SLF3S-1300F Liquid Flow Sensor – PROTOTYPE

- Low flow sensing up to 40 ml/min
- Calibrated and temperature compensated
- Turn down ratio 200:1 or better
- Very compact and light-weight form factor
- Response time below 20 ms

Product Summary
The SLF3S-1300F is Sensirion's new compact liquid flow sensor designed for high-volume applications. It enables precise and reliable measurements of dynamic liquid flow rates up to 40 ml/min bi-directionally. The SLF3S-1300F sensor features a digital interface (I²C) via a 6-pin standard electrical connector.
The SLF3S-1300F builds on the latest generation CMOSens® sensor chip that is at the heart of Sensirion's flow sensing platform and allows achieving an outstanding performance. The patented CMOSens® technology combines the sensor element, signal processing and digital calibration on a small CMOS chip. The well-proven CMOS technology is perfectly suited for high-quality mass production and is the ideal choice for demanding and cost-sensitive OEM applications.

The SLF3S-1300F sensor is still under development. Thus any specification is subject to change without prior notice (performance, communication, etc.).

Benefits of Sensirion's CMOSens® Technology
- High reliability and long-term stability
- Best signal to noise ratio
- Industry-proven technology with a track record of more than 15 years
- Designed for mass production and high process capability

Contents

1 Sensor Performance (preliminary data, subject to change without prior notice)

The following Table 1 lists preliminary specifications of the current prototypes. Please contact Sensirion if different specifications are required.

Parameter	SLF3S-1300F	Unit
H_2O Full scale flow rate	40	ml/min
H_2O Sensor output limit[1]	65	ml/min
Accuracy[2] (whichever error is larger)	5 0.1	% of measured value ml/min
Repeatability[2] (whichever error is larger)	0.5 0.01	% of measured value ml/min
Temperature coefficient[3] (additional error / °C; whichever is larger)	tbd tbd	% measured value / °C % full scale / °C
Mounting orientation sensitivity[4]	tbd	% of full scale
Calibrated for	Water	-

Table 1: Preliminary specifications for liquid flow sensor SLF3S-1300F (all data for medium H_2O, at 23°C, and for VDD 3.5V)

[1] Flow rate at which the sensor output saturates. See section 1.1 for performance between full scale and saturation point.
[2] Accuracy respectively repeatability specifications valid for flow rates below ±20 ml/min. See the charts in section 2 for the accuracy and repeatability specifications, respectively, between ±20 ml/min and full scale.
[3] Additional accuracy error in case liquid and ambient temperatures are similar but both deviating from 23 °C.
[4] Maximum additional offset when flow channel is vertical.

1.1 Specification Charts

The SLF3S-1300F liquid flow sensor shows bi-directional, linear transfer characteristics. The product comes fully calibrated for water.

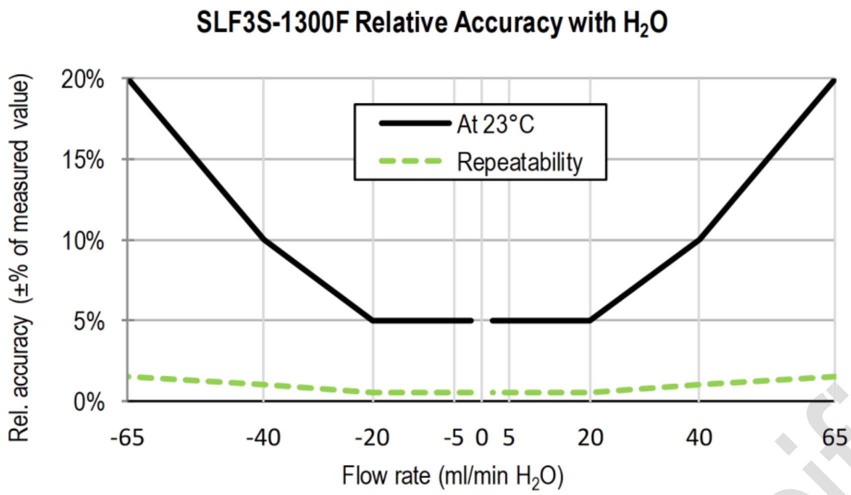


Figure 1: Liquid flow sensor accuracy and repeatability across the flow range of the SLF3S-1300F. Relative error in ±% of measured value for H_2O.

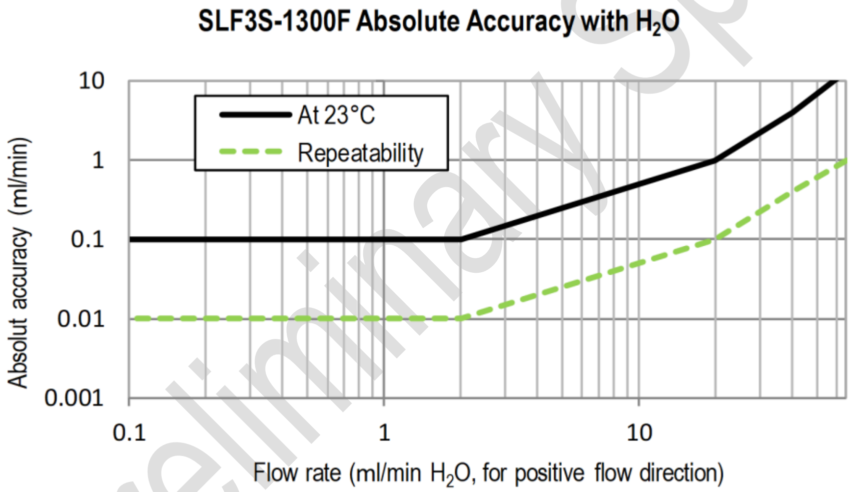


Figure 2: Liquid flow sensor accuracy and repeatability across the positive flow range of the SLF3S-1300F. Absolute error in ml/min for H_2O.

