Triaxial ±2g analog Accelerometer SMB363

KEY FEATURES

- Three-axis accelerometer
- Standard SMD package: QFN 4x4mm^2 footprint, 1.2mm height
- 2 operation modes: Standby- and Normal mode
- Ultra-low power consumption: 200µA in operation- and 1µA in Standby mode
- 1 ms turn on time form Standby- to operation mode
- Analog output signals: 3 parallel (X, Y, Z) and 1 serial (multiplexed X, Y, Z)
- Internal 1kHz first-order low-pass analog filter
- On-chip gain and offset compensation, calibrated on factory level.
- On-chip trimmed oscillator.
- Triggerable self-test capability of MEMS sensor element and ASIC
- RoHS lead-free compliant
- Based on automotive-proven Bosch MEMS wafer-fab technology processes.

TYPICAL APPLICATIONS

Tilt, motion and vibration sensing in
- Gaming
- Virtual reality
- Sports- and Life Style Wear
- Cell Phones
- Handhelds
- Healthcare
- Patient Monitoring
- Navigation
- Electronic Compass Compensation
- Computer Peripherals
- Man-Machine Interfaces

THE SMB363 IN GENERAL

The SMB363 is a triaxial low-g acceleration sensor for consumer market applications, available in a standard SMD QFN package with a footprint of $4x4mm^2$ and a height of 1.2mm. It allows measurements of static as well as dynamic accelerations. Due to its three perpendicular axes it gives the absolute orientation in a gravity field. As all other Bosch inertial sensors, the SMB363 is a two-chip arrangement, which combines an application-specific integrated circuit (ASIC) with a three-channel silicon accelerometer, to form a true micro electro mechanical system (MEMS).

The ASIC evaluates the output of the acceleration-sensing element, corresponding to the differential capacitance principle. The underlying MEMS technology processes have proven their capability according to the strictest automotive standards in more than 100 million Bosch inertial sensors a year so far.

The SMB363 provides 3 parallel analog output signals in a ±2g acceleration range. All acceleration signals are permanently available on 3 independent analog pads through 110kΩ resistors on each pad. This allows the user defining the signal bandwidth by the mean of external capacitors connected between each channel output and ground. Additional to the parallel X, Y and Z output signals there is the option to multiplex any axis to 1 supplementary output pin in a freely customized manner.

For each axis, an independent analog 1kHz first-order low-pass filter is included to provide preconditioning of the measured acceleration signal. Additional signal preconditioning steps are performed by a digital to analog converter for offset and gain correction purposes with a subsequent signal amplification. The output signals are fully ratiometric offering a sensitivity of 500mV/g at 2.5V supply voltage and 200µg/√Hz noise level.

The typical current consumption is 200µA in operation mode. Furthermore, the sensor can be switched into an Standby mode via supplementary selection pins. In Standby mode the sensor module features an ultra low current consumption of only 1µA. The return from Standby mode to full performance conditions is performed in less than 1ms.

The SMB363 sensor module is ready to use due to test and calibration at factory level. All calibration parameters, e.g. for offset and sensitivity, are stored in an internal EEPROM. The sensor also features full self-test capability for all three axes. It is activated via a digital self test activation pin which results in a physical deflection of the seismic mass in the sensing element due to electrostatic force. Thus, it provides full testing of the complete signal evaluation path including the MEMS acceleration-sensing element and the evaluation ASIC.

CONTENT

1 Specification

If not stated otherwise, the given values are maximum values over lifetime and full performance temperature and voltage ranges.

