Engineering guidelines for Mass Flow Controllers (SFC6xxx) and Mass Flow Meters (SFM6xxx)

Summary

This guide provides recommendations for evaluation, testing and integration of Sensirion Mass Flow Controllers and Meters. It is applicable to SFC6xxx as well as SFM6xxx products.

For clarity, the document was written for Mass Flow Controllers, yet most guidelines are also valid for Mass Flow Meters.

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

Sensirion offers several families of Mass Flow Controllers and Meters. The following covers the 6000 series family.

- SFC6000 (SFM6000) family offers the best price to performance ratio for a mass flow controller in a compact and lightweight package and is fully customisable to your needs. Minimum order quantities apply when purchasing from Sensirion.
- SFC6000D (SFM6000D) are SFC6000 mass flow controllers and SFM6000 mass flow meters available in fixed configurations with pre-configured multiple gas calibrations, different flow ranges and exchangeable fittings available via distribution.

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.

1.1. Flow Selection for SFC6000(D)/SFM6000(D)

The Sensirion SFC6000 flow controllers and SFM6000 flow meteres are available for full flow rates from 0.5 slm to 50 slm. SFC6000D and SFM6000D are available at different flow ranges, shown in **Table *1***, to suit your application best.

Product	Variant	Flow Range
SFC6000D-/SFM6000D-	5 slm	5 slm – 0 slm
	20 slm	20 slm – 0 slm
	50 slm	50 slm – 0 slm

Table 1. Flow ranges of the respective product variants of SFC6000D and SFM6000D

2. 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

There are several ways to operate Sensirion digital Mass Flow Controllers exist. They vary in complexity and implementation flexibilities.

- The EK-F5x evaluation kit together with Sensirion Control Center is the fastest way to start working with your device. It is a plug-and-play solution, which will enable you to control and configure your device (e.g. choose the gas calibration). The EK-F5x evaluation kit combines a power supply (adapters for most sockets worldwide are included) and a USB-A plug for your PC. It connects to your device with a M8 or DB9 plug (an adapter is available for other plugs – please contact Sensirion). EK-F5x is available from distribution. Please note, Mass Flow Controller or Flow Meter are not included and must be purchased separately.
- Most OEM projects will require designing custom cabling (including a power supply) together with an implementation in the desired programming language. The SFC6000 provides an I^2C and a RS-485 interface (the respective guides are found in Section 7.1 in Useful Resources). Sensirion provides ready-to-use libraries in C and Python, as illustrated in **Table *2***. These libraries can be used to control multiple devices at the same time (please make sure the devices have unique SHDLC and I^2C addresses for RS-485 and I^2C interfaces, respectively). However, this also involves the highest implementation effort out of the options mentioned here.