2 Specifications (preliminary data, subject to change without prior notice)

2.1 Electrical Specifications

Parameter	Symbol	Conditions	Min.	Typical	Max.	Units	Comments
Supply voltage DC	V_{DD}		3.2	3.5	3.8	V	
Power-up/down level	V_{POR}		2.3	2.5	2.7	V	
Supply current	I_{DD}	Measurement		4.5	6	mA	
		Idle mode		0.05	0.6	mA	
		Sleep mode			0.001	mA	

Table 2: DC characteristics

2.2 Timing Specifications

Parameter	Symbol	Min.	Typical	Max.	Units	Comments
Power-up time	t_{PU}			25	ms	Time to sensor ready
Soft reset time	t_{SR}			25	ms	Time between soft reset command or exit sleep mode and sensor ready
Warm-up time	t_w		tbd		ms	Time needed until sensor output is within specification according to section 1.1 at 50% full scale flow rate.
I²C SCL frequency	f_{I2C}		400	1000	kHz	
Update rate liquid flow value and High Flow flag	f_{flow}	1800	2000	2200	Hz	
Update rate temperature value and Air-in-Line flag	f_{temp}	73	83	111	Hz	
Recommended sensor read out frequency	f_{ro}	10	50-200	2000	Hz	Recommendations are based on explanations in section 3.1

Table 3: Timing specifications

2.3 Absolute Minimum and Maximum Ratings

Parameter	Rating	Unit
Operating temperature	+5 … +50	°C
Maximum relative humidity for long-term exposure	40°C dew point or 95 %RH, whichever is lower. non-condensing	
Short term storage temperature[5]	-40 … +60	°C
Short term storage humidity[5]	0…95 %RH, non-condensing	% RH
ESD HBM (human body model)[6]	tbd	kV
Maximum supply voltage	5.5	V

Table 4: Absolute minimum and maximum ratings

[5] Flow path empty. Short term storage refers to temporary conditions during e.g. transport.
[6] ESD level of sensor chip. ESD level of entire system or device to be determined by customer.

2.4 Pad Assignment

The liquid flow sensor is equipped with a 6-pin connector (Molex Part Number: 53261-0671; 1.25 mm pitch PicoBlade header, surface mount, right angle, 6 circuits) for electrical connection, see below Table 5.

Pad	Description	Comments
1	n.c.	Nonfunctional, connect to GND or leave floating
2	SDA (data)	Serial data, bidirectional
3	VDD	Supply voltage
4	GND	Ground
5	SCL (clock)	Serial clock, bidirectional
6	n.c.	Nonfunctional, connect to GND or leave floating

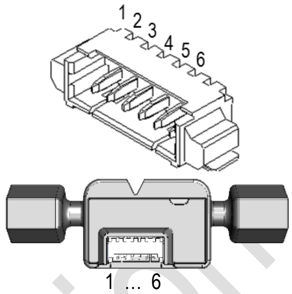


Table 5: Pin assignment

3 Sensor Output Signal Description

3.1 Flow Rate Measurement

After the sensor receives the “start continuous measurement” command it enters the continuous measurement mode and continuously performs measurements of ~0.5 ms length. Therefore, the flow rate value is updated every 0.5 ms (see Table 3).
The output flow rate value corresponds to the average $\bar{x}$ of all individual 0.5 ms measurements x_i since the last read out. This has the benefit that the user can read out the sensor at his own desired speed, without losing information and thus prevents aliasing. During the first 100 ms of averaging, the averaged value is obtained as the arithmetic mean.

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N} \qquad \text{for } t < 100 \text{ ms}$$

When the reading speed is slower than 100 ms, the sensor will continue to average, but with a different algorithm. In this algorithm exponential smoothing is used, with a smoothing factor α = 0.0125.

$$S_k = \alpha \cdot x_i + (1 - \alpha) \cdot S_{k-1}, \qquad S_0 = \bar{x}, \qquad \text{for } t > 100 \text{ ms}$$

Where S_0 is the arithmetic mean value after the first 100 ms and the output flow rate value corresponds to the last available S_k.

With an exponential smoothing factor of α = 0.0125 the user receives approximately an average value of the last 100 ms. In order not to lose information the sensor should be read out at least once every 100 ms.
Please refer to relevant literature for more information about exponential smoothing. When the sensor has entered exponential smoothing, this is indicated by bit 5 being set to high (=1) in the signaling flag output of the sensor (see section 3.3).

3.2 Temperature Measurement

The temperature is measured every ~12 ms (see Table 3) with the help of an additional onboard temperature sensor. It provides the chip’s temperature, which is influenced by the environmental, and the fluid’s temperature. The temperature values are not averaged as described above. The read out temperature value corresponds always to the latest temperature measurement available.

3.3 Extended Features for Failure Mode Detection

The SLF3S-1300F sensor uses Sensirion's latest flow chip generation. This enables detecting failures like air-in-line or flow rates exceeding the output limit of the sensor. Such conditions are indicated as signaling flags to the user.

In addition to the flow rate and temperature values, the user can therefore read out several signaling flags (see section 4.3.1), including two flags for failure mode detection as well as a flag indicating whether exponential smoothing is used as averaging algorithm of the flow rate data (see section 3.1).