Operating Range

Parameter	Symbol	Condition	Min	Typ	Max	Units
Acceleration Range	g_{FS2g}		± 2			g
Supply Voltage	V_{DD}	full performance	2.3	2.5	3.5	V
Digital Input Low Level	VIL	for TEST, ST, SEL.0 and SEL.1			0.3 * V_{DD}	V
Digital Input High Level	VIH	for TEST, ST, SEL.0 and SEL.1	0.7 * V_{DD}			V
Supply Current in Normal Mode	I_{DD}	analog and digital		200		µA
Supply Current in Standby Mode	I_{DDsbm}	analog and digital			1	µA
Operating Temperature	T_A	full performance	-40		+85	°C

Output Signal

Parameter	Symbol	Condition	Min	Typ	Max	Units
Zero-g Voltage	Off	In general		V_{DD} / 2		V
		T_A = 25°C, V_{DD} = 2.5V		1.25		
Sensitivity	S	In general		V_{DD} / 5		V/g
		T_A = 25°C, V_{DD} = 2.5V		0.5		
Zero-g Voltage Temperature Drift	TCO	-40°C ≤ T_A ≤ +85°C		±2		mg/K
Bandwidth 1st Order Filter	f_{-3dB}	with 470pF connected to AX, AY, AZ		1.00		kHz
Nonlinearity	NL	best fit straight line		±0.5		%FS
Self Test Response	TST	activated via test pin		0.3 * V_{DD}		mV
Output Noise	n_{rms}	rms		200		$\mu g / \sqrt{Hz}$

SENSOR PERFORMANCE AND OPERATING CONDITIONS

Parameter	Symbol	Condition	Min	Typ	Max	Units
Start-Up Time[3]	T_{st_up}	with 470pF connected to AX, AY, AZ		3		ms
Wake-Up Time[4]	T_{w_up}	with 470pF connected to AX, AY, AZ		1		ms
Output Resistance	R_x, R_y, R_z			110		kΩ
Pull-Down Resistance	$R_{pulldown}$	on ST and TEST pad		20		kΩ
Maximal Load on AMUX	C_L				25	pF
Setup Time on AMUX	T_{set_up}	with maximal load on AMUX Less than 1% error between signal and asymptotic values			50	µs

MECHANICAL TRAIT

Parameter	Symbol	Condition	Min	Typ	Max	Units
Cross Axis Sensitivity	$\overline{S}$	relative contribution between 3 axes		0.2		%
Alignment Error	δ_a	relative to package outline		±0.5		°

[3] The start-up time (incl. power on reset POR) is the total duration between application of the voltage supply and obtaining analog signals on the three channels with less than 1% error (full scale) between signal and respective asymptotic values. The start-up time is measured with on-chip capacitors, i.e. the mechanical time constant of the sensor is not taken into account.

[4] The wake-up time is the total duration between transiting from Standby to Normal mode and obtaining analog signals on the three channels with less than 1% (of full scale) error between signal and respective asymptotic values. The wake-up time is measured with on-chip capacitors, i.e. the mechanical time constant of the sensor is not taken into account.

2 Absolute Maximum Ratings

Parameter	Condition / Symbol	Min	Max	Units
Supply Voltage	V_{DD}	-0.3	3.6	V
Pad Voltage	V_{pad}	V_{ss}-0.3	V_{dd}+0.3	V
Power Supply Perturbations	V_{DD}_pert on V_{DD} 100 mV ripple peak to peak		0.05	µV s
Junction Temperature	T_j		+150	°C
Storage Temperature	T_{store}	-50	+150	°C
Room Temperature for Testing	T_{rt}	22	28	°C
Mechanical Shock	duration ≤ 50µs		10,000	g
	duration ≤ 1.0ms		2,000	g
	free fall onto hard surfaces		1.5	m
ESD	HBM, at any pin		2	kV
	CDM		500	V

3 SMB363 features

3.1 General Description

The SMB363 is a fully calibrated, triaxial low-g analog acceleration sensor. It allows measurements of static as well as dynamic accelerations in all three dimensions. Due to its three perpendicular axes it gives the absolute orientation in a gravity field. The sensor is set up as a two-chip stack arrangement consisting of a three-channel capacity differential MEMS acceleration-sensing element and an application specific integrated circuit (ASIC). Both parts are embedded in a standard, surface mountable quad flat no lead package (QFN). In the following, the QFN packed two-chip stack arrangement is defined as sensor module.

