

LD20-0600L Liquid Flow Sensor

Single-Use Liquid Flow Sensor for Biomedical Applications

- Ultra-low flow sensing up to ± 20 ml/h
- Compact, cost-effective, high performance
- Fast and reliable detection of failure modes
- Calibrated and temperature compensated
- Millisecond-fast response time



Product Summary

The LD20 sensor family is Sensirion's series of digital single-use liquid flow sensors designed for high-volume applications. It enables precise and reliable measurements of dynamic liquid flow rates from a few hundred $\mu\text{l/h}$ up to 1000 ml/h bi-directionally. The LD20 sensors feature a digital interface (I²C) via metal contact pads. The LD20 series builds on the latest generation CMOSens® sensor chip that is at the heart of Sensirion's flow sensing platform and allows to achieve 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.

Benefits of Sensirion's CMOSens® Technology

- High reliability
- Best signal to noise ratio
- Industry-proven technology with a track record of more than 20 years
- Designed for mass production and high process capability
- Optimized for low cost

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1 Sensor Performance

The following Table 1 lists the preliminary specifications of the single-use liquid flow sensor LD20-0600L. The product comes fully calibrated for water (H₂O). Please contact Sensirion if different specifications are required.

Parameter	LD20-0600L	Unit
H ₂ O Full scale flow rate	20	ml/h
H ₂ O Sensor output limit ¹	25	ml/h
Accuracy below full scale (whichever error is larger)	5	% of measured value
	0.05	ml/h
Repeatability below full scale (whichever error is larger)	0.5	% of measured value
	0.005	ml/h
Temperature coefficient ² (additional error / °C; whichever is larger)	tbd	% measured value / °C
	tbd	% full scale / °C
Mounting orientation sensitivity ³	tbd	% of full scale
Calibrated for	Water	-
Recommended maximum use duration	7	days
Shelf life ⁴	3	years

Table 1: Preliminary specifications for single-use liquid flow sensor LD20-0600L (all data for medium H₂O, at 23°C, and for VDD 3.5 V)

¹ Flow rate at which the sensor output saturates. See section 1.1 for performance between full scale and saturation point.

² Additional accuracy error in case liquid and ambient temperatures are similar but both deviating from 23 °C.

³ Maximum additional offset when flow channel is vertical.

⁴ When stored at 15°C - 35°C and 30 - 70 % RH

1.1 Specification Charts

The LD20 liquid flow sensors show bi-directional, linear transfer characteristics. The product comes fully calibrated for water (H₂O).

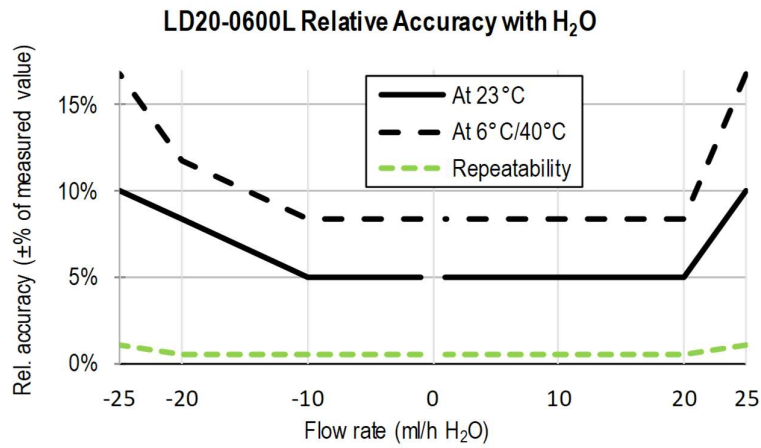


Figure 1: Liquid flow sensor accuracy and repeatability across the flow range of the LD20-0600L. Relative error in $\pm\%$ of measured value for H₂O.