The two signaling flags for failure mode detection, the *Air-in-Line* and the *High Flow flag*, report if an air-in-line or high flow event occurred at least once since the last readout took place. I.e. if the sensor is read out again after 50 ms have passed, the signaling flags will be output as "high", if an air-in-line or high flow condition was detected at least once at any time during the last 50 ms.

When using Sensirion's Viewer Software, the user has to select *Signaling Flags* under the *Type of Measurement* dropdown menu to display the signaling flags while taking measurements. An air-in-line condition is displayed as a "1" and a high flow condition is displayed as a "2". If both conditions occur simultaneously this is hence displayed as "3".

The following sections provide further details about the two available failure mode detection signaling flags.

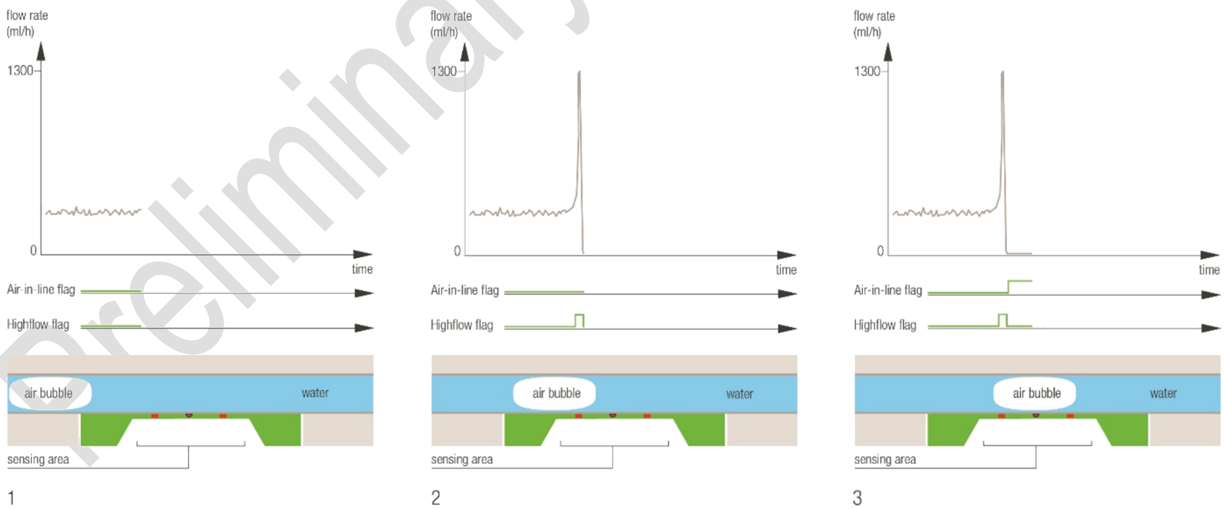
3.3.1 Detection of Air-in-Line

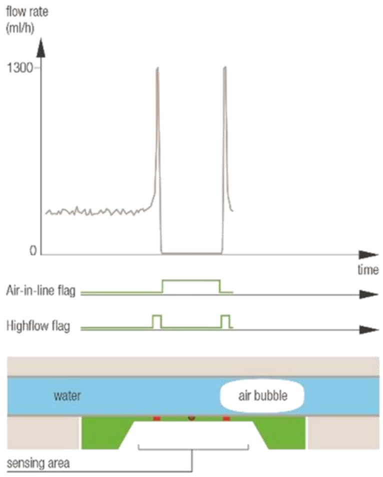
Owing to the thermal measurement principle of Sensirion's liquid flow sensors, the sensors can differentiate between air and liquid media filling the flow channel.

When air is passing through the sensor, bit 0 of the signaling flags is set to high (= 1). The bit 0 in the signaling flag output stays high until it is read out. See below.

Since the air bubble has an impact on the flow velocity profile inside the sensor's flow channel, the *High Flow flag* (see below) might also be set at the beginning and at the end of the air bubble.

The output of the signaling flags as well as the typically flow rate signal are visualized in the following graphs 1 to 5, while an air bubble travels through the sensor's flow channel from left to right.





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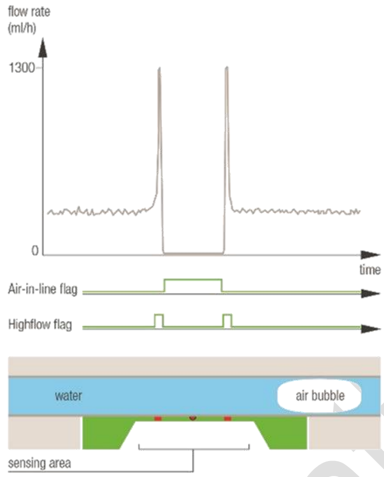

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3.3.2 Detection of High Flow Rates

During priming or flushing of fluidic systems, much higher flow rates than the sensor's output limit might be needed. The sensor is not damaged in these situations as long as the maximum recommended operating pressure is not exceeded. However, high flow rates (that exceed the output limit of the sensor) cause the sensor to saturate or output incorrect flow rate measurements. By checking the *High Flow* flag this potential error can be monitored and detected reliably.

