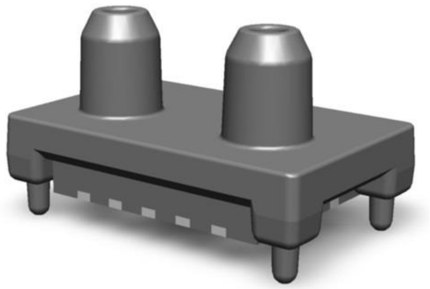
Preliminary Datasheet SDP3x-Digital

Digital Differential Pressure Sensor



- Smallest size enables portable applications
- Reflow solderable – Pick & Place
- Excellent repeatability, no drift, no offset
- Extended feature set – smart averaging
- Calibrated and temperature compensated

Product Summary

The SDP3x sensor family is Sensirion's series of small differential pressure sensors designed for high-volume applications where size is a key requirement. It builds on the next generation CMOSens® sensor chip that is at the heart of Sensirion's new differential pressure and flow sensing platform.
The digital SDP3x sensor features fast measurement speed, excellent accuracy and long-term stability and has no zero-point drift. Furthermore, it is reflow solderable and provides extended functionality, such as smart averaging, multiple temperature compensation modes and interrupts.

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
- High process capability

Content

1. Sensor Performance

1.1 Differential Pressure Specification[1]

Parameter	SDP31
Measurement range[2]	– 500 to + 500 Pa (± 2.0 in. H_2O)
Zero point accuracy[3,4]	0.1 Pa
Span accuracy[3,4]	3% of reading
Zero point repeatability[3,4]	0.03 Pa
Span repeatability[3,4]	0.5% of reading
Span shift due to temperature variation	< 0.5% of reading per 10°C
Offset stability	< 0.01 Pa/year
Span stability	< 0.2 %/year
Flow step response time (τ_{63})	< 3ms
Resolution	16 bit
Calibrated for	Air, N_2
Media compatibility	Air, N_2, O_2, non-condensing
Calibrated temperature range	-40 °C to +85 °C

1.2 Temperature Specification[5]

Parameter	Value
Measurement range	- 40 °C to +85 °C
Resolution	16 bit
Accuracy	2 °C
Repeatability	0.1°C

[1] Unless otherwise noted, all sensor specifications are valid at 25°C with VDD = 3.3 V and absolute pressure = 966 mbar.
[2] Other pressure ranges expected Q2/Q3 2016 or contact Sensirion
[3] Includes repeatability
[4] Total accuracy/repeatability is a sum of zero-point and span accuracy/repeatability.
[5] The measured temperature is the temperature of the bulk silicon in the sensor. This temperature value is not only depending on the gas temperature, but also on the sensor's surroundings. Using the signal to measure solely the gas temperature will need special precautions, such as isolating the sensor from external temperate influences.

2. Specifications

2.1 Electrical Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units	Comments
Supply Voltage	V_{DD}		3.0	3.3	4	V	For 5V supply contact Sensirion
Power-up/down level	V_{POR}		2.3	2.5	2.7	V	
VDD ramp up slew	$V_{DD, ramp}$		0.2			V/ms	Minimum voltage ramp up slew when powering up SDP3x
Supply current	I_{DD}	Measuring in Continuous mode		3.8	5.5	mA	
		Measuring in Triggered mode		3.8	5.5	mA	
		Idle state			1.1	mA	
IRQn driving strength					4	mA	

2.2 Timing Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units	Comments
Power-up time	t_{PU}				25	ms	Time to first reliable measurement
Soft reset time	t_{SR}				1	ms	Time between soft reset command and sensor ready
I2C SCL frequency	f_{I2C}			400	1000	kHz	
Update rate differential pressure value		Continuous mode	900	1000	1100	Hz	Upgrade to 2kHz expected in Q3 2016
Update rate temperature value		Continuous mode	112.5	125	137.5	Hz	Temperature value is updated once every eight pressure values
Measurement time		Triggered mode	30	33	36.3	ms	