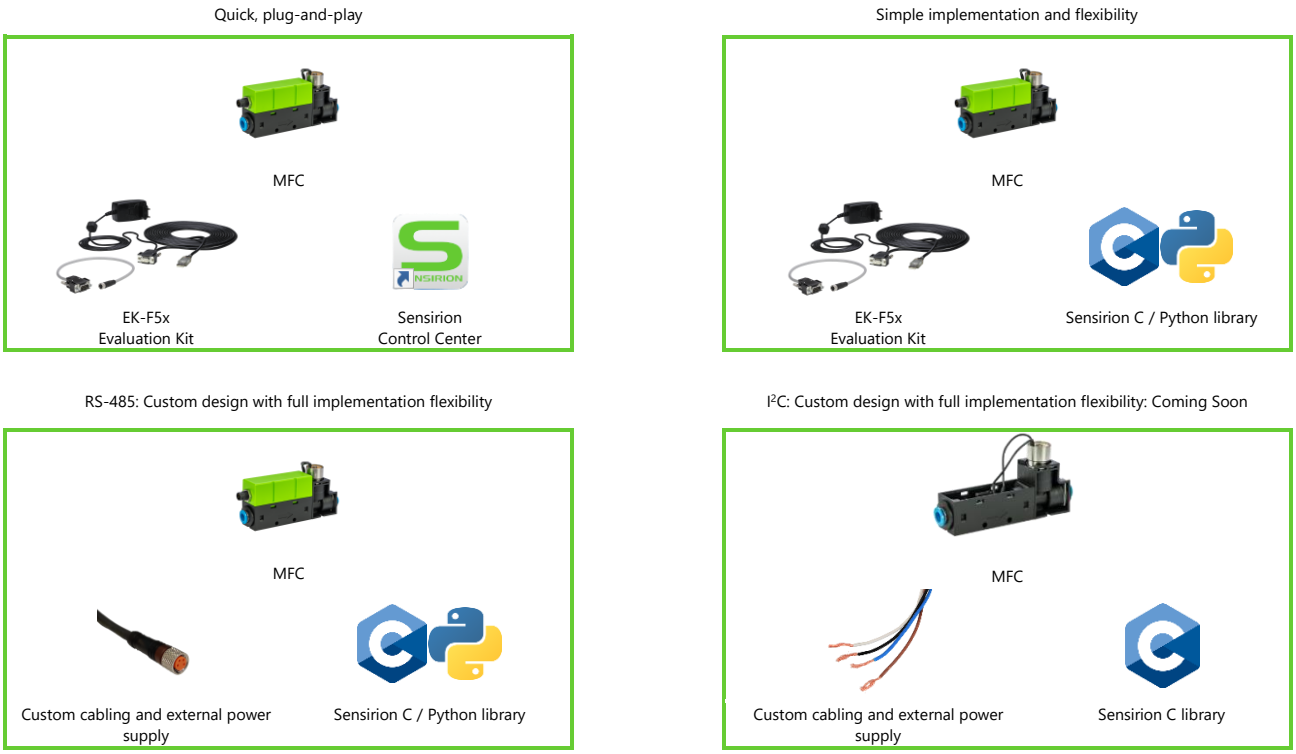


Figure 1. Overview of different options for evaluating digital Mass Flow Controllers and Mass Flow Meters

The following illustrates the available software drivers for respective PC interfaces for the SFC6000 and SFM6000 variants.

PC interface	Python driver	C driver	Sensirion Control Center
USB (EK-F5x Evaluation kit)	Available	Available (For Raspberry pi)	Available
RS-485	Under Development	Available (Arduino shield)	-
I2C	-	Under Development (For Arduino)	-

Table 2. The available drivers for different modes of communication for the SFC6000 and SFM6000. Links to the software can be found in the software tools section below.

2.2. Analog interface

The analog output pin gives out an analog linear voltage representing the flow value in standard liter per minute (slm). The formula for converting the voltage value to slm is given by:

$$Flow = \left(\frac{V_{out}}{4} - \frac{1}{8}\right) * \text{"}Full\ scale\ Flow\text{"}\ slm$$

i.e. the analog voltage range from 0.5 V to 4.5 V is linearly mapped to the flow range of 0 slm to full scale flow slm. The identical conversion formula applies for the analog input voltage.

3. Testing recommendations

It is recommended to start by testing the communication with the device, using the EK-F5x Evaluation Kit and Control Center.

As a second step, connect the device to a gas supply (or a source of vacuum). For better 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).

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 controller gain to adapt the controller accordingly. This can be done conveniently with Sensirion Control Center. For detailed instructions, see the "Control Center manual", linked in "Useful resources" Section 7.3.1.

4. 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. The conversion difference between standard litres and norm litres is around 7%, due to the different reference temperatures used for standard and norm litres. 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 7.1.

4.2. Settling time is longer than specified

The most common cause for observing longer than expected settling time is trying to verify it from a position of fully closed valve. Solenoid valves are commonly affected by so-called "sticking effect". To open the valve from 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 "Initstep" or "Controller gain" of the Mass Flow Controller, the behaviour 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 starting from zero flow the settling time may be longer than specification.

