

# Analog Barometric Air Pressure (BAP) Sensor

**SM1111-EEN-S-165-000**  
**Barometric Air Pressure (BAP) Sensor**

## FEATURES

- Fully integrated and compensated pressure sensor
- Measurement of absolute pressure: 60 - 165 kPa
- Full thermal compensation to accuracy  $\pm 1.0$  %FS
- Ratiometric analog output with wide linear range
- Two 16-bit ADCs for acquisition of pressure and temperature inputs; pressure acquired at 20 kS/s
- High Resolution Digital to analog converter (DAC)
- Diagnosis of sensor, sensor supply wiring, and NVM check-sum supervision at power-on
- Supply voltage 5.0 V  $\pm$  0.5V
- Large operating temperature range -40 to + 85°C
- Automotive qualified acc. to AEC-Q100



## DESCRIPTION

The SM1111-EEN-S-165-000 is an absolute pressure sensor for barometric air pressure measurement (BAP). It includes a piezo-resistive pressure sensor die and a signal processing IC, which performs amplification and thermal compensation of the pressure sensor output to provide a linear, thermally stable signal output. The sensor delivers calibrated output data at a ratiometric analog voltage output. The pressure range 60 to 165 kPa is mapped linearly to the nominal output range  $V_{AOUT,1}$  to  $V_{AOUT,2}$ . Sensor specific calibration data, configuration and product ID are stored in an embedded NVM.

## 1. Absolute Maximum Ratings

Stresses beyond these absolute maximum ratings listed below may cause permanent damage to the device. These are stress ratings only; operation of the device at these or any other conditions beyond those listed in the operational sections of this document is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability. All voltages referred to VSS. Currents flowing into terminals are positive, those drawn out of a terminal are negative.

| No. | Description           | Condition              | Symbol            | Minimum | Maximum | Units |
|-----|-----------------------|------------------------|-------------------|---------|---------|-------|
| 1   | Supply Voltage        |                        | VDD               | -0.3    | 6       | V     |
| 2   | Analog output Voltage |                        | V <sub>Aout</sub> | -0.3    | VDD+0.3 | V     |
| 3   | Analog output Current |                        | I <sub>Aout</sub> | -15     | +15     | mA    |
| 4   | Ambient Pressure      |                        | p <sub>A</sub>    | 1       | 600     | kPa   |
| 5   | Junction Temperature  |                        | T <sub>J</sub>    | -40     | 130     | °C    |
| 6   | Storage Temperature   |                        | T <sub>STG</sub>  | -40     | 125     | °C    |
| 7   | Power Dissipation     | T <sub>A</sub> ≤ 125°C | P <sub>el</sub>   |         | 38      | mW    |

## 2. ESD

| No. | Description                       | Condition                          | Symbol                   | Min. | Typ. | Max. | Units |
|-----|-----------------------------------|------------------------------------|--------------------------|------|------|------|-------|
| 1   | ESD HBM Protection at all Pins    | AEC Q100-002 (HBM) chip level test | V <sub>ESD(HBM)</sub>    | -2   |      | 2    | kV    |
| 2   | ESD CDM Protection at all Pins    | AEC Q100-011 (CDM) chip level test | V <sub>ESD(CDM)</sub>    | -500 |      | 500  | V     |
| 3   | ESD CDM Protection at Corner Pins | AEC Q100-011 (CDM) chip level test | V <sub>ESD(CDM), C</sub> | -750 |      | 750  | V     |

### 3. Recommended Operating Conditions

The recommended operating conditions must not be exceeded in order to ensure proper functionality of the device. All parameters specified in the following sections refer to these recommended operating conditions unless stated otherwise.

| No. | Description                 | Condition                  | Symbol          | Min. | Typ. | Max. | Units |
|-----|-----------------------------|----------------------------|-----------------|------|------|------|-------|
| 1   | Supply Voltage              |                            | $V_{VDD}$       | 4.5  | -    | 5.5  | V     |
| 2   | Output current at AOUT (DC) | pull-up resistor applied   | $I_{AOUT,sink}$ | -    | -    | 2.0  | mA    |
| 3   | Output current at AOUT (DC) | pull-down resistor applied | $I_{AOUT,src}$  | -2.0 | -    | -    | mA    |
| 4   | Operating Pressure Range    |                            | $p_A$           | 60   |      | 165  | kPa   |
| 5   | Operating Temperature       | ambient                    | $T_A$           | -40  |      | +85  | °C    |