The accelerometer features a low-pass characteristic, with a bandwidth limited to 1 kHz (nominal value). This value can further be reduced with external capacitors to improve or customize noise level. It is advised to reduce bandwidth to minimum value required in the application.

The bandwidth can be selected by the value of the capacitors connected to the AX, AY and AZ output. Each channel behaves like an independent low-pass RC filter, given by the internal 110kΩ resistor and the external capacitor.

3.1.1 MEMS Element

The production of the sensing element is based on standard semiconductor- and standard MEMS processes. The main steps are layer deposition, layer masking and layer structuring in a technology cycle, similar to the standard semiconductor manufacturing. In detail, the process cycle starts with the deposition of a thick epitaxial layer on a sacrificial oxide. The large thickness allows the design of working capacitances of up to 1pF. This in turn enables the hybrid two-chip stack assembly. The poly layer is patterned by deep reactive ion etching in an inductively coupled plasma (DRIE-ICP, the so-called Bosch process). A large aspect ratio and a very high anisotropy is achieved by periodic passivation of the side walls in between the etch intervals. Afterwards the sacrificial layer is removed. The sensing element is hermetically sealed by a bulk micromachined cap to prevent damages of the structure by dicing, packaging and operation of the device.

3.1.2 ASIC

The ASIC is produced in a standard CMOS process. It evaluates, corrects and amplifies the output signal of the MEMS acceleration-sensing element. Simplified considered, the ASIC consists mainly out of 3 capacity voltage converters and 3 signal conditioners, a channel multiplexer, a digital to analog converter an EEPROM memory and an internal RC oscillator. For customized testing and safety purposes an electrostatic force to the sensor electrodes can be induced and compared with a nominal condition. Thus, a general statement about the functional capability of the sensor module can be made at any time.

3.2 Channel Multiplexer

On the AX, AY, and AZ output pin there is always the possibility to grip the continuous analog output signals of the corresponding axis. Additional to these continuously available signals, there is the possibility to multiplex any of the 3 axis fully customized to one separate AMUX output pin via an internal channel multiplexer. This e.g. enables the option to read out all three axes at only one output pin.

Which of the acceleration signal of the 3 axis is actually multiplexed to the AMUX output pin – or in which sequence – can be selected through the corresponding SEL.0 and SEL.1 pins of the sensor module (see chapter 4.4).

4 Operation

4.1 Power-On Reset and Power-Up Sequence

The sensor features a on-chip power-on reset (POR). The POR is activated by power-on of the analog supply voltage. The POR is active during 100 µs (typical value).

4.2 Operation Mode Selection

Two operation modes can be selected: NORMAL and STANDBY mode. The Standby mode is selected by setting SEL1 and SEL0 according to the table given below.

Standby Mode	Operation feature	Current Consumption	Description
0	full performance	200 µA (typical)	Acceleration measurements of all axes (AX, AY, AZ and AMUX) are performed. All sensor features are enabled.
1	current saving	1 µA (typical)	Acceleration measurements are stopped, AX, AY, AZ and AMUX signals are driven to GND through 110kΩ resistors.

When Standby mode is activated, all sensor electrodes are connected to Vss. No electrostatic forces are generated to the electrodes. Power consumption is drastically reduced in this mode. All blocks are disabled except some bias generation and power-on reset generation. This feature enables ultra low power mode operation if the sensor module is turned into Standby mode e.g. between each acceleration measurement.