5. Design recommendations

5.1. The effect of orientation and temperature on accuracy

To achieve best accuracy, it is recommended to use a design where the Mass Flow Controller is mounted horizontally.

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. Large temperature gradient between the Mass Flow Controller and the gas it is used to control, may adversely influence the accuracy of the device.

5.2. The effect of vibrations on valve function

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.

5.3. Pressure drop, temperature 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. Additionally, the maximum flow rate can be affected by temperature. The magnetization of the valve decreases with a higher valve temperature caused by continuous operation or high ambient temperature. The maximum flow decreases, as the valve is less open.

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 Sensirion – it might be possible to order a similar mass flow controller with larger-sized valve. Larger valves offer a lower pressure drop at the cost of a decreased accuracy/resolution at low flows.

6. Fluidic and electrical connectors

Product reference	Fluidic connector	Electrical connector
SFC6000D/ SFM6000D	Push-in: tube outer diameter 6 mm, Downmount (exchangeable with Festo QSP 18 mm interface)	M8 (4 pin)

Table 3. Fluidic and electrical connectors

6.1. Mounting guide

The SFC6000 can be mounted from the bottom, the top or on a downmount manifold depending on application requirements. A more comprehensive description of the mounting options is coming soon.

6.1.1. Mounting from the bottom of device

With the help of tapping screws (PT-screw K30, diameter = 3mm) the devices can be secured on the plate from the bottom. One should not screw the tapping screws more than 8 mm into the body of the device. Do not use larger screws, as this introduces stress to the device, influencing performance.

6.1.2. Mounting from the top of device

The SFC6000 and SFM6000 can also be mounted from the top when removing their cap. This is done with M2.5 X 20 screws.

6.1.3. Downmount manifold

Downmount connectors are included with each distribution SFC6000D and SFM6000D.

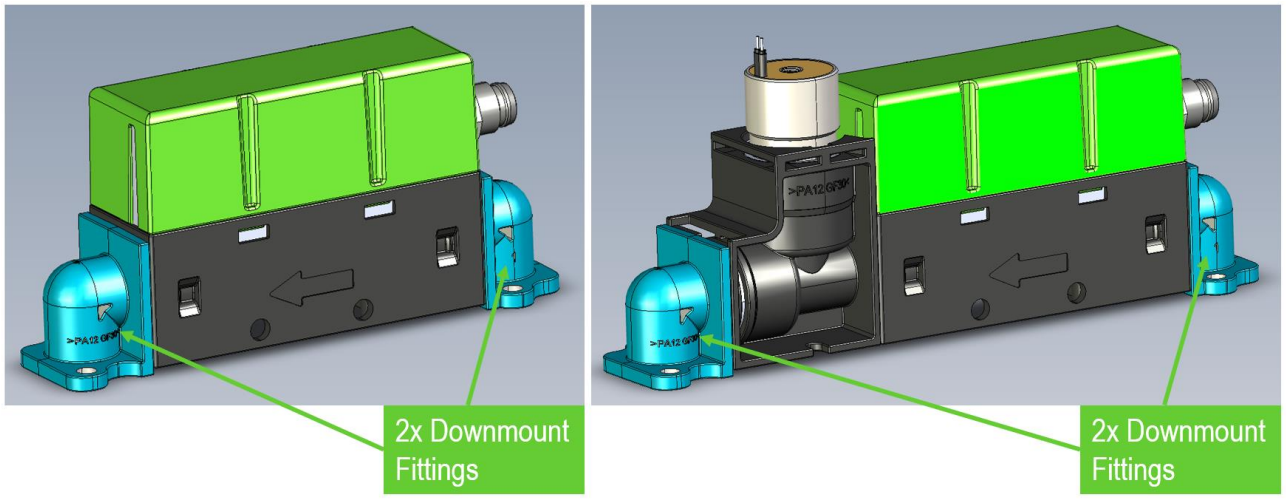


Figure 2. Dowmount fittings on SFM6000(D) (left) and SFC6000(D) (right).