### 4. External Components

| No. | Description                    | Condition | Symbol     | Min. | Typ. | Max. | Units |
|-----|--------------------------------|-----------|------------|------|------|------|-------|
| 1   | Supply bypass capacitor*)      |           | $C_{VDD}$  |      | 100  |      | nF    |
| 2   | Capacitor load at analog out*) |           | $C_{AOUT}$ |      | 10   |      | nF    |

\* Not tested in production

## 5. Electrical Characteristics

### 5.1 Global Sensor Parameters

| No. | Description                                          | Condition                                                | Symbol            | Min. | Typ. | Max. | Units   |
|-----|------------------------------------------------------|----------------------------------------------------------|-------------------|------|------|------|---------|
| 1   | Output Sensitivity                                   | VDD = 5.0V                                               | $C_1$             |      | 40   |      | mV/ kPa |
| 2   | Accuracy pressure measurement, mid temperature range | $T_{MID} = 0 \dots 85^{\circ}\text{C}$ ,<br>60...165kPa, | $\Delta P_{TMID}$ | -1.0 |      | +1.0 | kPa     |
| 3   | Accuracy pressure measurement, low temperature range | $T_{LOW} = -40^{\circ}\text{C}$ ,<br>60...165kPa,        | $\Delta P_{TLOW}$ | -2.0 |      | +2.0 | kPa     |

### 5.2 Voltage Supply

| No. | Description                               | Condition            | Symbol       | Min. | Typ. | Max. | Units |
|-----|-------------------------------------------|----------------------|--------------|------|------|------|-------|
| 1   | Current consumption                       | Continuous Operation | $I_{VDD}$    | 1.0  | 5.0  | 7.0  | mA    |
| 2   | Power OK reset threshold VDD, rising edge |                      | $V_{VDD,TH}$ | 2.1  | 2.35 | 2.6  | V     |

### 5.3 Analog Output

| No. | Description                        | Condition                                                                        | Symbol               | Min. | Typ.      | Max. | Units             |
|-----|------------------------------------|----------------------------------------------------------------------------------|----------------------|------|-----------|------|-------------------|
| 1   | Linear output range, upper limit   | $R_{AOUT,PD} = 5\text{ k}\Omega$ ,<br>linearity error $< 7.5\text{ mV}$          | $V_{AOUT,UL,5k}$     | 94   | 96        |      | %VDD              |
| 2   | Linear output range, upper limit   | $R_{AOUT,PD} = 40\text{ k}\Omega$ ,<br>linearity error $< 7.5\text{ mV}$         | $V_{AOUT,UL,40k}$    | 97   | 97.5      |      | %VDD              |
| 3   | Linear output range, lower limit   | $R_{AOUT,PU} = 5\text{ k}\Omega$ ,<br>linearity error $< 7.5\text{ mV}$          | $V_{AOUT,LL,5k}$     |      | 4         | 6    | %VDD              |
| 4   | Linear output range, lower limit   | $R_{AOUT,PU} = 40\text{ k}\Omega$ ,<br>linearity error $< 7.5\text{ mV}$         | $V_{AOUT,LL,40k}$    |      | 1.5       | 2    | %VDD              |
| 5   | Analog output source current limit | $V_{AOUT} = V_{SS}$                                                              | $I_{AOUT,sourceLIM}$ | -20  | -16       | -12  | mA                |
| 6   | Analog output sink current limit   | $V_{AOUT} = V_{DD}$                                                              | $I_{AOUT,sinkLIM}$   | 12   | 16        | 20   | mA                |
| 7   | Power-up time*                     | from $V_{DD} > 4.5\text{V}$ to output<br>settled to 90% of final value           | $t_{UP}$             |      |           | 5    | ms                |
| 8   | Step response time*                | pressure step<br>response; output<br>rising from 10%<br>to 90% of final<br>value | $t_{RESP}$           |      |           | 1    | ms                |
| 9   | Step response settling time*       | pressure step<br>response; output<br>settling to full<br>accuracy                | $t_{Settle}$         |      |           | 10   | ms                |
| 10  | Output noise*                      |                                                                                  | $V_{o,noise}$        |      | tbd (2.0) |      | mV <sub>rms</sub> |

\* Not tested in production

## 6. Functional Description

### 6.1 Overview

The SM1111-EEN-S-165-000 is a high precision, factory calibrated absolute pressure sensor for barometric air pressure (BAP) measurement. Pressure output data are available at an analog ratiometric voltage output.