2.3 Mechanical Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units	Comments
Allowable overpressure	P_{max}				0.25	bar	
Rated burst pressure	P_{burst}		1			bar	
Weight	W				1.5	g	

2.4 Materials

Parameter	
Wetted materials	Glass (silicon nitride, silicon oxide), LCP, green epoxy-based mold compound, epoxy-based resins
REACH, RoHS	REACH and RoHS compliant

2.5 Absolute Minimum and Maximum Ratings

Parameter	Rating	Units
Supply Voltage V_{DD}	-0.3 to 4.5	V
Max Voltage on pins (SDA, SCL, ADDR, IRQn)	-0.3 to V_{DD}+0.3	V
Input current on any pin	±70	mA
Operating temperature range	-40 to +85	°C
Storage temperature range	-40 to +85	°C
Max. humidity for long term exposure	40°C dew point	
ESD HBM (human body model)	2	kV

3. Pin Assignment

The SDP3x consists of a QFN package with a plastic cap covering the top and providing the pneumatic connections to the sensor. The pin assignments of the SDP3x-Digital can be found in Table 1

Pin no.	Name	Description
1	GND	Connect to ground
2	GND	Connect to ground
3	GND	Connect to ground
4	IRQn	Interrupt output. Active low. Keep floating when not used.
5	SCL	Serial Clock (I²C Interface)
6	GND	Connect to ground
7	VDD	VDD Supply
8	SDA	Bidirectional Serial Data (I²C Interface)
9	ADDR	I²C Address selection input. Expected Q2 2016. Connect to ground until implemented.
10	GND	Connect to ground
11	GND	Connect to ground
12-16	-	Reserved. Do not connect

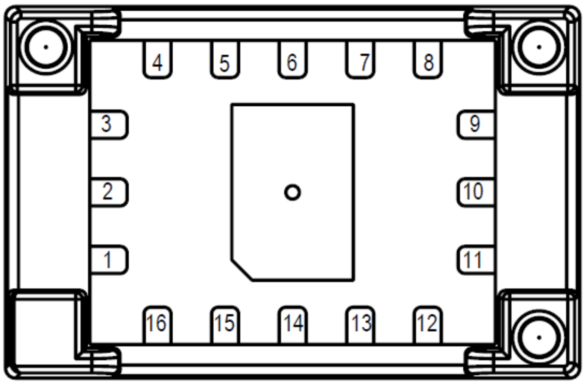


Table 1: *SDP3x-Digital pin assignment (bottom view).*

3.1 Power Pins (VDD, GND)

The power supply pins must be decoupled with a 100 nF capacitor that shall be placed as close to the sensor as possible.

3.2 Serial Clock and Serial Data (SCL, SDA)

The SCL and SDA are bidirectional pins of the I²C slave interface. The SCL is the Serial Clock pin and the SDA is the Serial Data pin. For more details about the I²C interface refer to section 5.

3.3 ADDR Pin (Expected Q2 2016)

The SDP3x-Digital supports different I²C addresses. With the ADDR pin an address can be selected. Connecting the ADDR pin to ground selects the default address. Other I2C addresses can be selected with a resistor connected to GND.

I2C Address (Hex)	Condition
0x21	ADDR connected to GND
0x22	ADDR connected with TBD Ohm to GND
0x23	ADDR connected with TBD Ohm to GND
0x24	ADDR connected with TBD Ohm to GND

3.4 IRQn Pin

The IRQn pin indicates whether new measurement results are available. The signal is active low, meaning that when the signal is high there is no new measurement data available. The IRQn will automatically clear when a differential pressure value is read out.
When the IRQn signal is not used, the pin should stay unconnected and must not be connected to GND or VDD.

3.5 Die Pad (Center Pad)

The die pad or center pad is visible from below and located in the center of the package. It is internally connected to GND and therefore there are no electrical constraints on connecting or not connecting the die pad to GND. For mechanical stability it is recommended to solder the center pad to the PCB.
The hole in the middle of the die pad must stay open during soldering.