When using products with downmount connectors, a specific manifold must be designed and manufactured by the user. In **Table *4*** in the useful resources section, CAD models for a suggested manifold designs for SFC6000(D) / SFM6000(D) can be found. They can be used as a starting point for a custom design.

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.

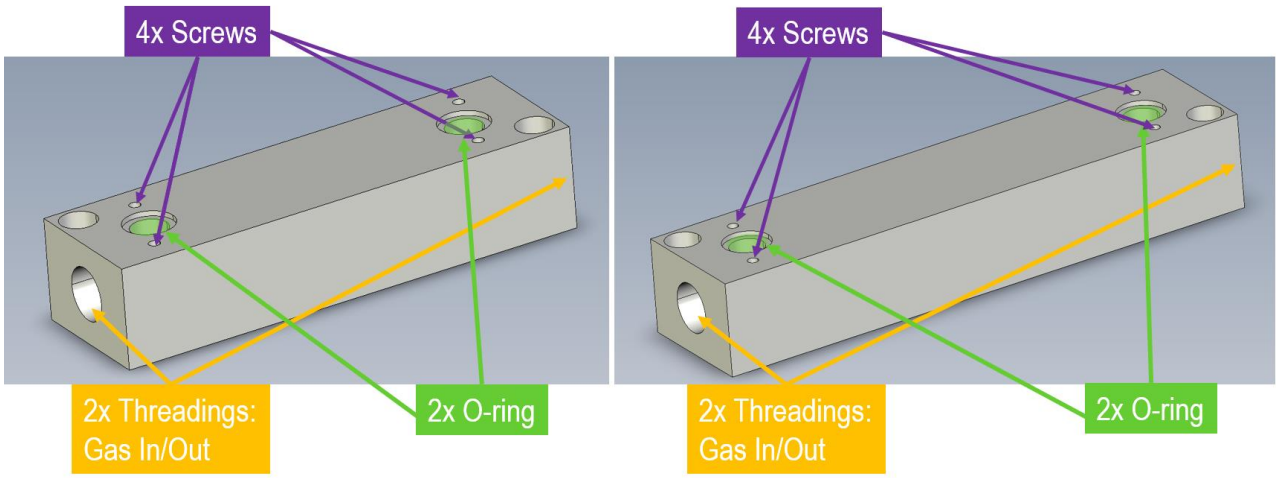


Figure 3. Downmount manifold design for SFM6000(D) (left) and SFC6000(D) (right).

7. Useful resources

7.1. Documentation

Various guides and application notes are available on Sensirion website.
Mass Flow Controllers (SFC): Product catalog (sensirion.com)
Mass Flow Meters (SFM): Product catalog (sensirion.com)
General technical download section: sensirion.com/products/downloads/

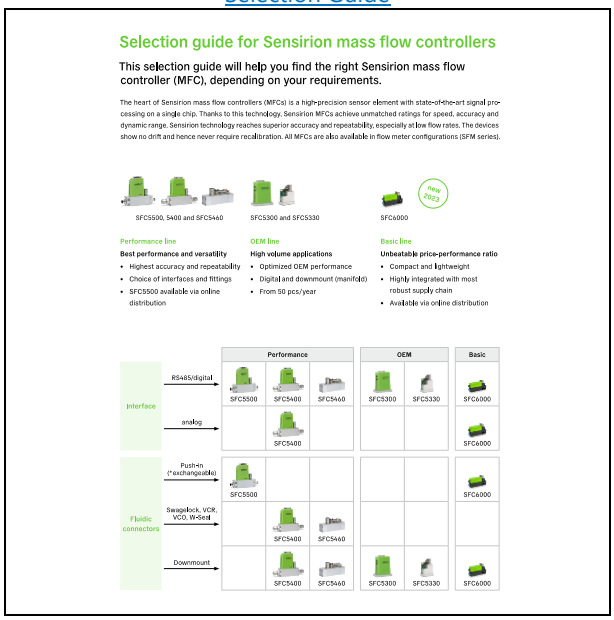
The most relevant resources are linked below.