### 6.2 Global Sensor Parameters

#### 6.2.1 Analog Pressure Transfer Function

At the analog output AOUT the SM1111 sensor provides a calibrated voltage which is following a linear function of output voltage versus absolute pressure. The output voltage is always referenced to the supply VDD, i.e. the output is ratiometric:

$$V_{A,out} = V_{DD} (c_1 P_A + c_0)$$

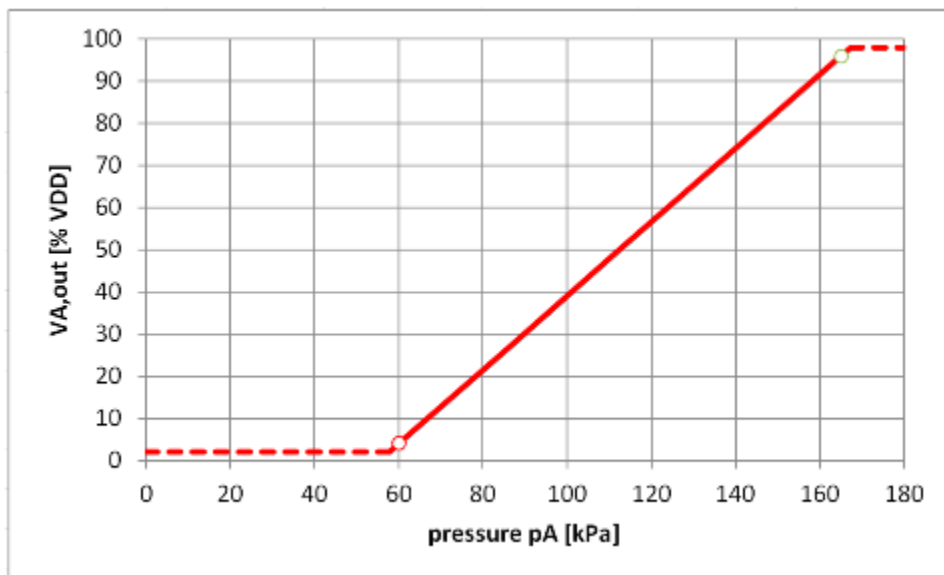
The characteristic parameters gain  $c_1$  and offset  $c_0$  are trimmed during the calibration process.

#### 6.2.2 Pressure Transfer Function

Pressure transfer function parameters, analog output

| Pressure  |                | AOUT voltage | @ VDD = 5.0 V | Sensitivity / Offset |         |       |
|-----------|----------------|--------------|---------------|----------------------|---------|-------|
| Symbol    | Pressure [kPa] | Symbol       | Voltage [V]   | Symbol               | Value   | Unit  |
| $P_{A,1}$ | 60             | $V_{AOUT,1}$ | 0.2           | $c_1$                | 0.876   | %/kPa |
| $P_{A,2}$ | 165            | $V_{AOUT,2}$ | 4.8           | $c_0$                | -48.571 | %     |

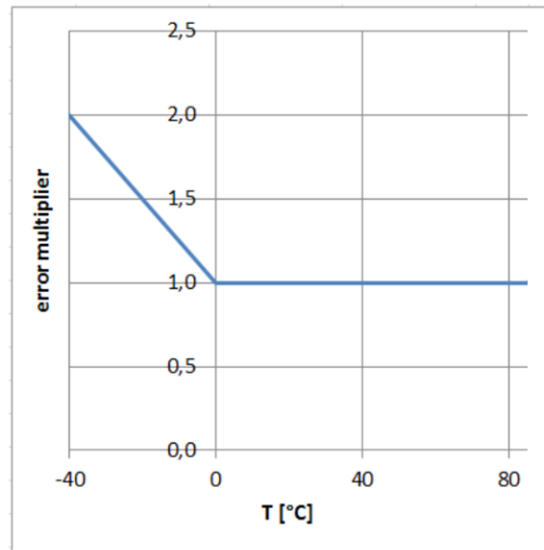
The transfer characteristic is depicted in the diagram below



### 6.2.3 Pressure Accuracy

The accuracy of the measured pressure output is given in medium temperature range  $T_{MID} = 0 \dots 85^{\circ}\text{C}$ , low temperature range  $T_{LOW} = -40^{\circ}\text{C} \dots 0^{\circ}\text{C}$ . Best accuracy is achieved in the medium temperature range.