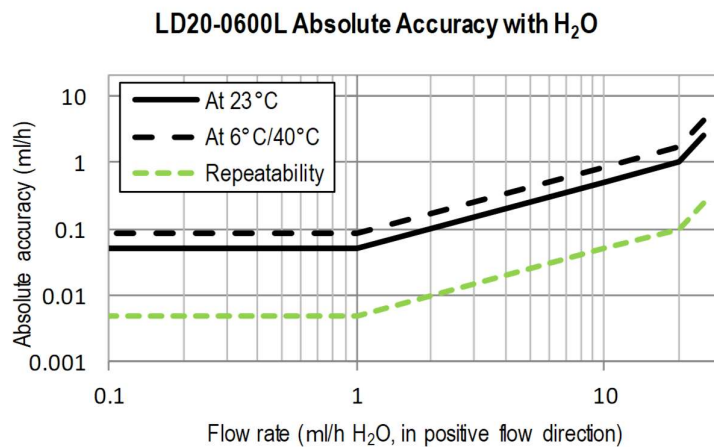


Figure 2: Liquid flow sensor accuracy and repeatability across the positive flow range of the LD20-0600L. Absolute error in ml/h for H₂O.

2 Specifications

2.1 Electrical Specifications

Parameter	Symbol	Conditions	Min.	Typical	Max.	Units	Comments
Supply voltage DC	VDD	Sensor only	3.2	3.5	3.8	V	
Power-up/down level	VPOR		2.3	2.5	2.7	V	
Supply current	IDD	Measurement	0.05	4.5	6.0	mA	VDD = 3.5 V
		Idle state		0.05	0.6	mA	
		Sleep mode			0.001	mA	

Table 2: Electrical 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.
I ² C 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

Stress levels beyond those listed in Table 4 may cause permanent damage to the sensor or affect its reliability. These are stress ratings only and functional operation of the sensor at these conditions is not guaranteed. Ratings are only tested each at a time.

Parameter	Rating	Unit
Operating temperature	+5 ... +45	°C
Operating humidity	0...95 %, non-condensing	% RH
Short term storage temperature ⁵	-40 ... +60	°C
Short term storage humidity ⁵	0...95 %, non-condensing	% RH
ESD HBM (human body model) ⁶	4 (class 3A)	kV
Supply voltage V _{DD}	-0.3 to 5.5	V
Burst pressure	tbd	bar

Table 4: Absolute minimum and maximum ratings

ESD Warning: The sensor is susceptible to ESD damages, especially when touching the connector pins. During handling and testing, suitable ESD precautions must be taken.

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 LD20 liquid flow sensor is equipped with 5 metal contact pads for electrical connection, see below Table 5 for the pad assignment.

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

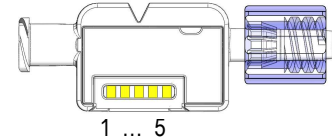


Table 5: Pad assignment

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.

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

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 $\alpha = 0.0125$.

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

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 $\alpha = 0.0125$ 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. When the sensor has entered exponential smoothing, this is indicated by bit 5 in the signaling flag output of the sensor being set to high (=1) (see section 3.3). The exponential smoothing signaling flag is only available from S/N 2040-xxxxxx and up, i.e. product ID revision 83 (see section 4.3.5).

Please refer to relevant literature for more information about exponential smoothing.

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 sensor's temperature, which is influenced by the ambient and fluid temperatures as well as the operating conditions of the sensor. 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 sensors of the LD20 series use 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. For example, if the sensor is read out after 50 ms have passed since the last readout took place, the corresponding signaling flag will be output as "high", if an air-in-line or high flow condition was detected at least once at any time during these 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. While the sampling time is faster than 100 ms, 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 a "3". When the sensor has entered exponential smoothing and bit 5 of the signal flag output is set to high, the signaling flag output as displayed in the Viewer Software hence changes to 33, 34, 35 respectively.

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

3.3.1 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 flag output is set to high (= 1). The bit 1 in the signaling flag output stays high until it is read out.

3.3.2 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, the bit 0 of the signaling flag output is set to high (= 1). The bit 0 in the signaling flag output stays high until it is read out. See Figure 3 below.

Since the air bubble has an impact on the flow velocity profile inside the sensor's flow channel, the *High Flow flag* (see section 3.3.1) 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 typical 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.