Datasheet

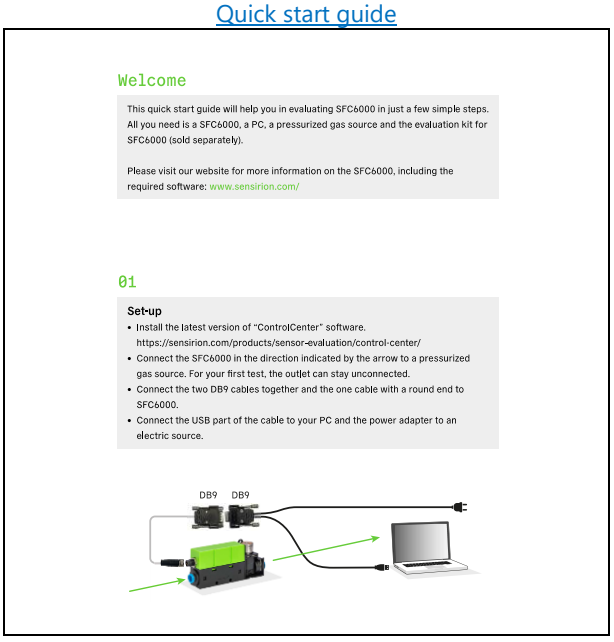

Datasheet – SFC6000D, SFM6000D
Best pirce-performance ratio Mass Flow Controller, Flow Meter
SFC6000D
SFM6000D
Highlights
Disruptive design with integrated electronics
High accuracy/repeatability (2% / 0.2% set point)
Wide control range (500:1)
RS485 and I²C digital interface
No drift and no re-calibration required
Ultra-fast settling time (100 ms)
The heart of SFC6000D and SFM6000D is the unsurpassed Sensirion CMOSens® technology. It combines a high precision sensor element with state-of-the-art signal processing on a single chip and thereby providing an accurately calibrated and temperature compensated signal. In fact, the full functionality of the device is integrated directly on the dedicated ASIC chip, which drastically limits the number of electrical components used. Thanks CMOSens® sensor technology, Sensirion's flow meters and controllers achieve unmatched ratings for speed, accuracy and repeatability at very attractive system cost. Due to the excellent long-term stability of CMOSens® chips, no recalibration is required.
Device Overview (Page 14: Full product list)

Product	Variant	Description
SFC6000D-	5 slm	High performance, low cost mass flow controller with multi-gas calibration.
	20 slm	
	50 slm	
SFM6000D-	5 slm	High performance, low cost mass flow meter with multi-gas calibration.
	20 slm	
	50 slm	