The accuracy band is widened linearly towards the min. temperature as shown below:



### 6.3 Voltage Supply

The sensor device is supplied from pin VDD (typical 5.0V). From this supply input several internal voltage regulators are generating stabilized voltage levels for analog and digital circuit sections. The different internal voltage levels are supervised by comparator structures ("power OK check").

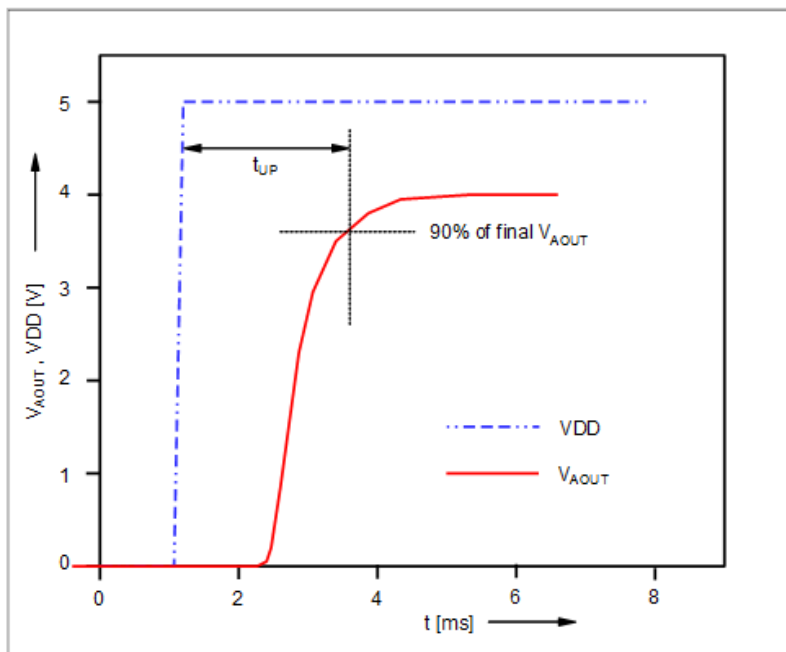
Also, a stabilized supply voltage for the internal resistive pressure cell is derived from VDD.

## 6.4 Analog Output

The analog output at AOUT is equipped with a rail-to-rail analog voltage buffer which is driven by a DA-converter.

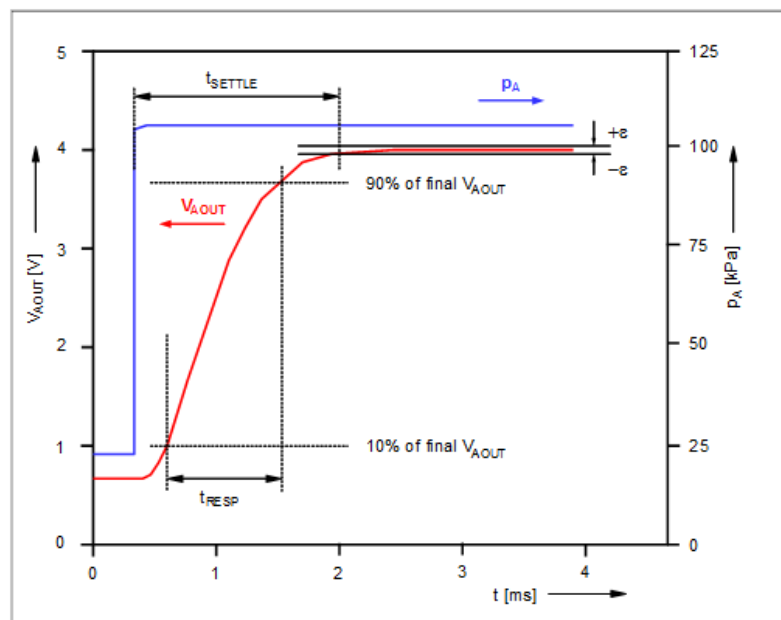
### Power-Up Delay Time

The settling of the pressure output AOUT after power-up is described by the power-up time (delay) as depicted in the following diagram.