4.3 Analog Output on AX, AY and AZ

By selecting the operation mode to “Normal” all 3 axis provide acceleration measurement signals simultaneously on the AX, AY and AZ pins according to the following equation.

$$A_X = \left(\frac{V_{DD}}{2} + S \cdot a_X\right) \qquad A_Y = \left(\frac{V_{DD}}{2} + S \cdot a_Y\right) \qquad A_Z = \left(\frac{V_{DD}}{2} + S \cdot a_Z\right)$$

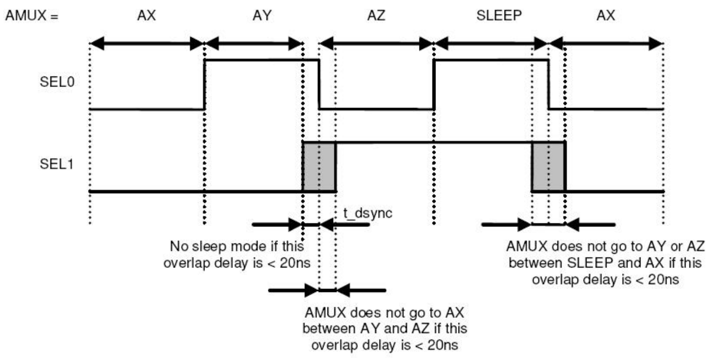
AX, AY and AZ are the vector components of the acting acceleration. According to chapter 1 the sensitivity corresponds to VDD/5 given in V/g. The maximal acceleration range is ± 2g.

4.4 Channel Multiplexer Output Selection

Using the Channel Multiplexer, it is possible to choose specific axis output signals on the AMUX pin. The channel selection on AMUX is performed by setting SEL.0 and SEL.1 according to the following table:

SEL.1	SEL.0	Output Signal on Channel Multiplexer Serial Output Pin (AMUX)
0	0	AMUX = AX
0	1	AMUX = AY
1	0	AMUX = AZ
1	1	Sensor Modul set to Standby Mode, no Signal on X, Y, Z and AMUX

<u>IMPORTANT NOTE:</u> SEL.0 and SEL.1 transitions must be synchronous within a 20ns tolerance to avoid the ASIC to switch to an unwanted state at transitions (valid for the four possible transitions where the two signals SEL.0 and SEL.1 have to change simultaneously). See also the figure given below.

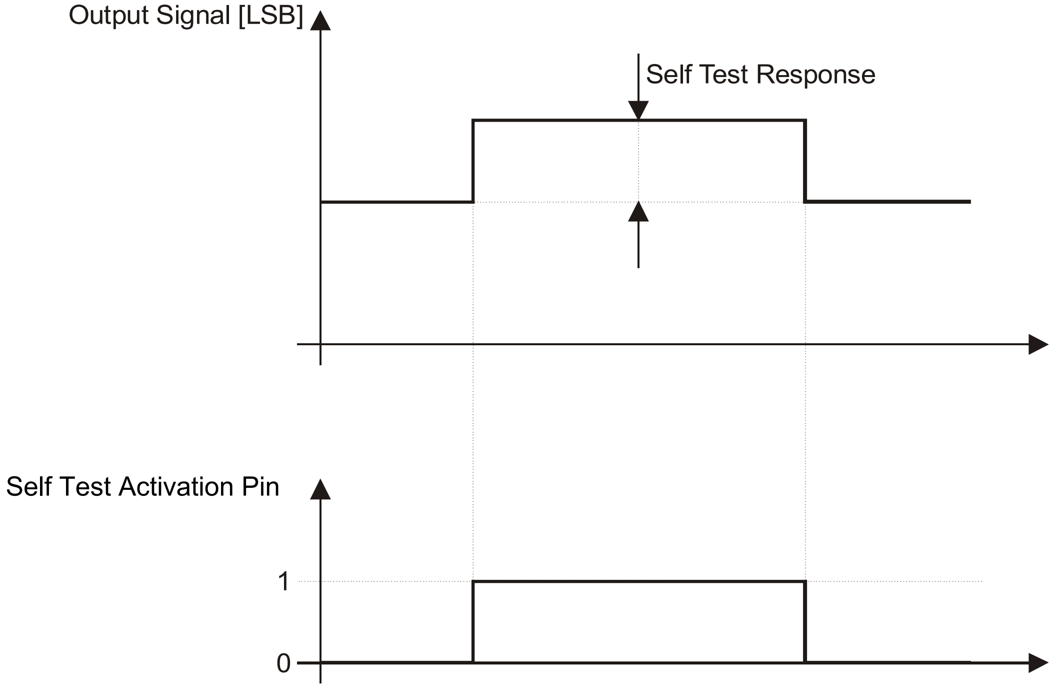


4.5 Self Test

The sensor features an on-chip self-test which can be activated by using the corresponding self test input pin. The self test is realized by a physical deflection of the seismic mass due to an electrostatic force. Thus, it provides full testing of the complete signal evaluation path including the MEMS sensor structure and the evaluation ASIC.