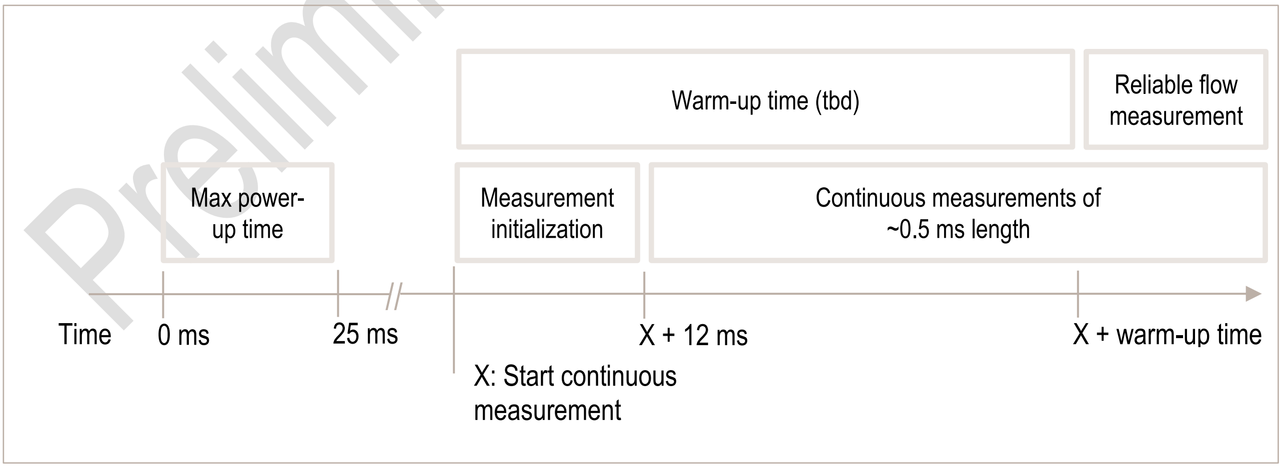
In cases, where the output limit is exceeded, bit 1 of the signaling flags is set to high (= 1). The bit 1 in the signaling flag output stays high until it is read out.

3.4 Sensor Start-Up and Warm-Up Behavior

The maximum time for system power-up is 25 ms until the sensor responds to communication requests.

After reset or start-up of the sensor, the sensor's internal heater is turned off and must be started by performing a *Start Continuous Measurement* command (see section 4.3.1). The very first measurement is delayed by approximately 12 ms for the SLF3S-1300F liquid flow sensor.

Due to the thermal measurement principle, a total warm-up time (to be determined for SLF3S-1300F) is necessary for a reliable measurement. This includes the 12 ms needed for measurement initialization.



4 Digital Interface Description

The sensor's digital interface is compatible with the I²C protocol. This chapter describes the available command set. For detailed information about the I²C protocol, please consult the document "NXP I²C-bus specification and user manual" (http://www.nxp.com/documents/user_manual/UM10204.pdf).
The physical interface consists of two bus lines, a data line (SDA) and a clock line (SCL) which need to be connected via pull-up resistors to the bus voltage of the system.

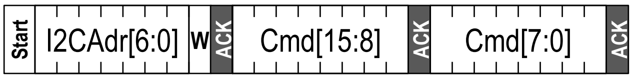
4.1 I²C Address

The sensor's I²C address is 8. The I²C header is formed by the I²C address followed by a read or write bit.

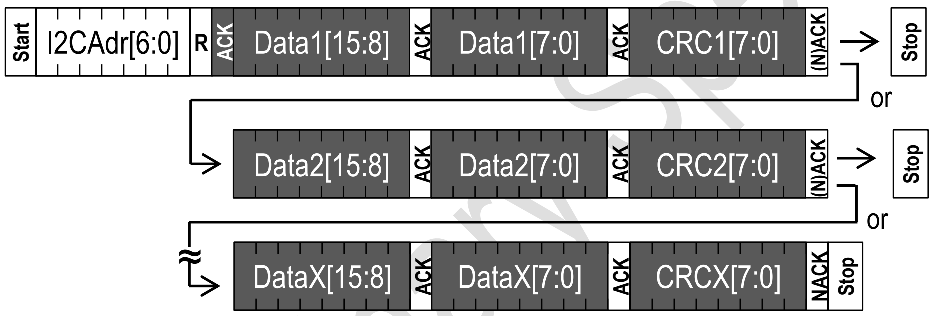
4.2 I²C Sequences

The commands are 16-bit. Data is read from the sensor in multiples of 16-bit words, each followed by an 8-bit checksum to ensure communication reliability.

I²C master sends the write header and writes a 16 bit command



I²C master sends the read header and receives multiple 16bit words with CRC byte.



Dark areas with white text indicate that the sensor controls the SDA (Data) line.

I²C sequences can be aborted with a NACK and STOP condition.

4.3 I²C Commands

The command set consists of a set of different commands:

- Start continuous measurement command
- Stop measurement command
- Soft reset
- Entering and exiting sleep mode
- Read product identifier and serial number

4.3.1 Start Continuous Measurement

The sensor measures both the flow rate and the temperature. Both measurement results can be read out through one single I²C read header while a continuous measurement is running.

Command	Command code (Hex)	Description
Start continuous measurement	0x3608	This command starts the continuous measurement mode. Outputs are the liquid flow rate, the chip's temperature and the signaling flags.

Table 6: I²C command to start continuous measurement

After the command has been sent, the chip continuously measures and updates the measurement results as described in section 3. New results (flow and temperature) can be read continuously with a single I²C read header for each pair of measurements.
After the start measurement command is sent:

- the first measurement result is available after 12 ms;
- small accuracy deviations (% m.v.) can occur while the sensor warms-up (see section 3.4).

While no measurement data is available yet the sensor will respond with a NACK to the I²C read header (I²C address + read bit).