### Step Response Timing

The reaction of the output to a step at the pressure input is described by a (basic) response time  $t_{RESP}$  which includes both chip internal latency time of the digital sensor signal processor and its characteristic filter response. To characterize the complete settling to the final output value at a given constant pressure, the parameter  $t_{SETTLE}$  is introduced. It specifies the time until the output signal is stable to an error band  $\epsilon$ , where  $\epsilon$  describes the specified pressure tolerance  $\Delta P$ . These parameters are depicted in the following timing diagram.



## 6.5 Diagnosis Functions

### 6.5.1 Sensor Bridge Diagnostics

Internal errors of the pressure sensor shall be detected and indicated at the signal output AOUT as described in the section **Error Indication** below.

#### Bridge Diagnostics

An integrated bridge diagnostic circuit supervises the resistive pressure sensor cell to detect any of the faults as follows:

##### *Sensor faults:*

- Short of any of the four bridge resistors of the pressure cell
- Interruption of any of the four of bridge resistors

##### *Wiring faults:*

- Open connection of any of the bridge supply or signal inputs SVDD, SVSS, SIP, or SIN
- Wrong connection of any sensor bridge terminal SIP or SIN to either SVDD or SVSS

For bridge diagnostics the signal input path pins SIP and SIN are pulled to ground with two matched low current sinks, which are active permanently (true background diagnostics). The voltage levels of the two signal path inputs (SIP and SIN) are monitored by two window comparators with detection thresholds of the low and high comparators at 25% SVDD and 75% SVDD, respectively.

The comparator outputs are combined in a logic (OR) and fed to a debouncing low pass filter. In case a *bridge check fail* event an error indicator bit will be set to initiate the error indication at AOUT (s. below).

#### Bridge Supply Diagnostics

Another comparator function checks if the supply to the sensor bridge is in its specified range. Also, in case of a *bridge supply fail* event an error indicator bit will be set to initiate the error indication at AOUT (s. below).

#### Error indication

If a bridge diagnosis failure or bridge supply failure occurred, this error will be indicated by pulling the output AOUT to ground level (VSS).

### 6.5.2 Configuration Memory Check

The integrity of data stored in the embedded NVM used as the configuration memory (calibration parameters, device configuration, device ID, etc.) is checked at power-up of the component by calculation of a check sum (CRC). If a CRC is detected no reliable pressure calculation is possible. Therefore, the sensor remains in idle state, without transferring pressure data to DAC output registers.

