

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, configurable I²C address 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

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1. Sensor Performance

1.1 Differential Pressure Specification¹

| Parameter | SDP31 |
|--|---|
| Measurement range ² | - 500 to + 500 Pa (± 2 inches H ₂ O) |
| 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 (T 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 Specification⁵

| 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 temperature 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 |
| I ² C 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 Maximum Ratings

| Parameter | Rating | Units |
|--------------------------------------|----------------------|-------|
| Supply Voltage V_{DD} | -0.3 to 4.5 | V |
| Max Voltage on pins SDA, SCL, 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 (I ² C Interface) |
| 6 | GND | Connect to ground |
| 7 | VDD | VDD Supply |
| 8 | SDA | Bidirectional Serial Data (I ² C Interface) |
| 9 | ADDR | I ² C Address selection input. |
| 10 | GND | Connect to ground |
| 11 | GND | Connect to ground |
| 12-16 | - | Reserved. Do not connect |

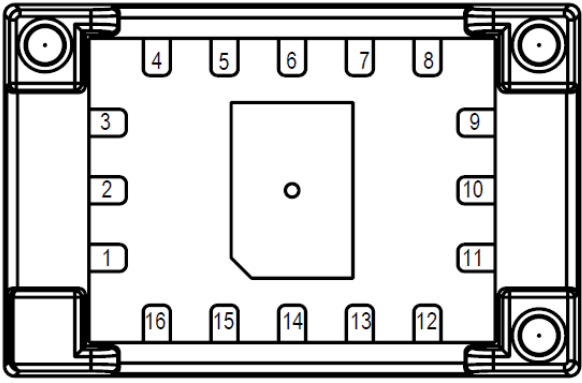


Table 1: SDP3x-Digital pin assignment (bottom view).

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

The SDP3x-Digital supports different I²C addresses. With the ADDR pin an address can be selected. Connecting the ADDR pin to GND selects the default address. Other I²C addresses can be selected with a resistor connected to GND. The maximum tolerance for the resistor is $\pm 5\%$. Do not connect the ADDR pin to VDD.

| I ² C Address (Hex) | Condition |
|--------------------------------|------------------------------------|
| 0x21 | ADDR connected to GND |
| 0x22 | ADDR connected with 1.2kOhm to GND |
| 0x23 | ADDR connected with 2.7kOhm 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 to high when a differential pressure value is read out. The IRQn pin will also be set to low after every soft reset or Power on Reset, until a measurement command is sent.

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.

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

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 $\alpha = 0.05$.

