable fittings

SFC5500 is fitted with a universal G ¼" flange, which allows for easy exchange of gas connectors. While Legris connectors are mounted by default, the user can purchase any connectors compatible with G ¼" thread and mount them on SFC5500 themselves. To do so, simply unscrew the fitted Legris connectors with a spanner and mount the new ones.

2 Compatible fittings

The table below shows an example of fittings compatible with SFC5500. Please note that the list is not exhaustive and only selected manufacturers of fittings are included.

Legris: 3101 series *Series 3133 and 3199 also compatible*	
4 mm / 5/32"	3101 04 13
6 mm	3101 06 13
8 mm / 5/16"	3101 08 13
10 mm	3101 10 13
12 mm	3101 12 13
Swagelok: SS-x-1-4RS series Important: Stainless Steel Gasket SS-4-RSD-ZV is also required and needs to be ordered separately.	

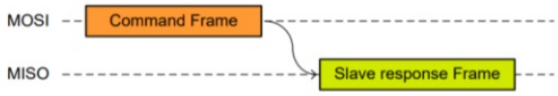
4 SHDLC Protocol Definition

SHDLC is a data link protocol, which is based on the UART byte transfer. It defines the data frames which are transferred from master to slave and vice versa.

The main features of the SHDLC protocol are:

- Master/Slave protocol
- Addressable (1 master and 1…255 slaves on the bus)
- Supports broadcasting
- Up to 255 bytes of data within one data frame (read and write)
- Half-duplex (no transmit and receive at the same time). This allows the usage of 2-wire RS485.
- Based on byte transfers (UART protocol used)
- Selectable baudrate

In SHDLC communication, every transfer is initiated by the master with a MOSI frame. The slave will response every received frame with a MISO frame as shown in the following picture:



Reference and Flow Conversions between mass and volumetric flow

Applications

In many applications mass flow is the desired quantity instead of volumetric flow. For example, in heating applications the calorimetric heating value, i.e. the number of gas molecules, is more important than the actual volumetric flow. Because of its thermal measurement principle Sensirion's SFMxxx flow meters are intrinsically mass flow meters.

In respiratory applications volumetric flow is typically of interest instead of the mass flow. The reason is that human lungs have a fixed volume and will contain a varying mass flow volume (a different number of molecules) depending on the ambient conditions such as pressure/altitude, temperature, and relative humidity. Chapter 3 explains the conversion from mass flow to volumetric flow for the SFMxxx series.

2 Conversions between Different Reference Conditions

Standard flow rate (e.g. slm) is the equivalent volumetric flow rate of the gas at the reference conditions (temperature and pressure). Although units such as slm or sccm look like a volumetric measurement they are a mass flow unit and for a given medium this corresponds to the number of molecules per unit of time.

All Sensirion flow meters with a flow output in slm or sccm are defined at the reference conditions of 20°C and 1013 mbar, for flow meters with outputs in norm liters per minute (typically SFM54xx) the reference condition is 0°C and 1013 mbar.

Mass flow rates at different reference conditions can easily be converted into each other with the following equation:

$$Q_{RC1} = Q_{RC2} * \left(\frac{T_{RC1}}{T_{RC2}}\right) * \left(\frac{P_{RC2}}{P_{RC1}}\right)$$

Q_{RC1} standard flow rate with reference conditions 1
Q_{RC2} standard flow rate with reference conditions 2
T_{RC1} reference temperature 1
T_{RC2} reference temperature 2
P_{RC1} reference pressure 1
P_{RC2} reference pressure 2

Introduction video: SFC5500 Mass Flow Controllers

Table 3 Datasheets, CAD models, and O-ring recommendations

Product reference	Datasheet	CAD model	Downmount manifold CAD model	Downmount recommended O-ring
SFC5500/ SFM5500-200slm	sensirion.com/resource /datasheet/sfc5500	sensirion.com/resource /cad/sfc5500-200		
SFC5500/ SFM5500- 50sccm 0.5slm 2slm 10slm		sensirion.com/resource /cad/sfc5500		
SFC5400/ SFM5400	sensirion.com/resource /datasheet/sfc5400	sensirion.com/resource /cad/sfc5400	sensirion.com/media/documents/Mounting_plate_SFX54xx.step	NORMATEC O-ring FKM NT 80.7/75 OR 2019 inner Ø 4,76 x 1,78 mm
SFC5460/ SFM5460	https://sensirion.com/resource/datasheet/sfc5460_sfm5460	https://sensirion.com/resource/cad/downmount_SFC5460_SFM5460		
SFC5300/ SFM5300	sensirion.com/resource /datasheet/sfc53x0_sf m53x0	sensirion.com/resource /cad/sfc5300	sensirion.com/media/document/Mounting_plate_SFX53xx	Defined by the design of the manifold (customer)
SFC5330/ SFM5330				

8.2. Software tools

8.2.1. Viewer and Recalibration software

SFC5xxx/SFM5xxx Viewer software
sensirion.com/media/documents/Sensirion_Mass_Flow_Controllers_SFC5xxx_Viewe.zip