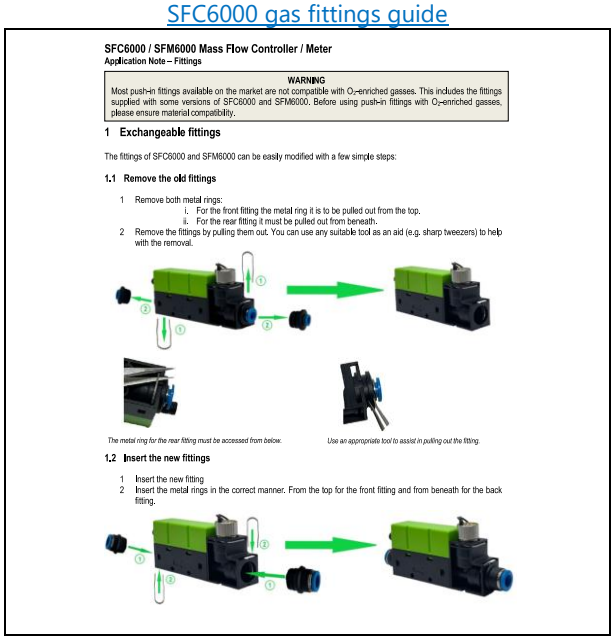
Selection Guide


Selection guide for Sensirion mass flow controllers
This selection guide will help you find the right Sensirion mass flow controller (MFC), depending on your requirements.
The heart of Sensirion mass flow controllers (MFCs) is a high-precision sensor element with state-of-the-art signal processing on a single chip. Thanks to this technology, Sensirion MFCs achieve unmatched ratings for speed, accuracy and dynamic range. Sensirion technology reaches superior accuracy and repeatability, especially at low flow rates. The devices show no drift and hence never require recalibration. All MFCs are also available in flow meter configurations (SFM series).
SFC5500, 5400 and SFC5440
SFC5300 and SFC5330
SFC6000
New 2023
Performance line
Best performance and versatility
Highest accuracy and repeatability
Choice of interfaces and fittings
SFC5500 available via online distribution
OEM line
High volume applications
Optimized OEM performance
Digital and downmount (manifold)
From 50 pcs/year
Basic line
Unbeatable price-performance ratio
Compact and lightweight
Highly integrated with most robust supply chain
Available via online distribution
Performance
OEM
Basic
Interface
RS485/digital
analog
Fluidic connectors
Push-in (*exchangeable)
Swagelock, VCR, VCO, W-Seal
Downmount

Quick start guide


Welcome
This quick start guide will help you in evaluating SFC6000 in just a few simple steps. All you need is a SFC6000, a PC, a pressurized gas source and the evaluation kit for SFC6000 (sold separately).
Please visit our website for more information on the SFC6000, including the required software: www.sensirion.com/
01
Set-up
Install the latest version of "ControlCenter" software. https://sensirion.com/products/sensor-evaluation/control-center/
Connect the SFC6000 in the direction indicated by the arrow to a pressurized gas source. For your first test, the outlet can stay unconnected.
Connect the two DB9 cables together and the one cable with a round end to SFC6000.
Connect the USB part of the cable to your PC and the power adapter to an electric source.
DB9
DB9

SFC6000 gas fittings guide


SFC6000 / SFM6000 Mass Flow Controller / Meter
Application Note – Fittings
WARNING
Most push-in fittings available on the market are not compatible with O_2-enriched gasses. This includes the fittings supplied with some versions of SFC6000 and SFM6000. Before using push-in fittings with O_2-enriched gasses, please ensure material compatibility.
1 Exchangeable fittings
The fittings of SFC6000 and SFM6000 can be easily modified with a few simple steps:
1.1 Remove the old fittings
1 Remove both metal rings:
i. For the front fitting the metal ring it is to be pulled out from the top.
ii. For the rear fitting it must be pulled out from beneath.
2 Remove the fittings by pulling them out. You can use any suitable tool as an aid (e.g. sharp tweezers) to help with the removal.
The metal ring for the rear fitting must be accessed from below.
Use an appropriate tool to assist in pulling out the fitting.
1.2 Insert the new fittings
1 Insert the new fitting
2 Insert the metal rings in the correct manner. From the top for the front fitting and from beneath for the back fitting.

SHDLC Communication Interface Reference

SENSIRION
THE SENSOR COMPANY

SFC6xxx and SFM6xxx RS485 SHDLC Interface

Document Summary

This document describes the SHDLC RS485 communication interface of the Sensirion SFC6xxx mass flow controller and SFM6xxx mass flow meter.
The intention of defining the SHDLC protocol was to have a single protocol for different Sensirion devices as massflow controllers, meters, and other microcontroller devices. The protocol is based on serial communication and is easy to implement. It allows communication between a single master and several connected slave devices.