Preceding command	Consecutive read	Description
Continuous measurement	Byte1: Flow 8msb Byte2: Flow 8lsb Byte3: CRC Byte4: Temp 8msb Byte5: Temp 8lsb Byte6: CRC Byte7: Signaling flags 8msb Byte8: Signaling flags 8lsb Byte9: CRC	After a start continuous measurement command, the measurement results can be read out. The temperature and the consecutive bytes don't need to be read out (every time). The read sequence can be aborted by a NACK and a STOP condition. Bit 0 and bit 1 of the signaling flags are used to detect air-in-line and high flow events. Bit 5 of the signaling flags indicates whether the sensor uses exponential smoothing for flow data averaging. Bit 2 … 4 and 6 … 15 are reserved for future use.

Table 7: Consecutive reads after I²C command to start continuous measurement

Bit	Signaling flag (set to high = 1, set to low = 0)
0	*Air-in-Line flag*
1	*High Flow flag*
2-4	*Unused, reserved for future use.*
5	*Exponential Smoothing active*
6-15	*Unused, reserved for future use.*

Table 8: Bit assignment of 16 bit signaling flags

4.3.2 Stop Continuous Measurement

Command	Command code (Hex)	Description
Stop continuous measurement	0x3FF9	This command stops the continuous measurement and puts the sensor in idle mode. After it receives the stop command, the sensor needs up to 0.5 ms to power down the heater, enter idle mode and be receptive for a new command.

Table 9: I²C command to stop continuous measurement

When the sensor is in continuous measurement mode, the sensor must be stopped before it can accept another command. The only exception is the soft reset command.
In idle mode the sensor will consume less power, but consider the sleep mode for most effective energy saving.

4.3.3 Soft Reset

Command	I²C address + W bit + command code (Hex)	Consecutive read	Description
General call reset	0x0006	NA	This sequence resets the sensor with a separate reset block, which is as much as possible detached from the rest of the system on chip. Note that the I²C address is 0x00, which is the general call address, and that the command is 8 bit. I.e., the soft reset command must not be preceded by an I²C write header. The reset is implemented according to the I²C specification.

Table 10: Reset command

After the reset command, the sensor will take maximum 25 ms to reset. During this time the sensor will not acknowledge its address nor accept commands.

4.3.4 Entering and Exiting Sleep Mode

In sleep mode, the sensor uses the minimum amount of current. The mode can only be entered from idle mode, i.e. when the sensor is not measuring.
This mode is particularly useful for battery operated devices. To minimize the current in this mode, the complexity of the sleep mode circuit has been reduced as much as possible, which is mainly reflected by the way the sensor exits the sleep mode.
In sleep mode the sensor cannot be soft reset.

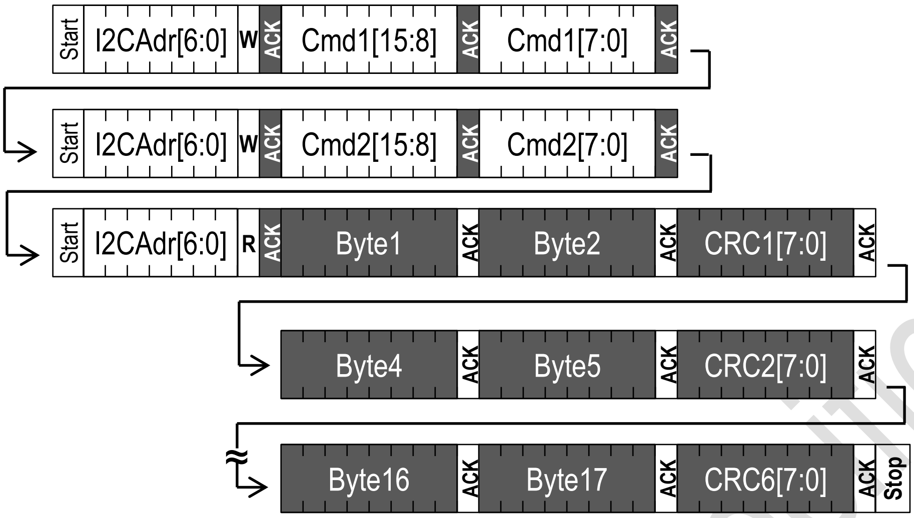
Command	Command code (Hex)	Consecutive read	Description
Enter Sleep mode	0x3677	NA	The sleep command can be sent after a stop continuous measurement command has been issued and the sensor is in idle mode.
Exit Sleep mode	NA	NA	The sensor exits the sleep mode and enters the idle mode when it receives the **valid I²C address and a write bit ('0')**. Note that the I²C address is **not** acknowledged. It is necessary to poll the sensor to see whether the sensor has received the address and has woken up. This should take maximum 25 ms.

Table 11: Sleep mode commands

4.3.5 Read Product Identifier and Serial Number

The product identifier and serial number can be read out after sending a sequence of two commands.

First the I²C master sends two consecutive write headers and writes 16 bits for each command. Then the I²C master sends the read header and receives 6 words of 16 bit with a CRC byte after each word.



Dark areas with white text indicate that the sensor controls the SDA (Data) line.