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

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

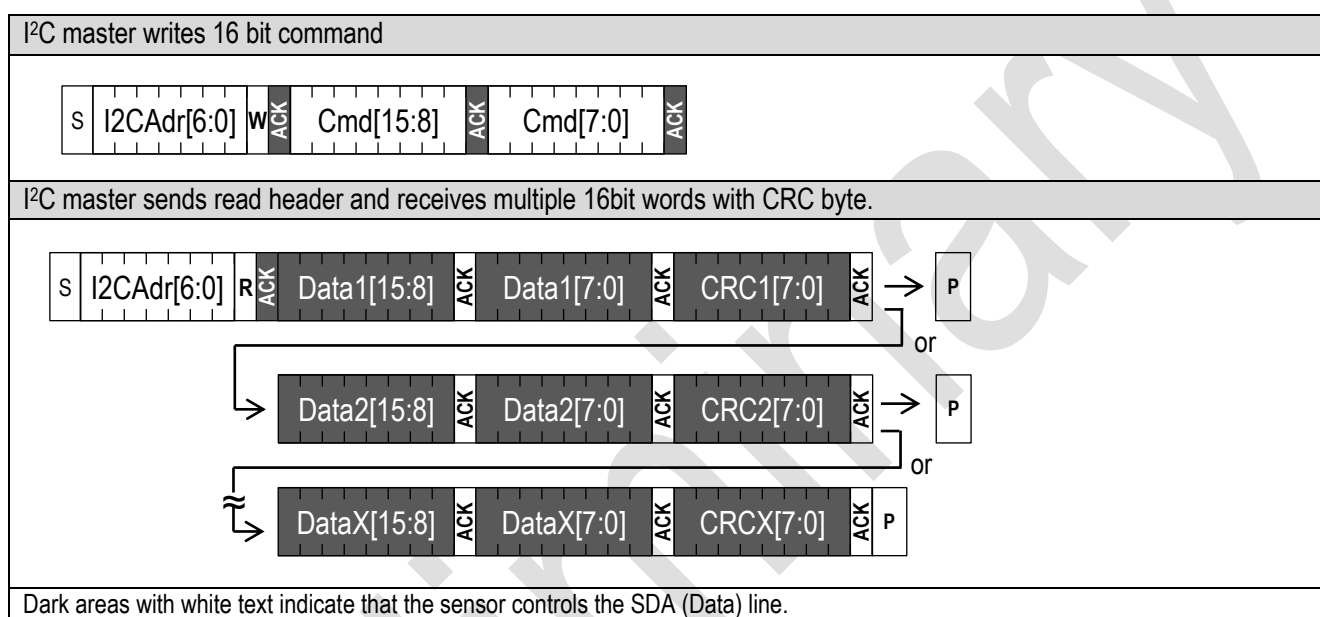
The SDP3x-digital interface is compatible with the I²C protocol. This chapter describes the command set for SDP3x-digital. For detailed information about the I²C protocol, please check the document "NXP I²C-bus specification and user manual".

5.1 I²C Address

The I²C address for SDP3x-digital can be selected with the ADDR pin. For more information refer to section 3.3.

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.



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
 - o Start Continuous measurement commands
 - o 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 I ² C 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 ² C 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 I ² C write header (I ² C address + W). The second command returns: <ul style="list-style-type: none"> - 32 bit product number <i>Unique product number and version of the SDP31 product: 0x03010185</i> - 64 bit unique serial number |

5.3.5 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. The reset is implemented according to the I²C specification.</u> |

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 (x ⁸ + x ⁵ + x ⁴ + 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