4. Measurement Modes

The SDP3x-Digital is a highly versatile differential pressure sensor and is very flexible regarding the measurement speed. This flexibility not only allows for optimizing the sensor's performance to a specific application, but also for adapting the sensor to different use cases. For example in one use case the sensor is detecting the smallest and quickest changes, whereas at another time the sensor can measure in larger intervals while consuming only little energy.

4.1 Continuous Mode vs Triggered Mode

In continuous mode the sensor is measuring at the highest speed and writes the measurement values to the I²C results buffer, where the I²C master can read out the value when it requires.
In triggered mode the sensor is default in an idle state and wakes up when the command is sent. It then powers up the heater and does a measurement. During this time the sensor doesn't acknowledge any I²C read header or stretches the clock. When the measurement is finished it turns off the heater and makes the measurement result available to be read out.

	Continuous mode	Triggered mode
Description	Measures continuously	Measures once after command is sent
Measurement speed and rate	Measurement result can be read out continuously and at any time, but not faster than 1ms (upgrade to 0.5ms expected in Q3 2016).	Measurement result is available in +/- 33ms after command. Clock stretching is available.
Measurement method	Sensor configuration is optimized for speed and accuracy.	Sensor configuration is optimized for low power consumption.
Recommended use	Best used where speed and accuracy are most important.	Best used where energy consumption is more important than speed.

4.2 Continuous Mode and 'Average till Read'

In continuous measurement modes a new measurement result is available every 1ms (upgrade to 0.5ms expected in Q3 2016). A new value can be read out every 1 ms and the IRQn will go low when a new measurement result is available.
If the 'average till read' option is chosen, the sensor averages all values (x_i) prior to the read out. This has the benefit that the user can read out the sensor at its own desired speed, without losing information and thus prevents aliasing. During the first 25 ms of averaging the averaged value is obtained as the arithmetic mean.

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N} \qquad \text{for } t < 25 \text{ ms}$$

When the reading speed is even slower than 25 ms, the sensor will continue to average, but with another algorithm. In this algorithm exponential smoothing is used, with a smoothing factor α = 0.05.

$$S_k = \alpha \cdot x_i + (1 - \alpha) \cdot S_{k-1}, \qquad S_0 = \bar{x}, \qquad \text{for } t > 25 \text{ ms}$$

Where S_0 is the arithmetic value after the first 25 ms.

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

4.3 Temperature Compensation Modes

The SDP3x is temperature compensated both for differential pressure and for mass flow compensated differential pressure. In use cases where the SDP3x is used to measure mass flow it is advised to use mass flow temperature compensation.
For more information about temperature compensation for differential pressure sensors, for example volume flow measurements in bypass, please refer to the selection guide in the differential pressure download center on our website.