Command	Command code (Hex)	Consecutive read	Description
Read product identifier	0x367C 0xE102	Byte1: Product number [31:24] Byte2: Product number [23:16] Byte3: CRC Byte4: Product number [15:8] Byte5: Product number [7:0] Byte6: CRC Byte7: Serial number [63:56] Byte8: Serial number [55:48] Byte9: CRC Byte10: Serial number [47:40] Byte11: Serial number [39:32] Byte12: CRC Byte13: Serial number [31:24] Byte14: Serial number [23:16] Byte15: CRC Byte16: Serial number [15:8] Byte17: Serial number [7:0] Byte18: CRC	Note that both commands need to be preceded with an I²C write header (I²C address + W). The second command returns: - 32 bit product and revision number. The number is listed in the table below. *Note that the last 8 bits are the revision number and are subject to change as long as the datasheet is preliminary.* - 64 bit unique serial number

Table 12: Read product identifier

Product	Product number
SLF3S-1300F	0x07030201

Table 13: Product number for SLF3S-1300F

4.4 Checksum Calculation

The 8-bit CRC checksum transmitted after each data word is generated by a CRC algorithm. Its properties are displayed in Table 14. The CRC covers the contents of the two previously transmitted data bytes. To calculate the checksum only these two previously transmitted data bytes are used.

Property	Value
Name	CRC-8
Protected data	read data
Width	8 bit
Polynomial	0x31 (x8 + x5 + x4 +1)
Initialization	0xFF
Reflect input	False
Reflect output	False
Final XOR	0x00
Example	CRC (0xBEEF) = 0x92

Table 14: Checksum definition

4.5 Conversion to Physical Values

Conversion of the liquid flow and temperature sensor signals to a physical value is done with the scale factor.

4.5.1 Scale Factors

Parameter	SLF3S-1300F
Liquid Flow	500 $(ml/min)^{-1}$
Temperature	200 $°C^{-1}$

Table 15: Scale factors

4.5.2 Liquid Flow

The digital calibrated liquid flow signal read from the sensor is a 16 bit signed integer number (two's complement number ranging from -32768 … 32767. Note that with the sensor's output limit being ±65 ml/min, it will only output values in the range -32500 … 32500). The integer value can be converted to the physical value by dividing it by the scale factor (liquid flow in ml/min = sensor output ÷ scale factor).

4.5.3 Temperature

The digital calibrated temperature signal read from the sensor is a 16 bit signed integer number (two's complement number ranging from -32768 … 32767). The integer value can be converted to the physical value by dividing it by the scale factor (temperature in °C = sensor output ÷ scale factor).

5 Fluidic Specifications and Connections

Parameter	SLF3S-1300F
Wetted materials	PPS, stainless steel 316L, Epoxy-based adhesive
Fluidic connector ports (fittings)	¼-28 flat bottom
Recommended torque for fitting connection	0.5 Nm ± 10 %
Recommended tubing ID	2 mm
Pressure drop (at 40 ml/min, H_2O, 23 °C)	< 4 mbar

Table 16: Fluidic specifications and connections

6 Mechanical Specifications

Parameter	SLF3S-1300F
Largest dimensions	~ (48 x 15.5 x 8.9) mm^3
Weight	~ 3.0 g
Inner diameter	~ 1.4 mm
Inner volume	~ 58 µl
Maximum recommended operating pressure[7]	12 bar
Rated burst pressure	25 bar

Table 17: Mechanical specifications

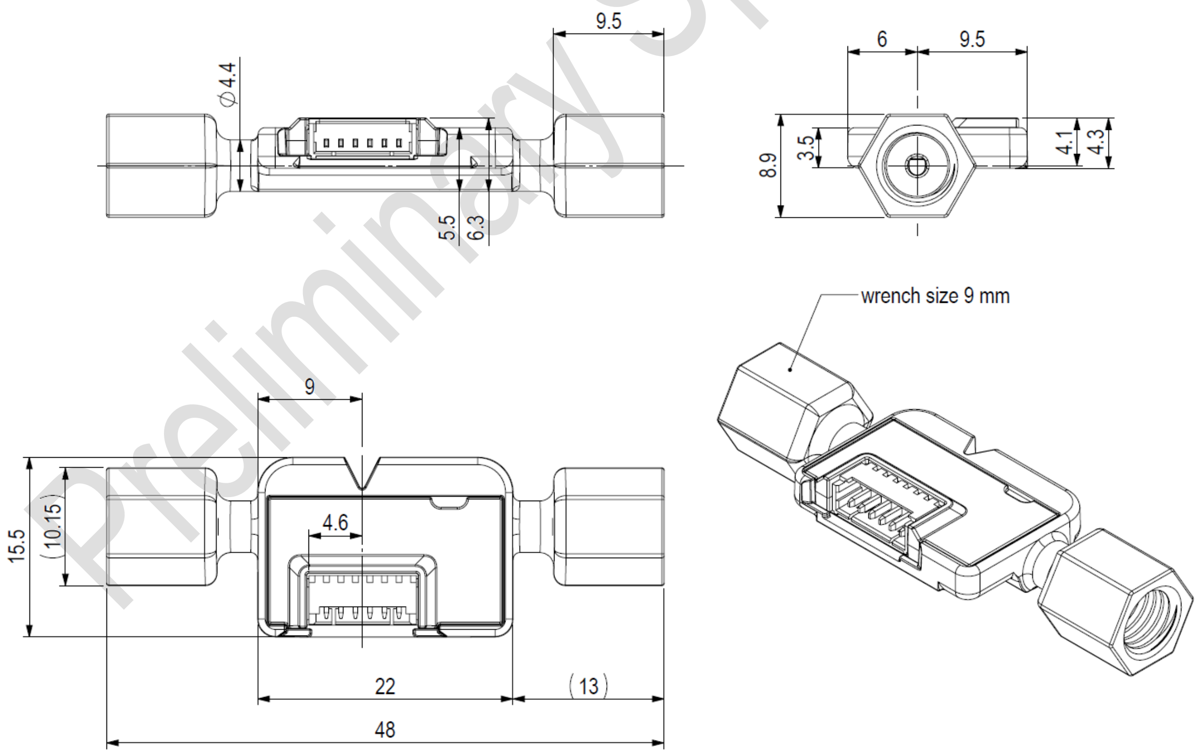


Figure 3: Dimensions of SLF3S-1300F (all dimensions in mm)

[7] Pressure ratings apply to sensor only; pressure rating of the fitting interface has to be assessed separately.

