PRESSURE SENSORS

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 ±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 +/- 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_{Aout}	-0.3	VDD+0.3	V
3	Analog output Current		I_{Aout}	-15	+15	mA
4	Ambient Pressure		p_A	1	600	kPa
5	Junction Temperature		T_J	-40	130	°C
6	Storage Temperature		T_{STG}	-40	125	°C
7	Power Dissipation	$T_A \leq 125°C$	P_{el}		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	$V_{ESD(HBM)}$	-2		2	kV
2	ESD CDM Protection at all Pins	AEC Q100-011 (CDM) chip level test	$V_{ESD(CDM)}$	-500		500	V
3	ESD CDM Protection at Corner Pins	AEC Q100-011 (CDM) chip level test	$V_{ESD(CDM), C}$	-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 ...85°C, 60...165kPa,	ΔP_{TMID}	-1.0		+1.0	kPa
3	Accuracy pressure measurement, low temperature range	T_{LOW} = -40°C, 60...165kPa,	ΔP_{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 kΩ, linearity error < 7.5 mV	$V_{AOUT,UL,5k}$	94	96		%VDD
2	Linear output range, upper limit	$R_{AOUT,PD}$ = 40 kΩ, linearity error < 7.5 mV	$V_{AOUT,UL,40k}$	97	97.5		%VDD
3	Linear output range, lower limit	$R_{AOUT,PU}$ = 5 kΩ, linearity error < 7.5 mV	$V_{AOUT,LL,5k}$		4	6	%VDD
4	Linear output range, lower limit	$R_{AOUT,PU}$ = 40 kΩ, linearity error < 7.5 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 VDD > 4.5V to output settled to 90% of final value	t_{UP}			5	ms
8	Step response time*	pressure step response; output rising from 10% to 90% of final value	t_{RESP}			1	ms
9	Step response settling time*	pressure step response; output settling to full accuracy	t_{Settle}			10	ms
10	Output noise*		$v_{o,noise}$		tbd (2.0)		mV_{rms}

* 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:

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

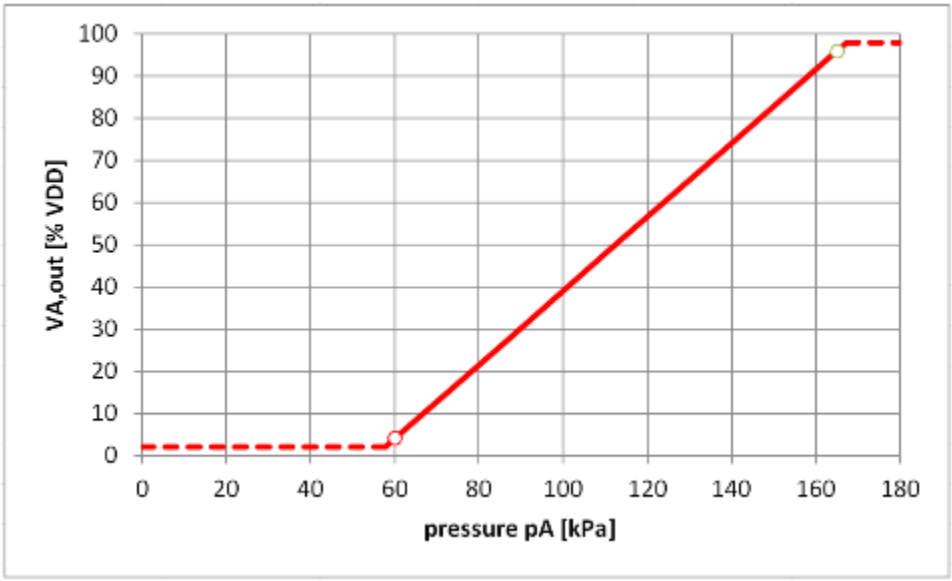
The characteristic parameters gain c_1 and offset c_0 are trimmed during the calibration process.