The self test is activated by setting the self test activation input pin to logic 1. The test acts on all three channels simultaneously. The typical change in output will be approximately 0.3 * V_{DD}, which corresponds to approximately 1.4g. The self test response remains as a static offset on the output as long as the self test activation input pin is not set back to logic 0.

While the self test is activated, any acceleration or gravitational force applied to the sensor will be observed in the output signal as a superposition of both acceleration and self test signal.

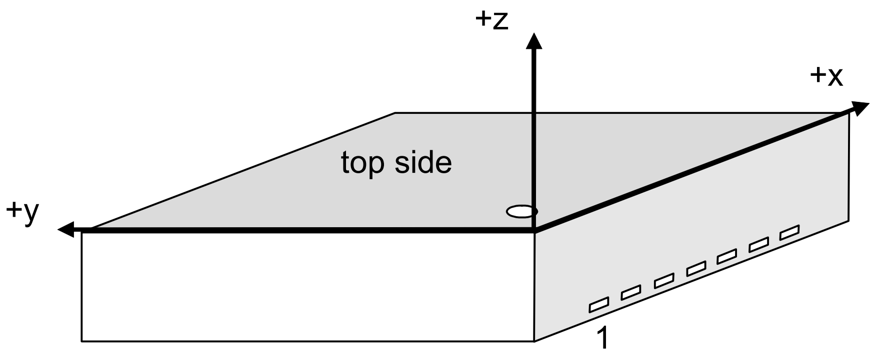


4.6 Polarity of the Acceleration Output

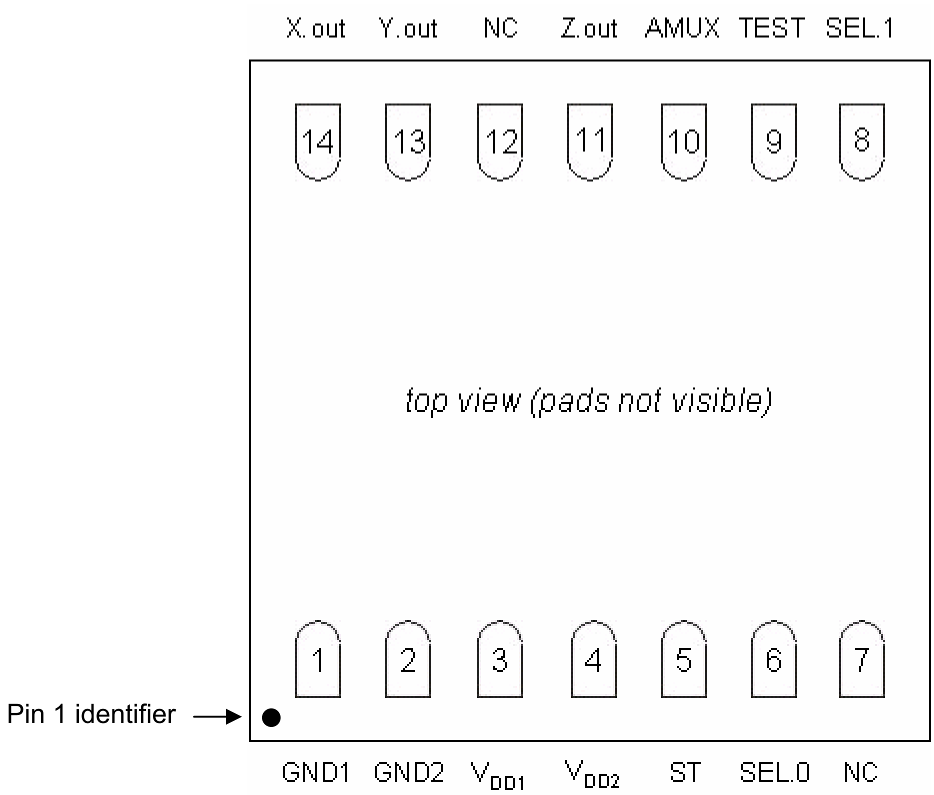
If the sensor is accelerated in the indicated directions, the corresponding channels will deliver a positive acceleration signal (dynamic acceleration).