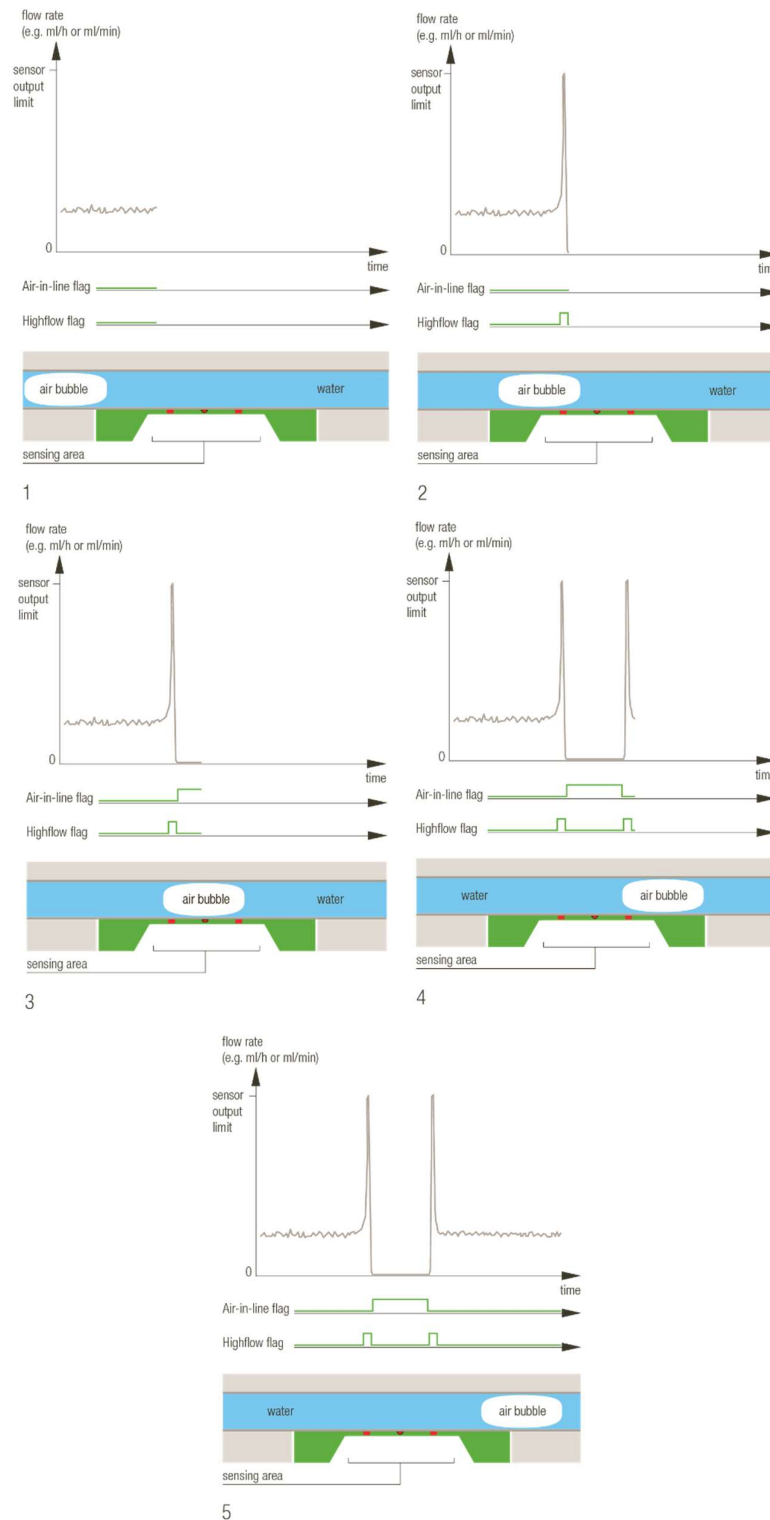


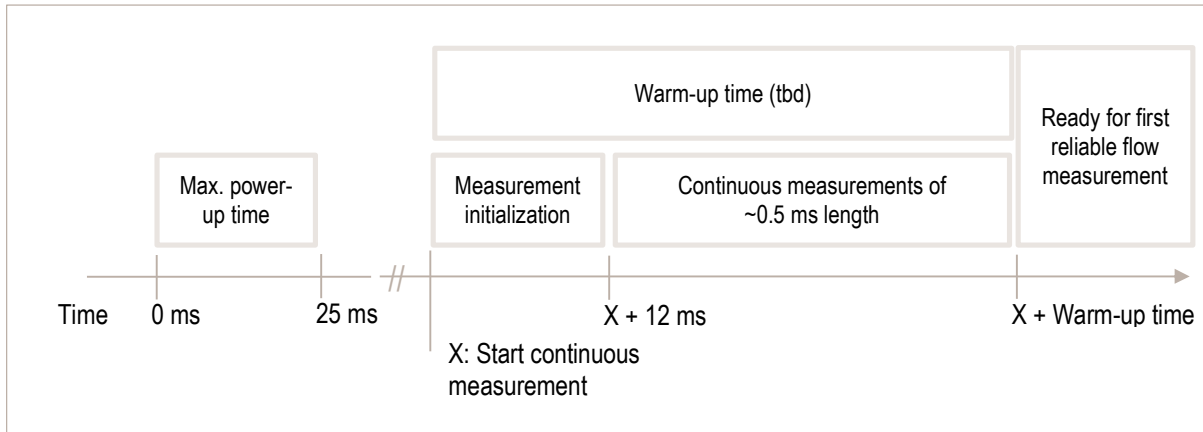
Figure 3: Detection of air-in-line events with the LD20-0600L. The graphs illustrate the air-in-line and high-flow flags while a bubble is passing through the sensor from left to right.

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 LD20-0600L liquid flow sensor.

Due to the thermal measurement principle a total warm-up time (to be determined for LD20-0600L) 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.

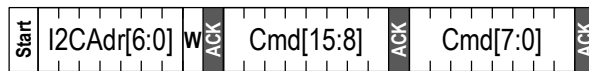
4.1 I²C Address

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

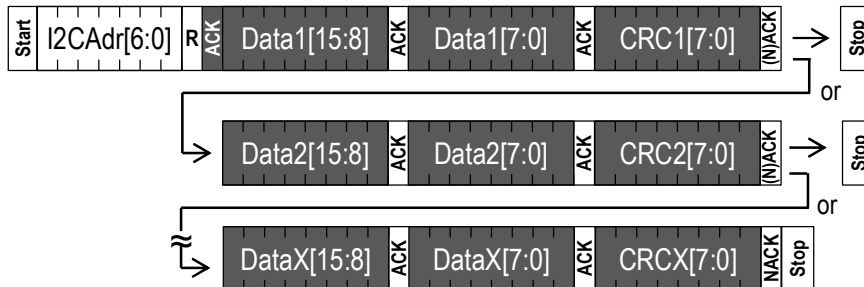
4.2 I²C Sequences

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 16-bit 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 when the continuous measurement is running.

Command	Command code (Hex)	Description
Start continuous measurement	0x3608	This command starts the continuous measurement mode for H ₂ O. Outputs are the liquid flow rate, the sensor'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, temperature, and signaling flags) can be read continuously with a single I²C read header for each set 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 (warm-up time to be determined).

When 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 commands, 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 flags (set to high = 1, set to low = 0)
0	<i>Air-in-Line flag</i>
1	<i>High Flow flag</i>
2-4	<i>Unused, reserved for future use.</i>
5	<i>Exponential smoothing active</i>
6-15	<i>Unused, reserved for future use.</i>

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	I ² C 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. <u>Note that the I²C address is 0x00, which is the general call address, and that the command is 8 bit.</u> I.e., the soft reset command must not be preceded by an I ² C write header. The reset is implemented according to the I ² C 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.