5. Digital Interface Description

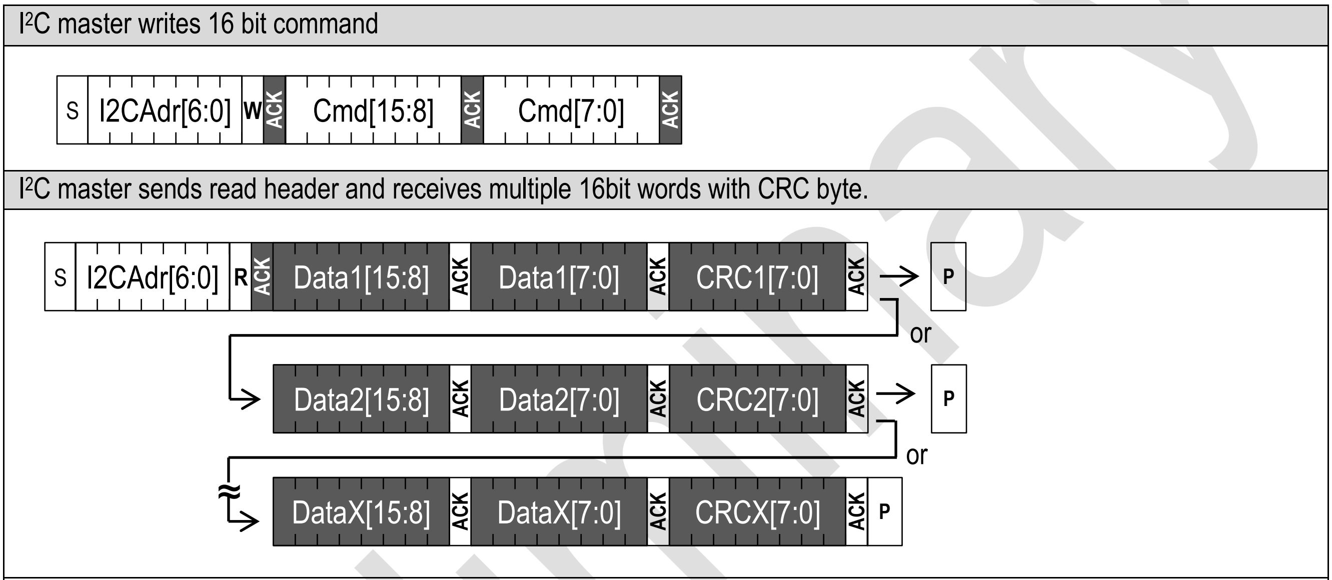
The SDP3x-digital interface is compatible with the I²C protocol. This chapter describes the command set for SDP3x-digital. For detailed information about the I²C protocol, please check the document "NXP I²C-bus specification and user manual".

5.1 I²C Address

The I²C address for SDP3x-digital is 0x21 (b 0100 001). The address is followed by a read or write bit.
Selection of other I²C addresses is expected to be available Q2 2016.

5.2 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.



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.

5.3 I²C Commands

The command set of the SDP3x-digital consists of a set of different commands:

- Continuous measurement
    - Start Continuous measurement commands
    - Stop measurement command
- Triggered measurement commands
- Read product identifier and serial number
- Soft reset

5.3.1 Start Continuous Measurement

The sensor measures both the differential pressure and temperature. Both measurement results can be read out through one single I²C read header.
Continuous measurements can be started up in different configurations by a set of commands.

Command code (Hex)	Temperature compensation	Averaging
0x3603	Mass flow	Average till read
0x3608	Mass flow	None - Update rate 1ms
0x3615	Differential pressure	Average till read
0x361E	Differential pressure	None - Update rate 1ms

After one of the commands has been sent, the chip continuously measures and updates the measurement results. New results can be read continuously with only an I²C read header. (Measurement) commands must not be sent until the stop measurement command has been sent.

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

Preceding command	Consecutive read	Description
continuous measurement	Byte1: DP 8msb Byte2: DP 8lsb Byte3: CRC Byte4: Temp 8msb Byte5: Temp 8lsb Byte6: CRC Byte7: Scale Factor differential pressure 8msb Byte8: Scale Factor differential pressure 8lsb Byte9: CRC	After a start continuous measurement commands, the measurement results can be read out. The temperature and scale factor don't need to be read out (every time). The read sequence can be aborted by a NACK and a STOP condition.

5.3.2 Stop Continuous Measurement

Command	Command code (Hex)	Description
Stop continuous measurement	0x3FF9	This command stops the continuous measurement. It powers off the heater and makes the sensor receptive for another command. The Stop command is also required when switching between different continuous measurement commands.

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 as described in section 5.3.5. In idle mode the sensor will consume less power.

5.3.3 Triggered Measurement

During a triggered measurement the sensor measures both differential pressure and temperature. The measurement starts directly after the command has been sent. The command needs to be repeated with every measurement.

Command code (Hex)	Temperature compensation	Clock stretching
0x3624	Mass flow	
0x3726	Mass flow	Yes
0x362F	Differential pressure	
0x372D	Differential pressure	Yes

During the 33ms that the sensor is measuring, no command can be sent to the sensor. After the 33ms the result can be read out and any command can be sent to the sensor.
Monitoring whether or not the sensor is ready with its measurement can be done with the following methods.