Example: If the sensor is at rest or at uniform motion in a gravity field according to the figure given below, the output signals are:

- ± 0g for the X channel
- ± 0g for the Y channel
- + 1g for the Z channel



4.7 Pin Configuration

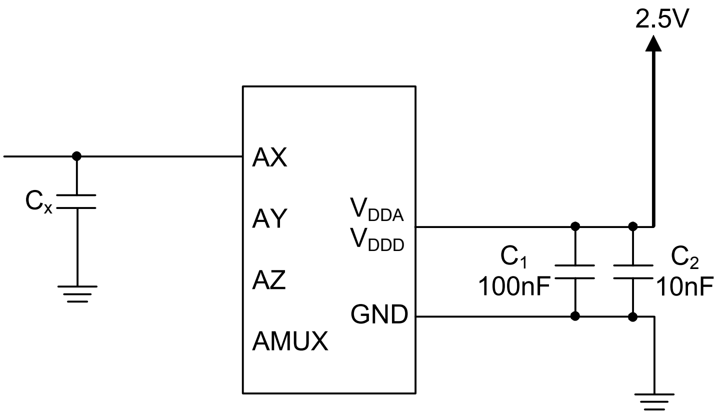


Pin	Name	Digital Analog	Description
01	GND1	A	Ground Connection Pin 1
02	GND2	A	Ground Connection Pin 2
03	VDD1	A in	Supply Voltage Connection Pin 1
04	VDD2	A in	Supply Voltage Connection Pin 2
05	ST	D in	Self Test Activation Pin
06	SEL.0	D in/out	Channel Multiplexer Selection Pin 1 and SPI I/O in test mode [1)]
07	NC	--	Not connected.
08	SEL.1	D in	Channel Multiplexer Selection Pin 2
09	TEST	D in/out	Do not connect! Pin used for factory trimming and calibration!
10	AMUX	A out	Channel Multiplexer Serial Output Pin
11	AZ	A out	Z Acceleration Parallel Output Pin
12	NC	--	Not connected.
13	AY	A out	Y Acceleration Parallel Output Pin
14	AX	A out	X Acceleration Parallel Output Pin

[1)] Connect to GND if Standby mode and multiplexed outputs will not be used.

4.8 Connecting Diagram

The following external components (c_1 and c_2) are recommended to decouple the power source.



According to the following equation a customized cut-off frequency can be realized by a simple dimension of C_x to create a RC low pass filter. The below given equation corresponds to the x-axis but it is also representative for the y- and z-axis.