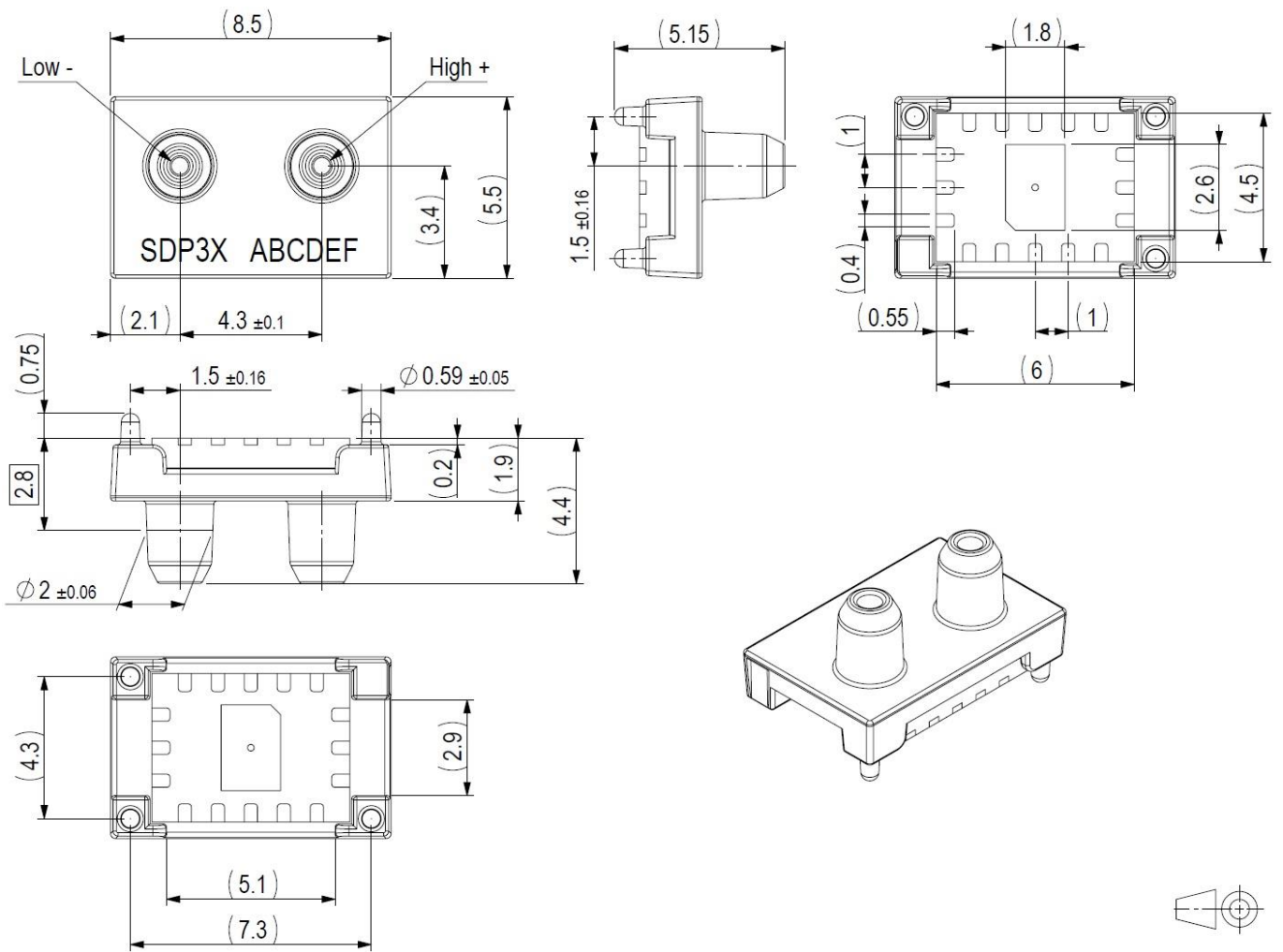
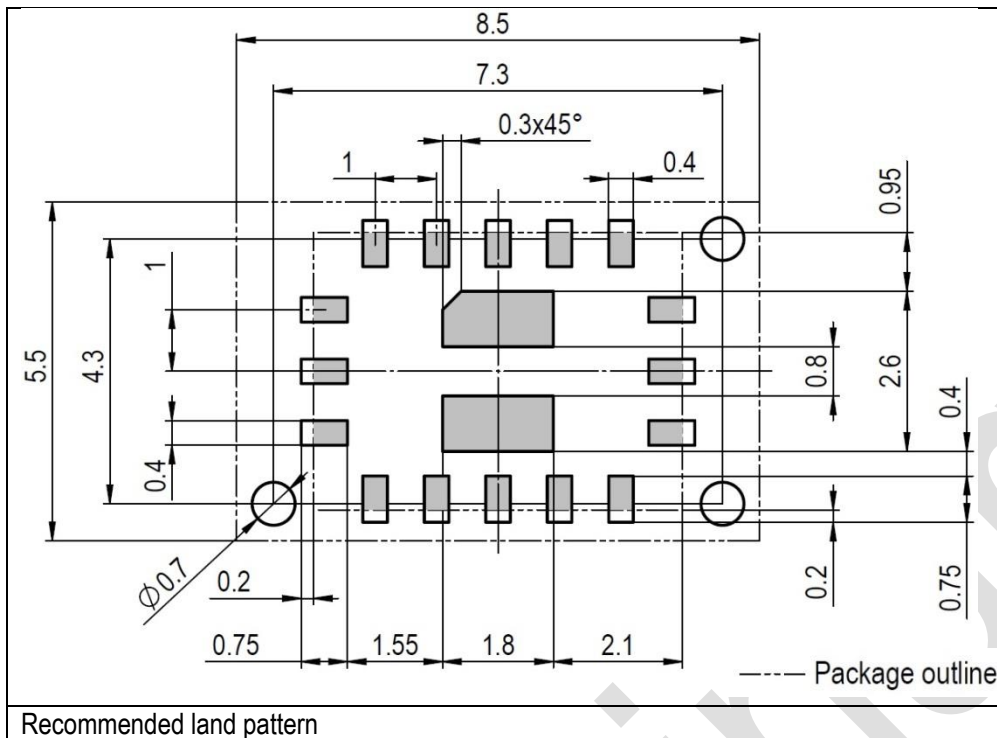