7 Mechanical Mounting of the SLF3S-1300F Sensor

For mechanical mounting of the SLF3S-1300F sensors, Sensirion provides a mounting clamp. The SLF3x mounting clamp is made from POM (Polyoxymethylene).
See Figure 4 below for the two possible mounting orientations of the clamp and how to correctly insert the SLF3S-1300F sensor into the clamp.

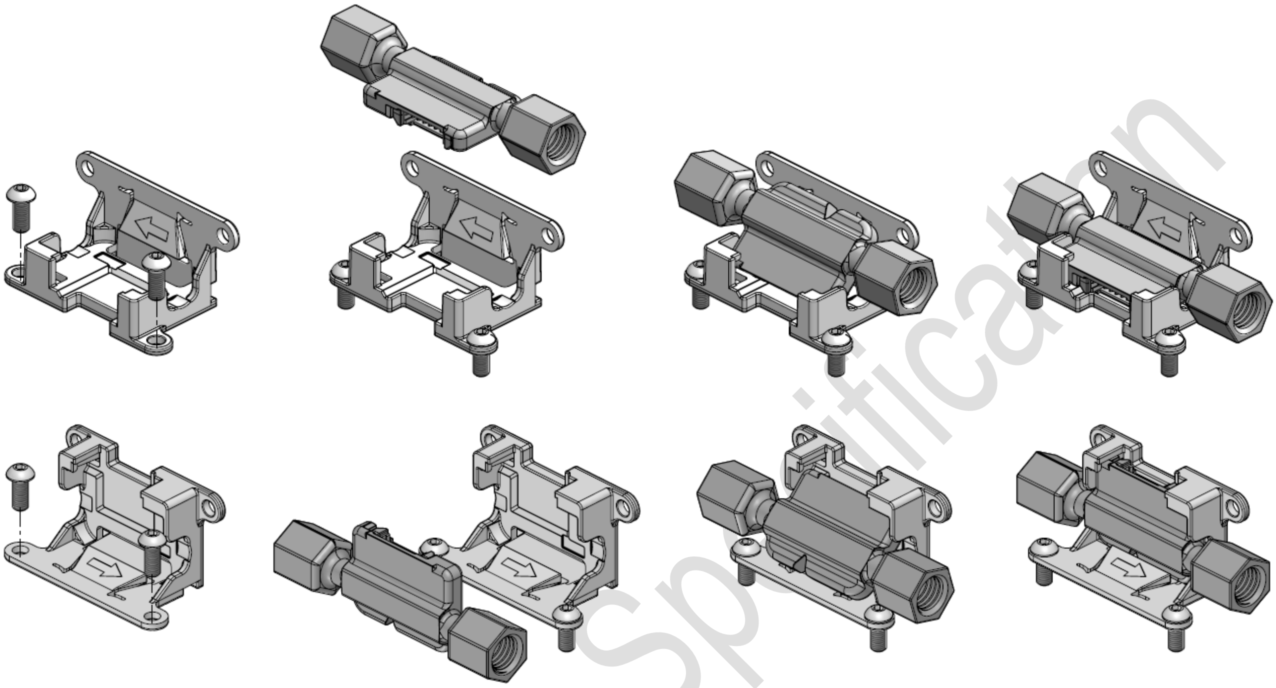
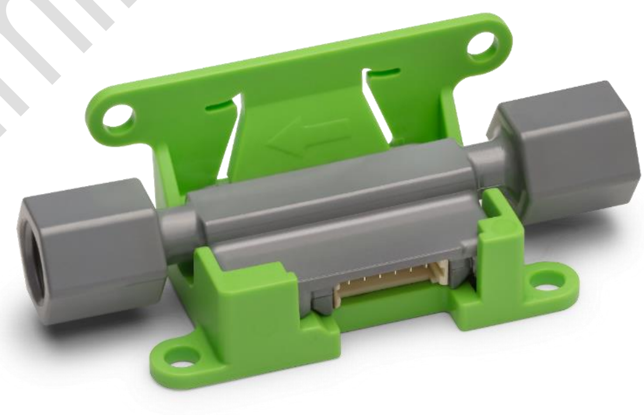


Figure 4: Guidelines for mounting of the SLF3S-1300F sensor inside the SLF3x mounting clamp

The arrow visible on the clamp's clip holding down the sensor indicates the positive flow direction of the SLF3S-1300F sensor. The 6-pin connector is facing the front of the clamp to allow for an easily accessible cable connection. Standard M2.5 sized screws can be used for the fixation of the clamp.



See Figure 5 for detailed dimensions of the SLF3x mounting clamp.