$$f_{c\_x} = \frac{1}{2\pi \cdot 110k\Omega \cdot c_x}$$

4.9 Handling Instruction

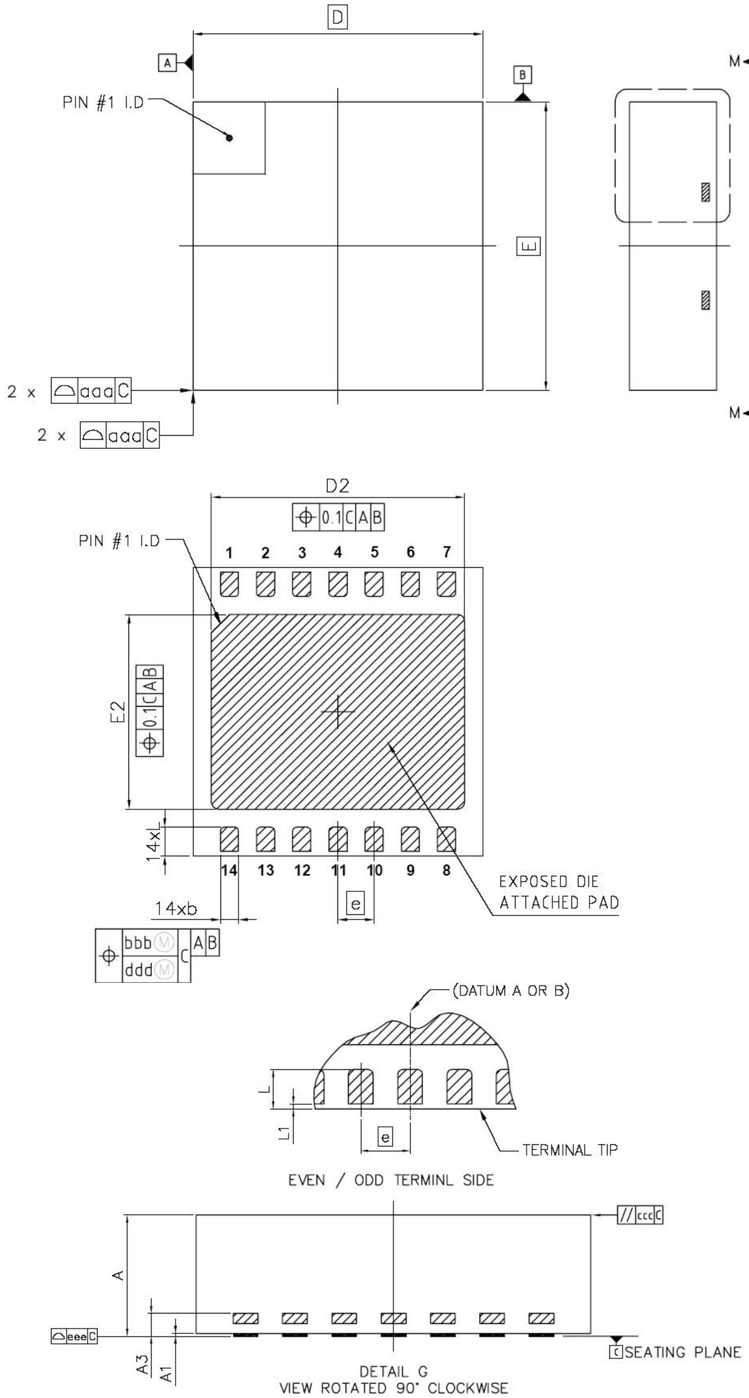
Micromechanical sensors are designed to sense acceleration with high accuracy even at low amplitudes and contain highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand g's. However, these limits might be exceeded in conditions with extreme shock loads such as e.g. hammer blow on or next to the sensor, dropping of the sensor onto hard surfaces etc.
We recommend to avoid g-forces beyond the specified limits (see section 2) during transport, handling and mounting of the sensors in a defined and qualified installation process.

This device has built-in protections against high electrostatic discharges or electric fields (2kV HBM); however, anti-static precautions should be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the supply voltage range. Unused inputs must always be tied to a defined logic voltage level.

5 Package

5.1 Outline Dimensions

The sensor housing is a standard QFN package. It is compliant with JEDEC Standard MO-229 Type VGGD-3. Its dimensions are the following:



Dim		Typ	
A		1.20	
A1			
A3		0.203 REF	
b		0.25	
D		4.00 BSC	
E		4.00 BSC	
D2		3.50	
E2		2.70	
e		0.50 BSC	
L		0.40	
L1			
aaa		0.10	
bbb		0.10	
ccc		0.10	
ddd		0.05	
eee		0.08	

Notes:

1.0 Dimensioning & Tolerancing confirm to ASME Y14.5M-1994.

2.0 All Dimensions are in millimeters and angles in degrees.

3.0 Dimension b Applies to metallized terminal and IS. Measured between 0.25mm and 0.30mm from terminal tip. Dimension L1 represents terminal full back from package edge up to 0.1mm is acceptable.