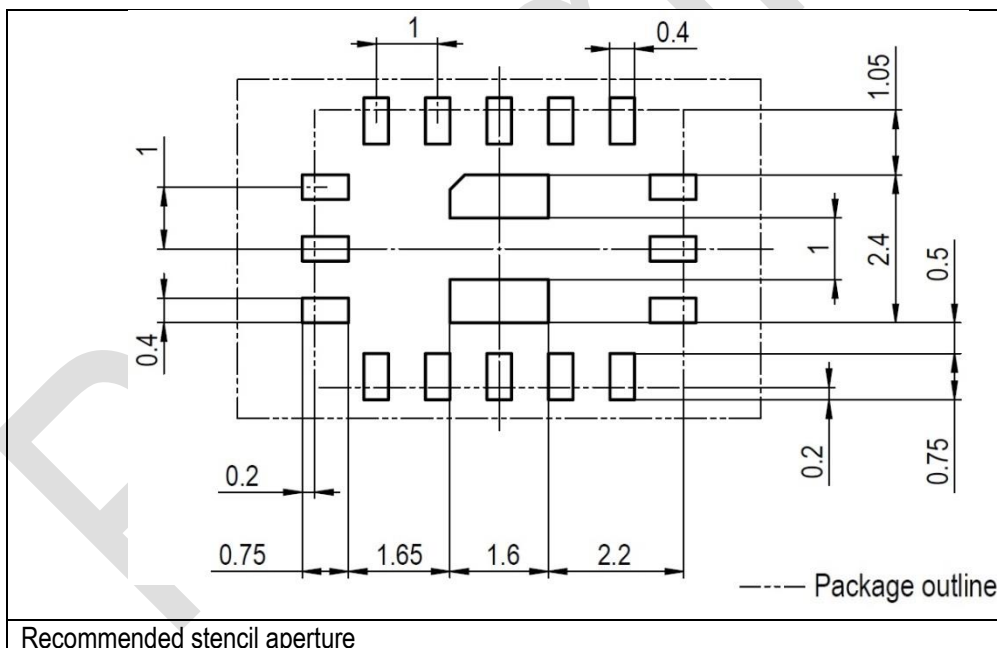