In the following, there are some of the SHDLC protocol key features:

- Based on an **byte orientated** hardware (like UART, . . .)
- **Half-duplex** system, which allows to use half-duplex hardware
- **Single Master/Multiple Slaves** protocol without the need for bus arbitration
- Allows up to **255 bytes payload data** for read or write transfers
- **Broadcasting** allows to safe bus load and synchronize devices

I2C Communication Interface Reference

SENSIRION
THE SENSOR COMPANY

SFC6xxx and SFM6xxx I²C Interface

Document Summary

The SFC6xxx series is the latest version of Sensirion Mass Flow Controllers. Thanks to the additional on-chip possibilities of the latest Sensirion flow sensor generation, the controller runs on the flow chip and no additional micro-controller is needed.

The current samples provide either an I²C interface, a RS-485 interface, or an analog version (will be available in the near future). In this document the I²C interface is described.

When starting from set point 0 the known sticking effect is caused by the valve. In order to prevent an overshoot after set point 0 we recommend to use a set point slightly above 0. This will keep the valve slightly open and allow a much faster and smoother controller performance. When using the I²C interface, the user can tune the initialization step and the overall controller gain in case the performance is not sufficient.

Different controller tests were done with different waveforms: step answers, ramps, sinusoidal, saw tooth, etc. The controller can follow the set point for all different waveforms.

All data below is preliminary and may be subject to change.

Reference and Flow Conversions between mass and volumetric flow

Reference and Flow Conversions

Applicable to following sensors
All SFMs

Key content
- Concept of mass flow vs. volumetric flow
- Conversion between different reference conditions
- Conversion from mass-flow to volumetric-flow

Summary
This application note explains the difference between mass flow and volumetric flow.
Depending on the industry and manufacturer of flow meters, the reference conditions are different and flow values cannot be compared without converting them to the same reference conditions. The conversion between different reference conditions and from mass flow to volumetric flow under consideration of the environmental conditions of temperature, humidity and pressure are outlined in this document.

1 Introduction

Gas is a well compressible media, and the gas density therefore depends on the pressure and temperature of the gas, As such, a fixed volume of gas contains a different number of gas molecules, varying with temperature and pressure. To uniquely define a specific gas flow, which is a measure of a volume of gas per unit of time, it is necessary to reference the conditions under which the measurement is performed. Depending on the industry and the manufacturer of flow meters, these reference conditions are different and flow values can often not directly be compared without converting them to identical reference conditions.

Gas flow can either be measured in units of volumetric flow or mass flow.

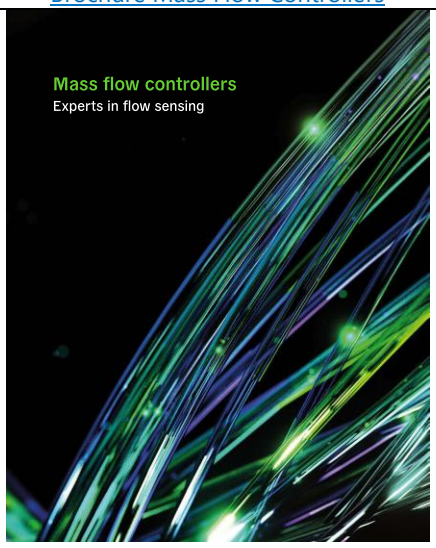
Volumetric flow
Volumetric flow refers to a measured gas volume per unit of time under the referenced pressure and temperature conditions. The most common units are "liters per minute [l/min]" or "actual cubic feet per minute [acfm]".

Mass flow or standard volumetric flow
Standard volumetric flow refers to the volumetric flow at standard conditions defined for temperature and pressure, Common units are "standard liters per minute [slm]", "standard cubic centimeters per minute [sccm]" or "normliters per minute [nlm/m]".