Method	Available	Description
Clock stretching	Only for clock stretching commands	The sensor starts the measurement after the triggered measurement command with clock stretching. When an I2C read header is sent within 33ms the sensor performs clock stretching after acknowledging the read header. When the sensor has finished the measurement, it makes the result available by releasing the SCL.
Polling	Only for non-clock stretching commands	In this mode the sensor does not acknowledge (NACK) an I^2C read header as long as no measurement result is available.
IRQn	Always	The IRQn is always available to monitor whether the sensor is ready with the measurement. When the IRQn is low, the sensor indicates that a new measurement result can be read out. The IRQn is self-clearing when the result is read-out.

When new measurement data is available it can be read out by sending an I2C read header and reading out the data from the sensor. In the table below the data layout of the results can be found.

Preceding command	Consecutive read	Description
Triggered measurement	Byte1: DP 8msb Byte2: DP 8lsb Byte3: CRC Byte4: Temp 8msb Byte5: Temp 8lsb Byte6: CRC Byte7: Scale Factor differential pressure 8msb Byte8: Scale Factor differential pressure 8lsb Byte9: CRC	After a triggered measurement command, the results can be read out when the sensor is finished with the measurement. The temperature and scale factor don't need to be read out (every time). The read sequence can be aborted by a NACK and a STOP condition.

5.3.4 Read Product Identifier

During assembly and start-up of the machine it might be required to check some basic parameters in the sensor - for example to check if the correct sensor is integrated.
The product identifier and serial number can be read out after sending a sequence of two commands.

Command	Command code	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 number *Unique product number and version of the SDP31 product: 0x03010182* - 64 bit unique serial number

5.3.5 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. The reset is implemented according to the I²C specification.

After the reset command the sensor will take maximum 1ms to reset. During this time the sensor will not acknowledge its address nor accept commands.

5.4 Checksum Calculation

The checksum byte is generated by a CRC algorithm with the following properties:

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

5.5 Conversion to Physical Values

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

5.5.1 Scale Factors

Parameter	SDP31
Differential Pressure	60 Pa^{-1}
Temperature	200 $°C^{-1}$

5.5.2 Differential Pressure

The digital calibrated differential pressure signal read from the sensor is a signed integer number (two's complement number). The integer value can be converted to the physical value by dividing it by the scale factor (differential pressure in Pascal = sensor output ÷ scale factor).