Figure 1: SDP3x. All dimensions in mm.

7. Soldering



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.



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*.

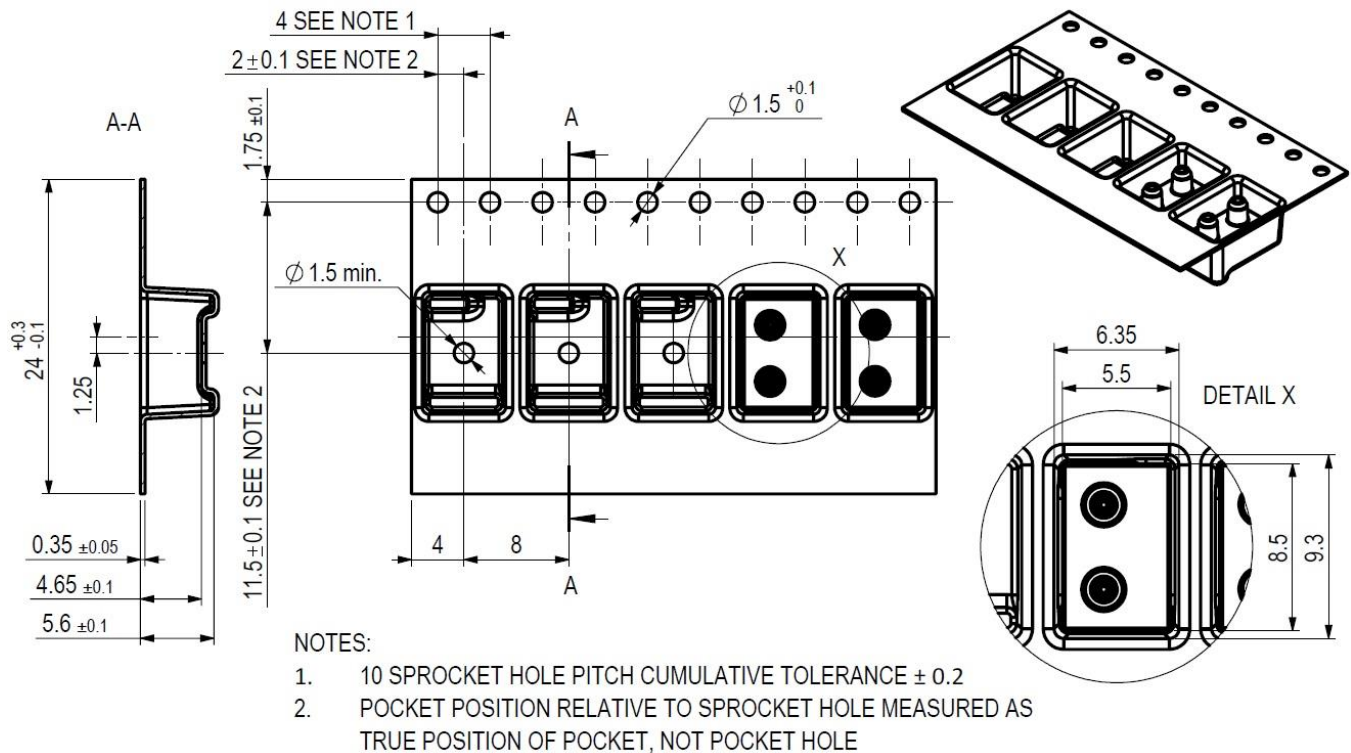


Figure 2: Sketch of packaging tape and sensor orientation. Header tape is to the right and trailer tape to the left on this sketch

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 ² C | 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 1 st review round. Preliminary release. |
| 02.02.2016 | ANB | V0.4 | Minor updates |
| 30.03.2016 | ANB | V0.5 | Minor updates. IRQn clarification. |

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 (including death). Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the datasheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, 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 "Handling Instructions" 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.

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Headquarters and Subsidiaries

SENSIRION AG
Laubisruetistr. 50
CH-8712 Staefa ZH
Switzerland

phone: +41 44 306 40 00
fax: +41 44 306 40 30
info@sensirion.com
www.sensirion.com

Sensirion AG (Germany)
phone: +41 44 927 11 66

Sensirion Inc., USA
phone: +1 805 409 4900
info_us@sensirion.com
www.sensirion.com

Sensirion Japan Co. Ltd.
phone: +81 3 3444 4940
info-jp@sensirion.com
www.sensirion.co.jp

Sensirion Korea Co. Ltd.
phone: +82 31 337 7700~3
info-kr@sensirion.com
www.sensirion.co.kr

Sensirion China Co. Ltd.
phone: +86 755 8252 1501
info-cn@sensirion.com
www.sensirion.com.cn

To find your local representative, please visit www.sensirion.com/contact