4.0 Coplanarity applies to the exposed heat sluig as well as the terminal.

5.0 Radius on terminal is optional.

6.0 Deviation to MO-229 Type VGGD-3:

Lead Length	L: 0.4 mm	instead of 0.45 to 0.65 mm
Package thickness	A: 1.2 mm	instead of 0.9 to 1.0 mm

5.2 Marking

5.2.1 Mass Production Samples

Labeling	Name	Symbol	Remark
	Product Number	TTT	
	Sub Lot ID	L	Coded alphanumerical
	Date Code	YM	Y: year ,alphanumerical 9=2009 A=2010, … M: month, Coded alphanumerical Jan=1 Dec=C
	Sensor Lot #	SSSS	
	ASIC Lot #	AAAA	
	Pin 1 identifier	●	

5.2.2 Engineering Samples

Labeling	Name	Symbol	Remark
*363A YWWAA ##### ##### ●	Eng.Sample ID	*	Engineering Samples are always marked with an asterisk.
	Product Name	363A	
	Date Code	YWW	Y: year ,alphanumerical WW: calendar week
	Strip Code	AA	
	ASIC Lot #	#####	
	SENSOR Lot #	#####	
	Pin 1 identifier	●	

5.3 Moisture Sensitivity Level and Soldering

The moisture sensitivity level of the SMB363 sensors corresponds to JEDEC Level 3, see also

- IPC/JEDEC J-STD-020C "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices"

- IPC/JEDEC J-STD-033A "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices".

The sensor fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C.

5.4 RoHS Compliancy

The SMB363 sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive, see also:

Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003
on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

6 Disclaimer

6.1 Engineering Samples

Engineering samples (marked with *) may not fulfill the complete technical data within this specification. As well, Engineering samples (marked with *) are not determined for use in safety relevant automotive applications, life support appliances reselling or passing to final consumers. The customer indemnifies Bosch Sensortec for product liability claims or waives of recourse to Bosch Sensortec, if third parties advance due to or in connection with a failure, a defect in function or misuse of the customer samples supplied by Bosch Sensortec.

6.2 Limiting values

Limiting values given are in accordance with the Absolute Maximum Ratings (Chapter 2). Stress above one or more of the limiting values may cause permanent damage to the device. Operation of the device at these or at any other conditions above is not implied. Exposure to limiting values for extended periods may also affect device reliability.

6.3 Life support- and automotive applications

The SMB363 is not designed for use in life support- or safety relevant automotive appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Again, the customer of Bosch Sensortec using or selling the SMB363 for use in such applications do so at one's own risk and agree again to fully indemnify Bosch Sensortec for any damages resulting from such improper use or sale.

Document History and Modification

Rev. No	**Chapter**	**Description of Modification/Changes**	**Date**
0.0		Begin	14-Mar-06
0.1		Progress	22-May-06
1.0		Review	27-May-06
1.1	3.2 4.8	Pin Configuration (pin 8 to 12)	06-Jul-06
1.2	Page 3 par. 3 Page 3 par. 4 1 1 1 3.2 4.4 4.5 4.5 4.6 5.2	110kΩ instead of 110kW 200 µV/√Hz instead of 250 µV/√Hz Table OPERATING RANGE Digital Input Table OUTPUT SIGNAL Table SENSOR PERFORMANCE Headline Block Diagram Sel.0 and Sel.1 interchanged 0.3*V_{DD} instead of 0.13*V_{DD} 1.4g instead of 640mg drawing 5.2.1 and 5.2.2 new	05-Sep-06

Bosch Sensortec GmbH
Gerhard-Kindler-Strasse 8
72770 Reutlingen

Leopold.Beer@bosch-sensortec.com
www.bosch-sensortec.com

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