5.5.3 Temperature

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

6. Package Outline

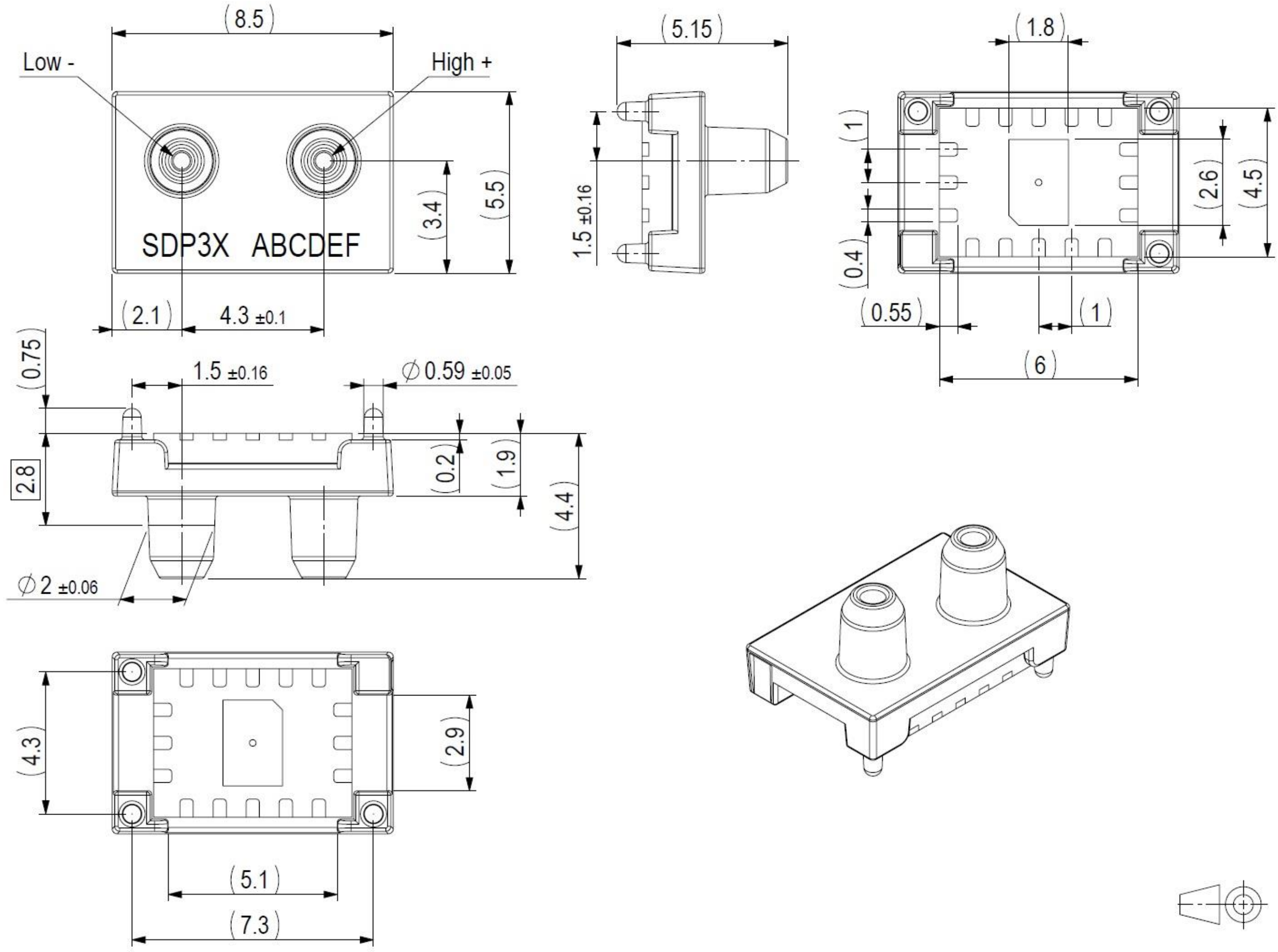
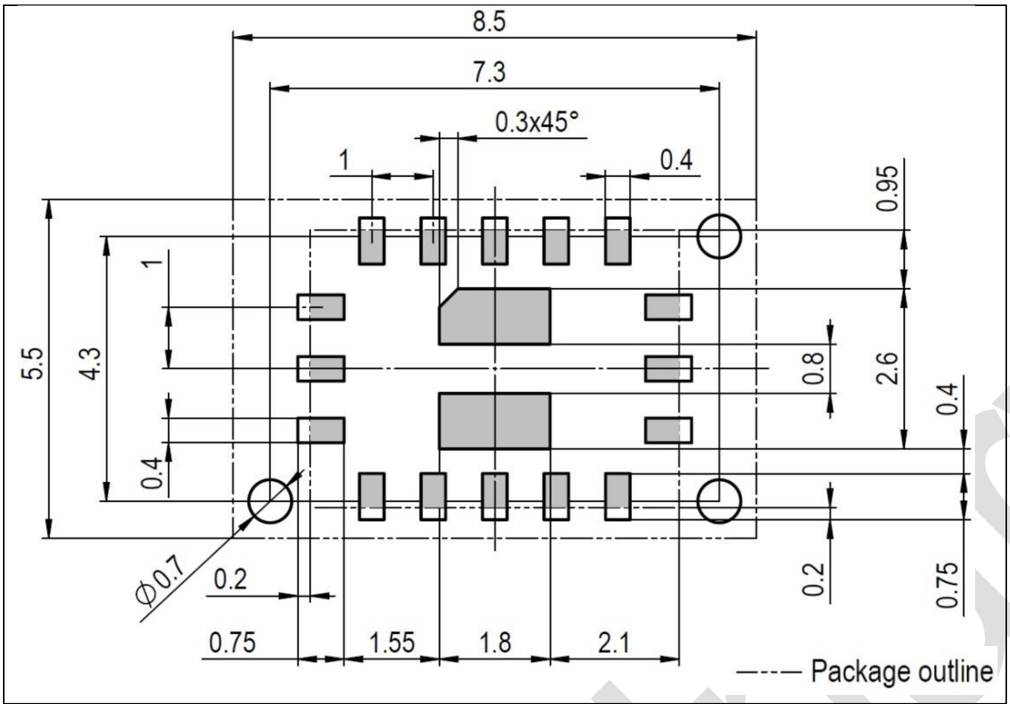