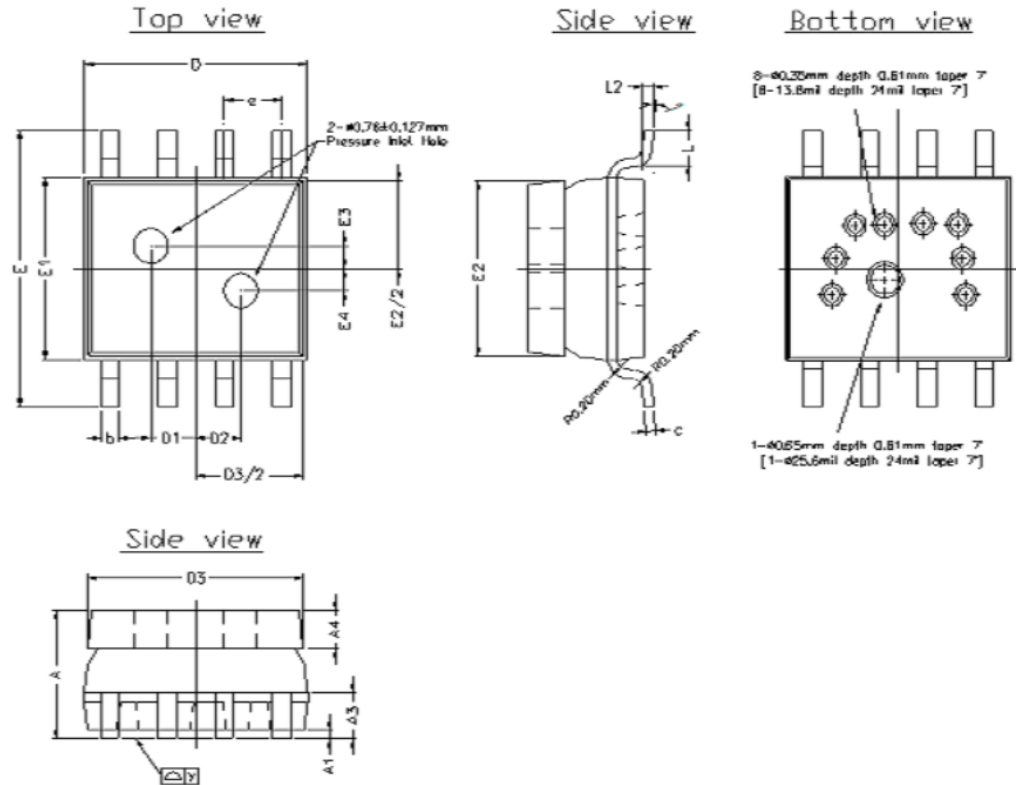
#### Error Indication

If an NVM CRC error occurs, the pin AOUT will remain in high impedance state after power-up. This state can be indicated to a receiver by a pull-down (or pull-up) resistor on the output line, which will force the output of the device out of the regular voltage range.

## 7. Package Reference

The SM1111-EEN-S-165-000 is available in a Pb free, RoHs compliant, 8-pin SO plastic package according to JEDEC MO-012-F, variant AA. The package is classified to Moisture Sensitivity Level 3 (MSL 3) according to JEDEC J-STD-020E with a soldering peak temperature of 260°C. **Note:** Thermal resistance junction to ambient  $R_{th,ja}$  is 160 °C/W, based on JEDEC standard JESD-51.

Package Outline:



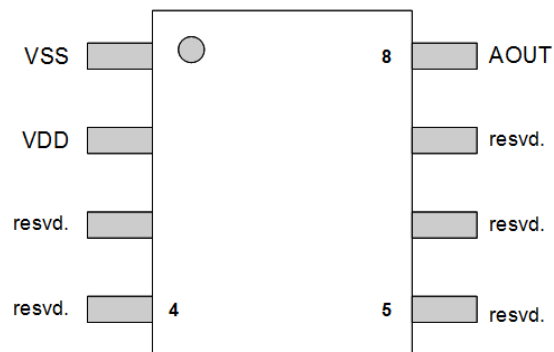
**Note:** Contact factory for specific location and type of pin 1 identification.

Package Characteristics:

| Description                                   | Symbol | Unit | Min. | Typ.     | Max. |
|-----------------------------------------------|--------|------|------|----------|------|
| Package height                                | A      | mm   |      | 2.79     |      |
| Stand off                                     | A1     | mm   |      | 0.19     |      |
| Width of terminal leads                       | b      | mm   |      | 0.41     |      |
| Thickness of terminal leads                   | c      | mm   |      | 0.20 Ref |      |
| Length of terminal for soldering to substrate | L      | mm   |      | 0.76     |      |
| Angle of lead mounting area                   | Ø      | °    | 0    | -        | 8    |
| Lead pitch                                    | e      | mm   |      | 1.27 BSC |      |
| Package length                                | D      | mm   |      | 4.95     |      |
| Package total width                           | E      | mm   |      | 6.00     |      |
| Package body width                            | E1     | mm   |      | 3.95     |      |

| Description                                   | Symbol  | Unit | Min. | Typ.     | Max. |
|-----------------------------------------------|---------|------|------|----------|------|
| Thickness of the lid                          | A4      | mm   |      | 0.83 Ref |      |
| Length of lid                                 | D3      | mm   |      | 4.80     |      |
| Width of lid                                  | E2      | mm   |      | 3.80     |      |
| Off center position, longitudinal, inlet hole | D1 / D2 | mm   |      | 1.00     |      |
| Off center position, lateral, inlet hole      | E3 / E4 | mm   |      | 0.49     |      |