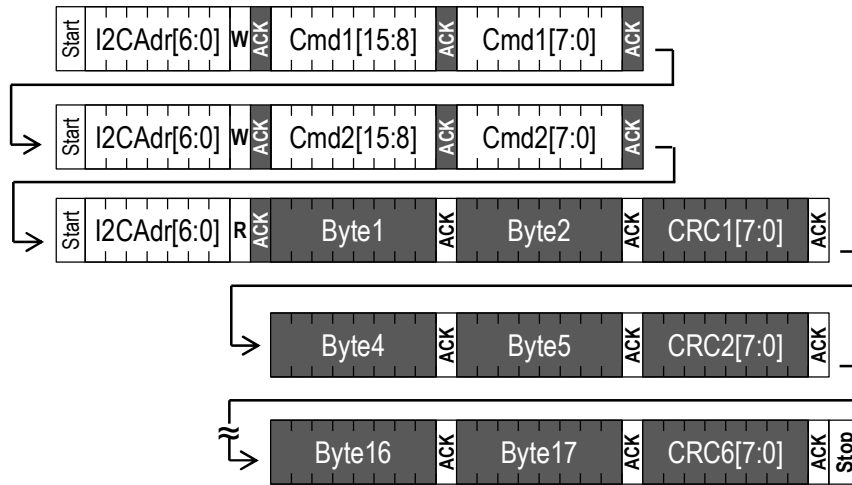
Command	Command code (Hex)	Consecutive read	Description
Enter Sleep mode	0x3677	NA	The sleep command can be sent after a stop continuous measurement command has been issued and the sensor is in idle mode.
Exit Sleep mode	NA	NA	The sensor exits the sleep mode and enters the idle mode when it receives the valid I²C address and a write bit ('0') . Note that the I ² C 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 each to be preceded with an I ² C write header (I ² C address + W). The second command returns: <ul style="list-style-type: none"> - 32-bit product and revision number. The product number is listed in the table below. <i>Note that the last 8 bits are the sensor's revision number and are subject to change as long as the datasheet is preliminary.</i> - 64-bit unique serial number

Table 12: Read product identifier

Product	Product number
LD20-0600L	0x070103xx

Table 13: Preliminary product number for LD20-0600L. Note that the last 8 bits are the sensor's revision number and can be subject to change. Thus, they are indicated by xx only.

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 ($x^8 + x^5 + x^4 + 1$)
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	LD20-0600L
Liquid Flow	1200 (ml/h) ⁻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 ± 25 ml/h, it will only output values in the range -30000 ... 30000)). The integer value can be converted to the physical value by dividing it by the scale factor (liquid flow in ml/h = sensor output \div 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 \div scale factor).

5 Fluidic Specifications and Connections

Parameter	LD20-0600L
Wetted materials	Polyetherimide (PEI), Liquid-Crystal-Polymer (LCP), medical-grade epoxy-based adhesive
Fluidic connector ports (fittings)	Luer Lock fittings
Recommended tubing ID for Luer Lock fittings	tbd
Pressure drop (at 20 ml/h, H ₂ O, 23 °C)	< 0.1 mbar

Table 16: Fluidic specifications and connections

6 Mechanical Specifications

Parameter	LD20-0600L
Largest dimensions	~ 45.6 x 15.5 x 11.2 mm
Weight	~ 2.5 g
Inner diameter	~ 0.8 mm
Inner volume	~ 30 µl
Maximum recommended operating pressure ⁷	3 bar
Rated burst pressure	10 bar