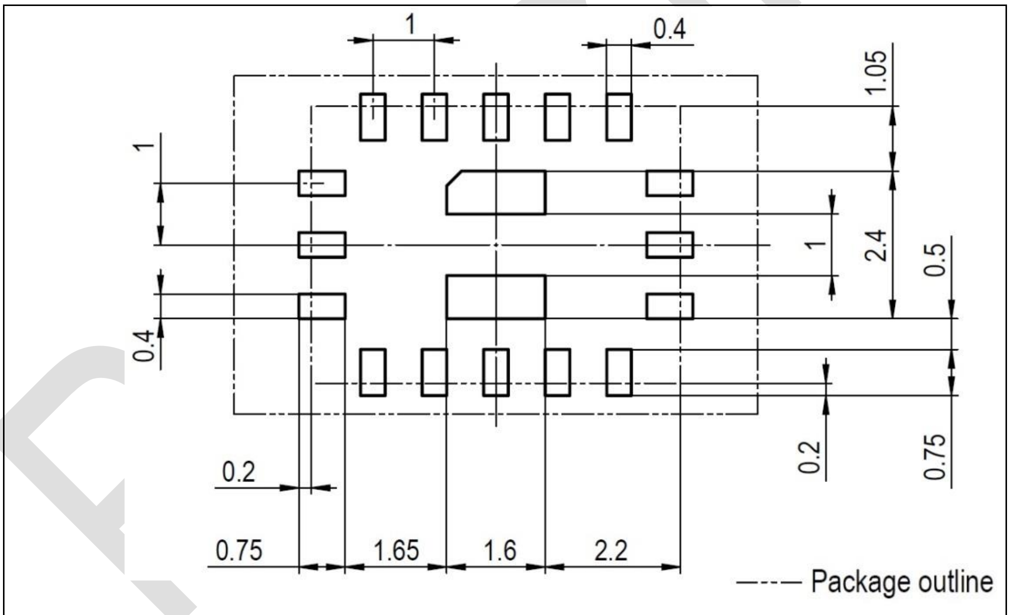
Figure 1: *SDP3x. All dimensions in mm.*

7. Soldering



Recommended land pattern

The solder mask is understood to be the insulating layer on top of the PCB covering the copper traces. It is recommended to design the land pattern as a Non- Solder Mask Defined (NSMD) type.



Recommended stencil aperture

The sensor must enter the reflow process only once, with a minimal temperature and exposure time. When both sides of the PCB are reflow soldered or multiple reflow runs are required, the sensor must be soldered in the last soldering run. In any case the temperature should not exceed 255°C; temperatures above 200°C should be limited in time to a maximum of 150 seconds.

Ensure that the ports of the sensor are well protected during assembly and soldering so that no dust, solder flux or other liquids can enter the flow channel. In no case, a board wash shall be applied. Therefore it is strongly recommended to use "no-clean" solder paste.

It is important to note that the diced edge or side faces of the I/O pads may oxidize over time, therefore a solder fillet may or may not form. Hence there is no guarantee for solder joint fillet heights of any kind.

8. Shipping Package

SDP3x are provided in tape & reel shipment packaging. Standard packaging size is 1500 units per reel. The drawing of the packaging tapes with sensor orientation is shown in *Figure 2*.