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	%

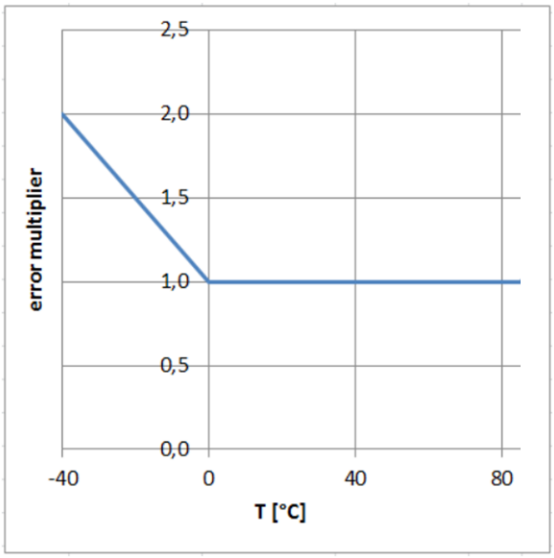
The transfer characteristic is depicted in the diagram below



6.2.3 Pressure Accuracy

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

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



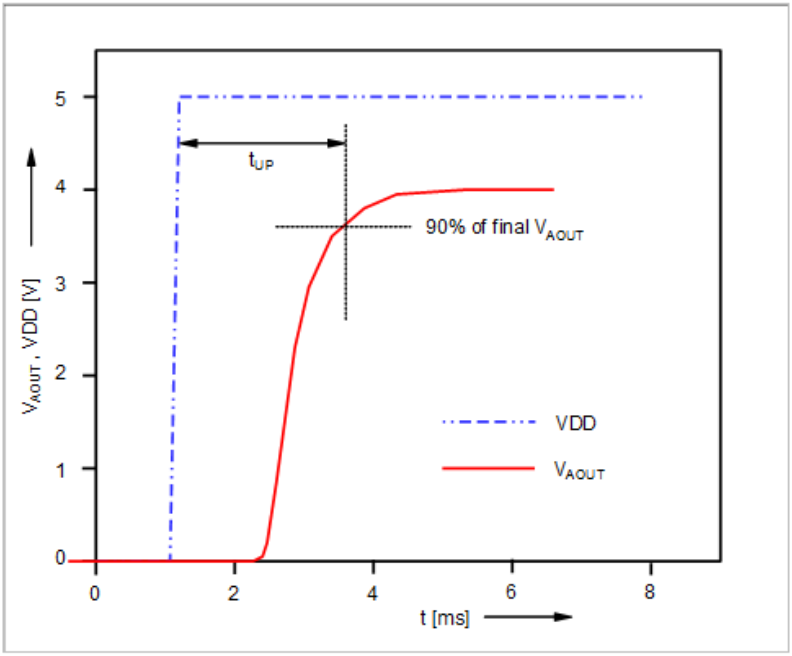
6.3 Voltage Supply

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.

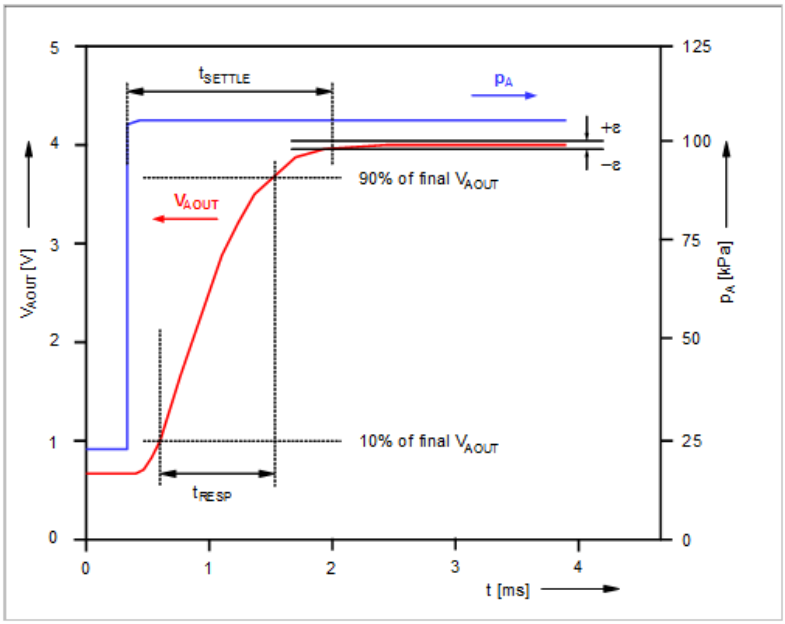
6.4 Analog Output

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 ε, where ε describes the specified pressure tolerance ΔP. 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).