Because standard volumetric flow is referenced to a defined temperature T and pressure p, the number of molecules n in the volume V can be calculated using the ideal gas law ($p \cdot V = n \cdot k \cdot T$). In other words, standard volumetric flow refers to the number of molecules per unit of time and therefore to the mass per unit of time, For a given gas, a sensor measuring volumetric flow at standard conditions will deliver the same readings as a mass flow sensor.

SFMxxx mass flow meters
Mass flow meters of the SFMxxx series are based on the thermal flow measurement principle and provide a mass flow output in slm, which is a mass flow unit. For example, 1 standard litre per minute (slm) means that the measured mass flow corresponds to a volumetric flow of 1 litre per minute under standard conditions. Sensirion's flow meters with a flow value in units of slm or sccm are defined at standard conditions of 20°C and 1013mbar (please refer to the specific datasheets).

Brochure Mass Flow Controllers



SENSIRION

REACH and RoHS declaration SFC

REACH- and RoHS - Declaration

We declare that all these **Mass Flow Controllers for Gases** supplied by Sensirion AG comply with

Mass Flow Controllers for Gases	REACH	RoHS
SFC3xxx	yes	yes
SFC4xxx	yes	yes
SFC5xxx	yes	yes
SFC6xxx	yes	yes
Eval-Kit EK•F5x	yes	yes

- the EU regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals, **REACH** (Reg. 1907/2006 /EC),
  i.e. the following limit values are not exceeded
  - Substances of Very High Concerns (SVHC) 1000 ppm

  The information is based on data provided by our suppliers.
  No attempt has been made to verify this information by third party analysis.
- the EU regulation on the Restriction of Hazardous Substances in electrical and electronic equipment, **RoHS** (Reg. 2011/65/EU and the delegated directive 2015/863/EU)
  i.e. the following limit values are not exceeded
  - Lead (Pb), Mercury (Hg), Hexavalent Chromium (CrVI) 1000 ppm
  - Cadmium (Cd) 100 ppm
  - Polybrominated biphenyls (PBB) and Polybrominated diphenyl ethers (PBDE) 1000 ppm
  - Phthalates: DEHP, BBP, DBP and DIBP 1000 ppm
  - Copper alloy in the plugs of the eval-kits: Compliant with exception 6c of 2011/65/EU.

Disclaimer: All information in this declaration is given to the best of our present knowledge and belief. The information given doesn't imply giving a warranty within the meaning of the warranty law.

Signed for and on behalf of Sensirion AG

Staefa, 22 February 2023

Dr. Adrian Ruf
EHS Manager

Introduction video: SFC6000 Mass Flow Controllers

Introduction video

Informational video: 4 Questions at 4 PM

4 Questions at 4 PM

7.2. CAD models

Product	CAD model	Link
SFC6000D/ SFM6000D	Push in with green cap, Downmount with green cap, Downmount manifold	https://sensirion.com/resource/cad/sfc-sfm6000

Table 4. SFC6000D and SFM6000D and downmount manifold CAD models.

7.3. Software tools

7.3.1. Control Center software

Sensiron Control Center and manual
https://sensirion.com/products/sensor-evaluation/control-center/

7.3.2. Software drivers

Python driver (For use with EK-F5x evaluation kit or custom cabling)
https://github.com/Sensirion/python-uart-sfx6xxx

C driver (For use with Raspberry-Pi)
https://github.com/Sensirion/raspberry-pi-uart-sfx6xxx

Arduino Library
https://github.com/Sensirion/arduino-uart-sfx6xxx

7.4. Calibration 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.

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

Important Notices

Warning, Personal Injury
Do not use this product as safety or emergency stop devices or in any other application where 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 data sheet 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, 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
SENSIRION 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 SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION 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.
SENSIRION 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. SENSIRION 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.
SENSIRION 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 customer's technical experts. Recommended parameters can and do vary in different applications.
SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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