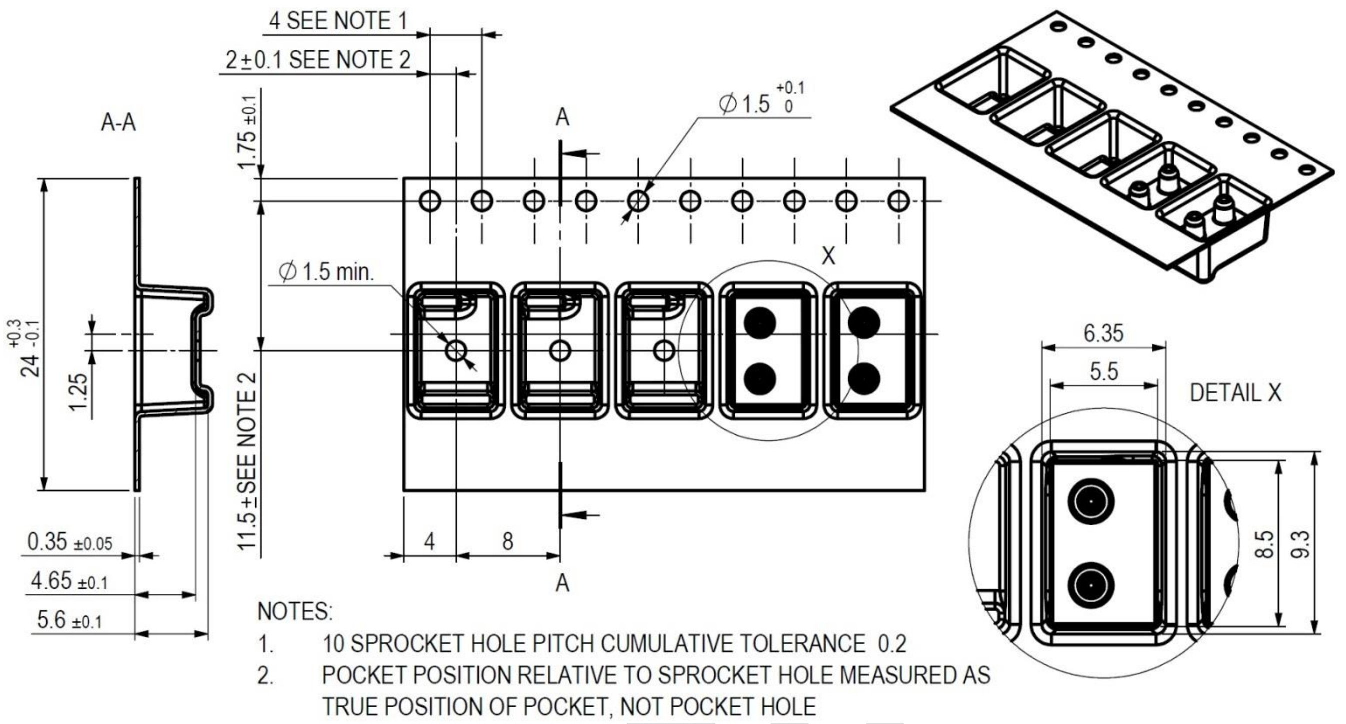


Figure 2: *Sketch of packaging tape and sensor orientation. Header tape is to the right and trailer tape to the left on this sketch*

9. Ordering Information

Use the part names and item numbers shown in the following table when ordering SDP3x differential pressure sensor. For the latest product information and local distributors, visit www.sensirion.com.

Part name	Description / Output	Product number	Packaging	Tape & Reel size
SDP31	I^2C	1-101445-01	Tape & Reel (QFN Quad 2 configuration)	1500

Revision History

Date	Author	Version	Changes
13.11.2015	ANB	V0.1	First Draft
22.12.2015	ANB	V0.2	Rework of all chapters
01.02.2016	ANB	V0.3	Rework after 1st review round. Preliminary release.
02.02.2016	ANB	V0.4	Minor updates