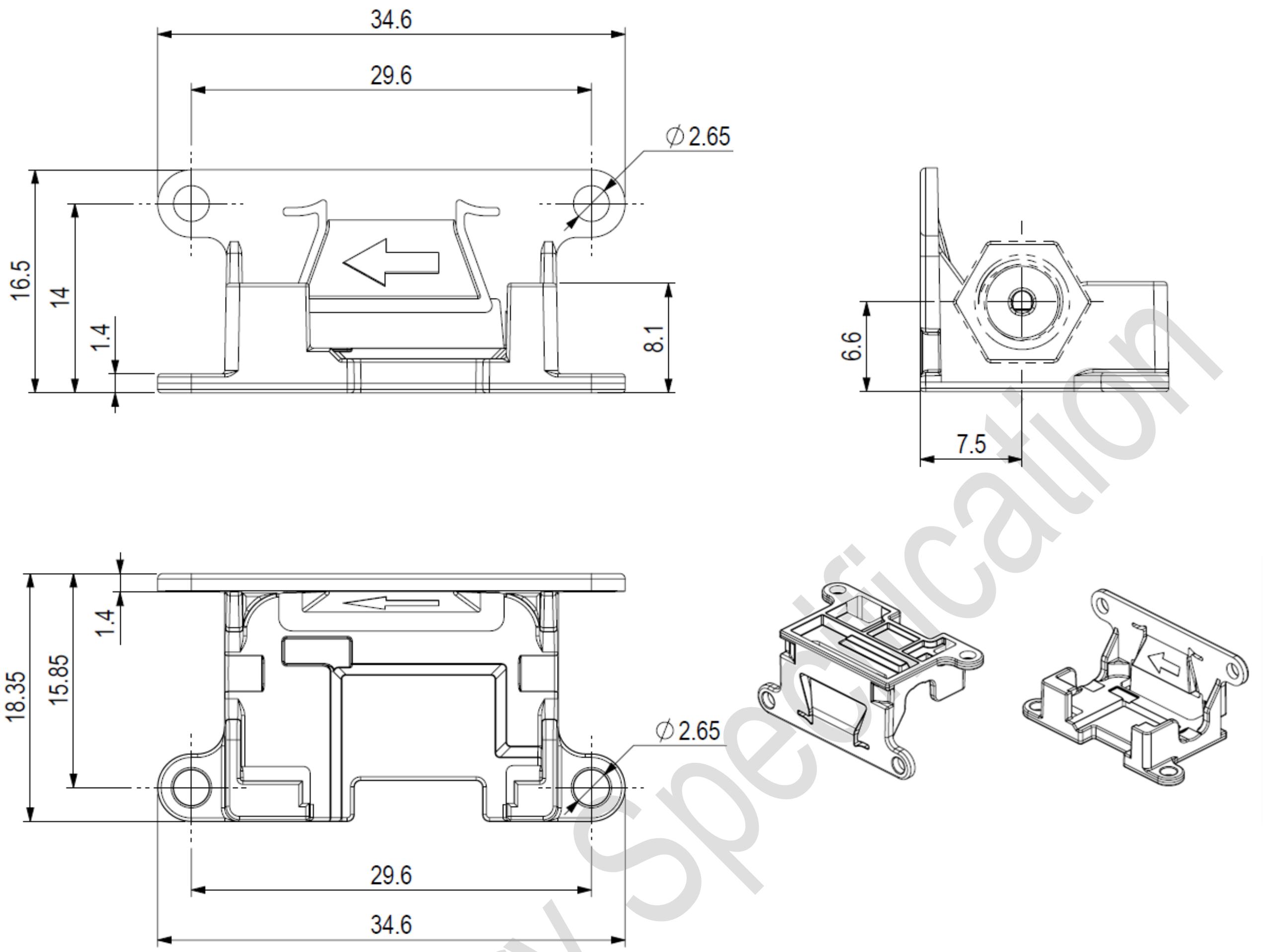


Figure 5: Dimensions of SLF3x mounting clamp (all dimensions in mm)

8 Ordering Information

Standard shipment includes only the sensor, neither cables nor fluidic connection material. In order to allow for fast and easy technology evaluation Sensirion offers a comprehensive SLF3S-1300F evaluation kit.

Each SLF3S-1300F evaluation kit contains:

- **1 pc SLF3S-1300F** liquid flow sensor (prototype)
- **1 pc SLF3x mounting clamp** to enable mechanical fixation of the sensor
- **1 pc SCC1-USB Sensor Cable** with USB connector for plug-and-play connection to a PC
- **1 pc adapter cable** from 6-pin connector to 4-pin M8 which serves as link between sensor and SCC1-USB Sensor Cable, 15 cm length
- **1 pc ribbon cable** from 6-pin connector to pigtail, 30 cm length
- **A set of fluidic fittings**
- **PC Software** (Viewer & Data Export Tool)

Use the product names and article numbers shown in the following table when ordering SLF3S-1300F liquid flow sensors and the SLF3x mounting clamp.

Product	Description	Article Number
SLF3S-1300F sensor	40 ml/min, prototype with ¼-28 flat bottom ports	3.000.091
SLF3S-1300F evaluation kit	For detailed contents see above	3.000.120
Accessories	Description	Article Number
SLF3x mounting clamp	Mounting support for mechanical fixation	1.000.062

Packaging of the SLF3x mounting clamp will be in bags of 250 pieces (+/- 2%).
Note: The clamp will be delivered separately from the SLF3S-1300F sensors as bulk good.

9 Tray Package

For OEM applications, the liquid flow sensor can be purchased in larger quantities without any additional parts or accessories. In this case the SLF3S-1300F sensors are shipped in trays of 50 pcs each.
The tray dimension is (350 x 260 x 19.5) mm^3. By piling them up, the height per tray can be considered as 15 mm.

10 Important Notices

10.1 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.

10.2 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.

10.3 No Warranty

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