SFC5xxx/SFM5xxx Viewer Software manual
sensirion.com/media/documents/GF_AN_SFC5xxx_Viewer_D1.pdf

SFC5xxx/SFM5xxx Recalibration software
sensirion.com/media/documents/SFC5xxx_SFM5xxx_RecalibrationTool_V1_72.msi

SFC5xxx/SFM5xxx Recalibration software manual
sensirion.com/resource/user_guide/recalibrationtool/sfc5xxx/sfm5xxx

8.2.2. Software drivers

Python driver
github.com/Sensirion/python-shdlc-sfc5xxx

LabVIEW, C and C# drivers
sensirion.com/media/documents/SFC5XXX_Sample_Code.zip

8.3. Calibration, lifetime, and FAQ

Thanks to the stability of the MEMS-based sensor element and the robust mechanical design, Sensirion Mass Flow Controllers do not drift and do not require recalibration in the field.
High manufacturing standards used during production ensure that our Mass Flow Controllers are extremely reliable and have a very low failure rate. This is supported by field surveys and measurements.

The mean time between failures of Sensirion devices has been found to be 169 years. The detailed analysis based on several a thousand parts in the field can be found in a dedicated application note:
sensirion.com/resource/application_note/mean_time_between_falilure_analysis

The high-quality valves used are rated for 100 million cycles. The EEPROM memory of the MFC is rated for 50 000 write cycles. This de-facto limits the number of times a calibration, user gain, etc can be changed. Please take this into consideration, when implementing the Mass Flow Controller.

FAQ:
sensirion.com/products/support/faq/

Important Notices

Warning, Personal Injury
Do not use this product as a safety or emergency stop device or in any other application where the failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using, or servicing this product, please consult the datasheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, the Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates, and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product.

See application note “ESD, Latch-up and EMC” for more information.

Warranty

SENSATION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material, and workmanship defined in SENSIRION’s published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION’s discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION’s reasonable satisfaction, to have arisen from SENSIRION’s faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION’s factory at the Buyer’s expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSATION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSATION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.

SENSATION is only liable for defects of this product arising under the conditions of operation provided for in the data sheet and proper use of the goods. SENSATION explicitly disclaims all warranties, express or implied, for any period during which the goods are operated or stored not in accordance with the technical specifications.
SENSATION does not assume any liability arising out of any application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. All operating parameters, including without limitation recommended parameters, must be validated for each customer’s applications by the customer’s technical experts. Recommended parameters can and do vary in different applications.
SENSATION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve the reliability, functions, and design of this product.

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Version 1.0 – Aug 2022

Documents / Resources

	SENSIRION SFC5xxx High-precision, configurable, fast, multi-gas flow sensor [pdf] User Guide SFC5xxx High-precision configurable fast multi-gas flow sensor, SFC5xxx, High-precision configurable fast multi-gas flow sensor, precision configurable fast multi-gas flow sensor, configurable fast multi-gas flow sensor, multi-gas flow sensor, flow sensor

References

- GitHub - Sensirion/python-shdlc-sfc5xxx: Driver for the SFC5xxx flow sensors / SFM5xxx flow meters which have an UART interface using the SHDLC protocol.
- Technical download
- Gas flow sensors
- Mass flow controllers
- FAQ
- sensirion.com/resource/application_note/mean_time_between_falilure_analysis
- sensirion.com/resource/user_guide/recalibrationtool/sfc5xxx/sfm5xxx
- Smart sensor solutions
- Smart sensor solutions
- Smart sensor solutions
- Smart sensor solutions
- Smart sensor solutions
- GitHub - Sensirion/python-shdlc-sfc5xxx: Driver for the SFC5xxx flow sensors / SFM5xxx flow meters which have an UART interface using the SHDLC protocol.
- sensirion.com/media/documents/3271586C/62CFDBE5/Mounting_plate_SFX54xx.step
- sensirion.com/media/documents/C4701AE5/62B3FFEE/SFC5xxx_SFM5xxx_RecalibrationTool_V1_72.msi
- sensirion.com/media/documents/C53F1183/62D00120/Mounting_plate_SFX53xx.step
- Technical download
- Gas flow sensors
- Mass flow controllers

- FAQ
- sensirion.com/resource/application_note/mean_time_between_falilure_analysis
- sensirion.com/resource/cad/downmount_SFC5460_SFM5460
- sensirion.com/resource/cad/sfc5300
- sensirion.com/resource/cad/sfc5400
- sensirion.com/resource/cad/sfc5500
- sensirion.com/resource/cad/sfc5500-200
- sensirion.com/resource/datasheet/sfc53x0_sfm53x0
- sensirion.com/resource/datasheet/sfc5400
- sensirion.com/resource/datasheet/sfc5460_sfm5460
- sensirion.com/resource/datasheet/sfc5500_sfm5500
- sensirion.com/resource/user_guide/recalibrationtool/sfc5xxx/sfm5xxx