#### Pin Configuration



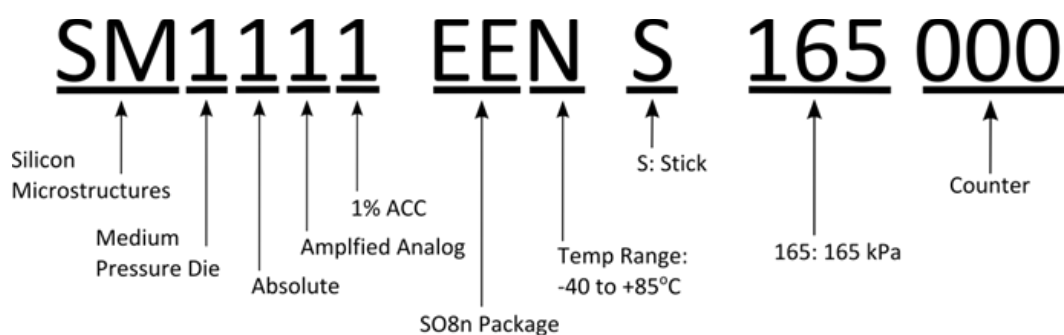
#### Pin Description

| Pin | Name     | Type | Description                         |
|-----|----------|------|-------------------------------------|
| 1   | VSS      | S    | Ground (Negative device supply)     |
| 2   | VDD      | S    | Supply Voltage                      |
| 3   | Reserved | -    | Reserved, Connect to VSS (on PCB)   |
| 4   | Reserved | -    | Reserved, Connect to VSS (on PCB)   |
| 5   | Reserved | -    | Reserved, Connect to VSS (on PCB)   |
| 6   | Reserved | -    | Reserved, Connect to VSS (on PCB)   |
| 7   | Reserved | -    | Reserved, Connect to VSS (on PCB)   |
| 8   | AOUT     | A_O  | Analog voltage output (ratiometric) |

## Ordering Information

| Order Code           | Minimum Pressure Range | Positive Pressure Range | Pressure Type | Supply Voltage | Port Configuration | Shipping Method |
|----------------------|------------------------|-------------------------|---------------|----------------|--------------------|-----------------|
| SM1111-EEN-S-165-000 | 60 kPa                 | 165 kPa                 | Absolute      | 5 V            | Dual Hole          | Stick           |
| SM1111-EEN-T-165-000 |                        |                         |               |                |                    | Tape & Reel     |

## Part Number Legend



## Silicon Microstructures Warranty and Disclaimer:

Silicon Microstructures, Inc. reserves the right to make changes without further notice to any products herein and to amend the contents of this data sheet at any time and at its sole discretion.

Information in this document is provided solely to enable software and system implementers to use Silicon Microstructures, Inc. products and/or services. No express or implied copyright licenses are granted hereunder to design or fabricate any silicon-based microstructures based on the information in this document.

Silicon Microstructures, Inc. makes no warranty, representation, or guarantee regarding the suitability of its products for any particular purpose, nor does Silicon Microstructures, Inc. assume any liability arising out of the application or use of any product or silicon-based microstructure, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters which may be provided in Silicon Microstructure's data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals", must be validated for each customer application by customer's technical experts. Silicon Microstructures, Inc. does not convey any license under its patent rights nor the rights of others. Silicon Microstructures, Inc. makes no representation that the circuits are free of patent infringement. Silicon Microstructures, Inc. products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Silicon Microstructures, Inc. product could create a situation where personal injury or death may occur. Should Buyer purchase or use Silicon Microstructures, Inc. products for any such unintended or unauthorized application, Buyer shall indemnify and hold Silicon Microstructures, Inc. and its officers, employees, subsidiaries, affiliates, and distributors harmless 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 such claim alleges that Silicon Microstructures, Inc. was negligent regarding the design or manufacture of the part.

Silicon Microstructures, Inc. warrants goods of its manufacture as being free of defective materials and faulty workmanship. Silicon Microstructures, Inc. standard product warranty applies unless agreed to otherwise by Silicon Microstructures, Inc. in writing; please refer to your order acknowledgement or contact Silicon Microstructures, Inc. directly for specific warranty details. If warranted goods are returned to Silicon Microstructures, Inc. during the period of coverage, Silicon Microstructures, Inc. will repair or replace, at its option, without charge those items it finds defective. The foregoing is buyer's sole remedy and is in lieu of all warranties, expressed or implied, including those of merchantability and fitness for a particular purpose. In no event shall Silicon Microstructures, Inc. be liable for consequential, special, or indirect damages.

While Silicon Microstructures, Inc. provides application assistance personally, through its literature and the Silicon Microstructures, Inc. website, it is up to the customer to determine the suitability of the product for its specific application. The information supplied by Silicon Microstructures, Inc. is believed to be accurate and reliable as of this printing. However, Silicon Microstructures, Inc. assumes no responsibility for its use. Silicon Microstructures, Inc. assumes no responsibility for any inaccuracies and/or errors in this publication and reserves the right to make changes without further notice to any products or specifications herein

Silicon Microstructures, Inc.™ and the Silicon Microstructures, Inc. logo are trademarks of Silicon Microstructures, Inc. All other service or product names are the property of their respective owners.

© Silicon Microstructures, Inc. 2001-2019. All rights reserved.