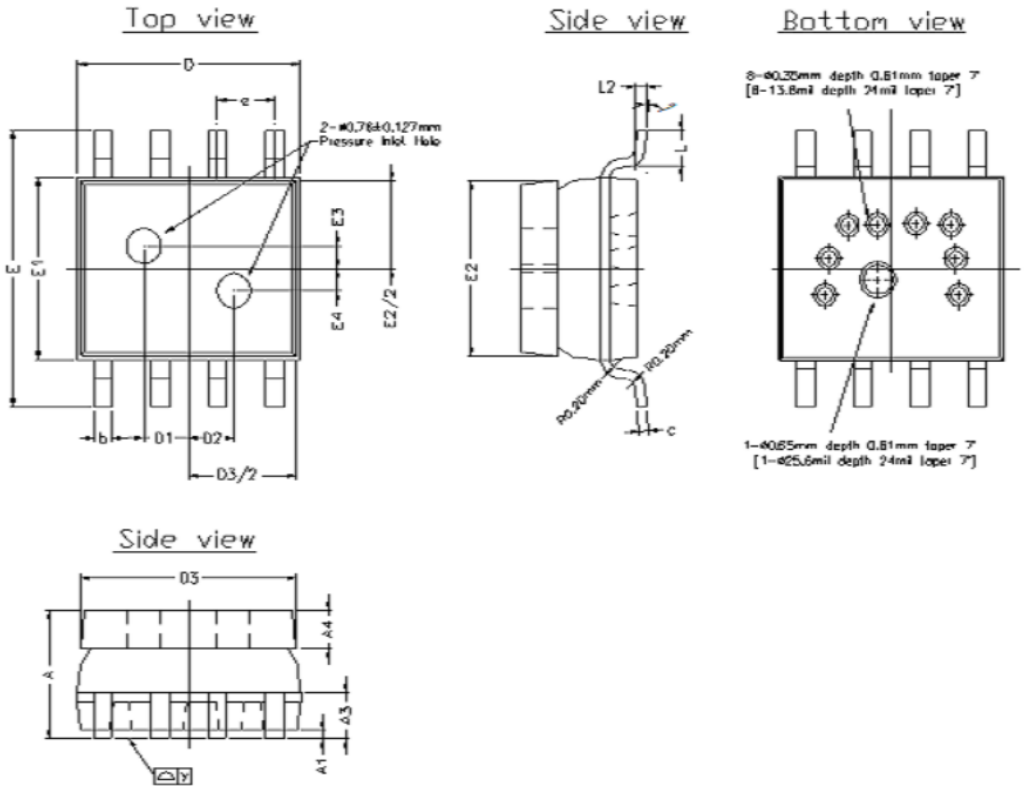
6.5.2 Configuration Memory Check
The integrity of data stored in the embedded NVM used as the configuration memory (calibration parameters, device configuration, device ID, etc.) is checked at power-up of the component by calculation of a check sum (CRC). If a CRC is detected no reliable pressure calculation 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:



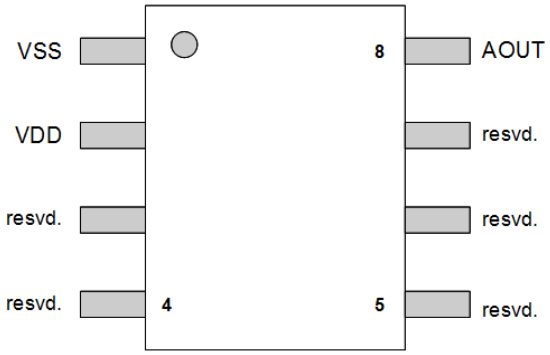
Note: Contact factory for specific location and type of pin 1 identification.

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	Θ	°	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



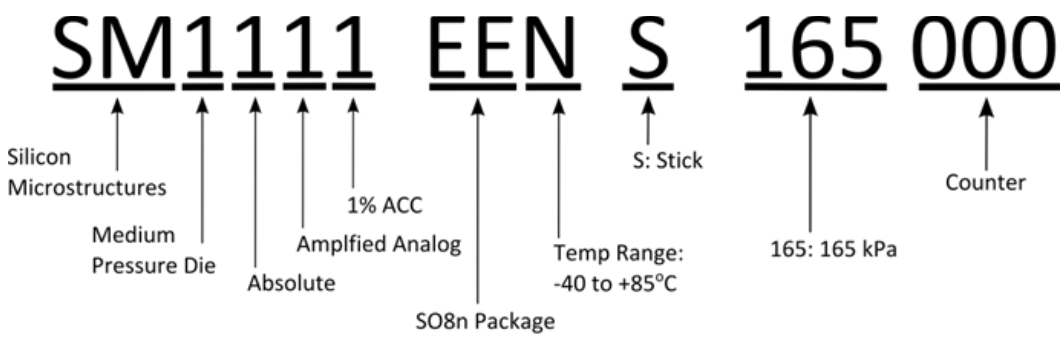
Pin Description

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



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