Table 17: Mechanical specifications

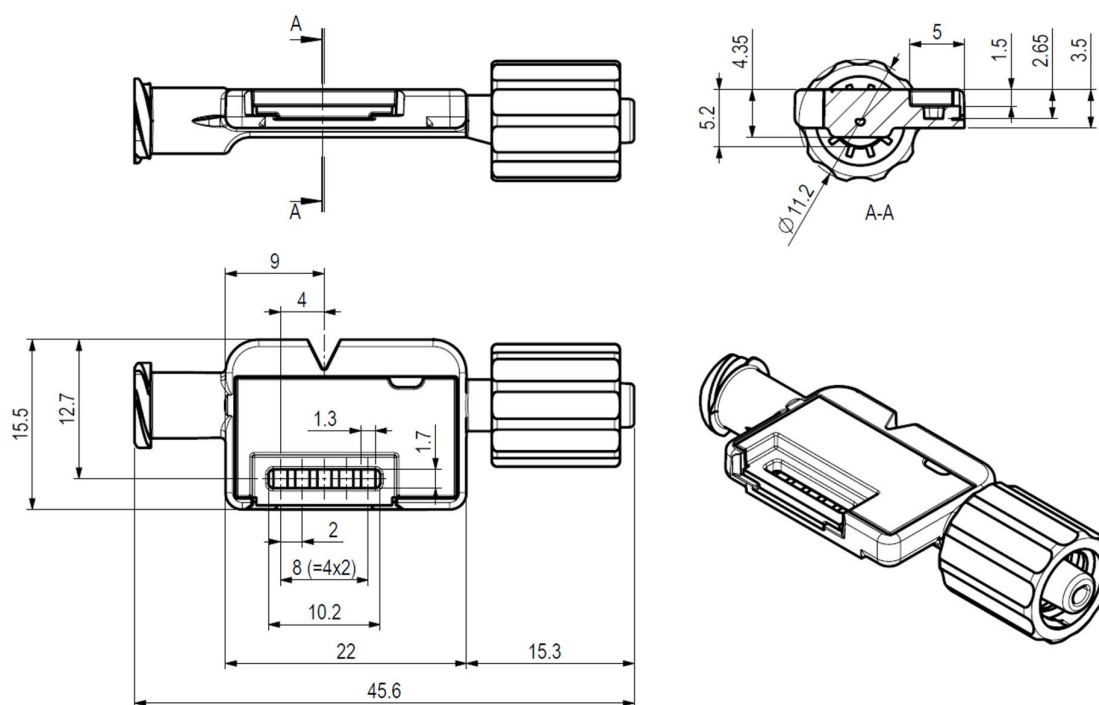


Figure 4: Preliminary dimensions of LD20-0600L (all dimensions in mm)

⁷ Pressure ratings apply to sensor only, not in combination with attached tubing.

7 Ordering Information

Use the product names and article numbers shown in the following table when ordering LD20-0600L liquid flow sensors or the LD20 evaluation kit. Only the LD20 evaluation kit is available via Sensirion's worldwide distribution network. Please find an overview for your region under: www.sensirion.com/distributor-search.

Product	Description	Article Number
LD20-0600L single-use liquid flow sensor	20 ml/h, with Luer Lock connectors	1-101645-01
SEK-LD20, EvalKit for LD20-0600L	Sensors and base stations, without SCC1-USB cable (for detailed contents see below)	3.000.477
Accessories	Description	Article Number
LD20 base station	Mounting support with 4-pin M8 connector	3.000.476
SCC1-USB sensor cable	USB cable for connection to a PC	1-101007-01

Table 18: Ordering information

For fast and easy technology evaluation, Sensirion offers an evaluation kit (SEK-LD20, EvalKit for LD20-0600L).



Each LD20-0600L evaluation kit contains:

- **3 pcs LD20-0600L liquid flow sensors**
- **3 pcs LD20 base stations** used as a reusable electrical interface connector (injection molded, POM, for evaluation purposes only). It holds the sensor with the help of a clip-in mechanism and contains a PCB featuring additional ESD protection. The base station fits to all LD20 versions and connects the contact pads of the sensor via spring pins with a 4-pin M8 connector. Consequentially, it serves as a link between sensor and SCC1-USB Sensor Cable.
- **PC Software** (Viewer & Data Export Tool)

Please note

- The SCC1-USB sensor cable which is required for a plug-and-play connection to a PC is not part of the LD20 evaluation kit. It needs to be ordered separately through Sensirion's distribution network.
- The LD20 base station is not commercially available in larger numbers. It is provided in single quantities as part of the LD20 evaluation kit for testing purposes only. Sensirion has published Engineering Guidelines to support customers with their own design.

8 Packaging Information

Standard shipment includes only the sensor, neither cables, base station, nor fluidic connection material.

The LD20 liquid flow sensors are shipped in trays of 50 pcs each.

The tray dimension is (350 x 260 x 19.5) mm³. By piling them up, the height per tray can be considered as 15 mm.

9 Important Notices

9.1 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.

9.2 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.

9.3 No Warranty

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