



# MS5607-02BA03

# Barometric Pressure Sensor, with stainless steel cap

#### **SPECIFICATIONS**

- High resolution module, 20cm
- Fast conversion down to 1 ms
- Low power, 1  $\mu$ A (standby < 0.15  $\mu$ A)
- QFN package 5.0 x 3.0 x 1.0 mm<sup>3</sup>
- Supply voltage 1.8 to 3.6 V
- Integrated digital pressure sensor (24 bit ΔΣ ADC)
- Operating range: 10 to 1200 mbar, -40 to +85 °C
- I<sup>2</sup>C and SPI interface up to 20 MHz
- No external components (Internal oscillator)
- Excellent long term stability

The MS5607-02BA is a new generation of high resolution altimeter sensors from MEAS Switzerland with SPI and I2C bus interface. This barometric pressure sensor is optimized for altimeters and variometers with an altitude resolution of 20 cm. The sensor module includes a high linearity pressure sensor and an ultra low power 24 bit  $\Delta\Sigma$  ADC with internal factory calibrated coefficients. It provides a precise digital 24 bit pressure and temperature value and different operation modes that allow the user to optimize for conversion speed and current consumption. A high resolution temperature output allows the implementation of an altimeter/thermometer function without any additional sensor. The MS5607-02BA can be interfaced to virtually any microcontroller. The communication protocol is simple, without the need of programming internal registers in the device. Small dimensions of only 5.0 mm x 3.0 mm and a height of only 1.0 mm allow for integration in mobile devices. This new sensor module generation is based on leading MEMS technology and latest benefits from MEAS Switzerland proven experience and knowhow in high volume manufacturing of altimeter modules, which have been widely used for over a decade. The sensing principle employed leads to very low hysteresis and high stability of both pressure and temperature signal.

# **FEATURES**

# **FIELD OF APPLICATION**

Mobile altimeter / barometer systems

Bike computers

Variometers

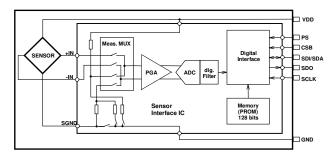
Dataloggers

Mobile phones / GPS

# **TECHNICAL DATA**

Sensor Performances (VDI	= 3 V)						
Pressure	Min	Тур	Max	Unit			
Range	10		1200	mbar			
ADC		24		bit			
Resolution (1)		/ 0.084 / .036 / 0.0		mbar			
Accuracy 25°C, 750 mbar	-1.5		+1.5	mbar			
Error band, -20°C to + 85°C 300 to 1100 mbar (2)	-2.5		+2.5	mbar			
Response time (1)	0.5 /	1.1 / 2.1 8.22	/ 4.1 /	ms			
Long term stability		±1		mbar/yr			
Temperature	Min	Тур	Max	Unit			
Range	-40		+85	°C			
Resolution		<0.01		°C			
Accuracy	-0.8		+0.8	°C			
. ,	Notes: (1) Oversampling Ratio: 256 / 512 / 1024 / 2048 / 4096 (2) With autozero at one pressure point						

# **FUNCTIONAL BLOCK DIAGRAM**



# PERFORMANCE SPECIFICATIONS

# **ABSOLUTE MAXIMUM RATINGS**

Parameter	Symbol	Conditions	Min.	Тур.	Max	Unit
Supply voltage	$V_{DD}$		-0.3		+4.0	V
Storage temperature	Ts		-40		+125	°C
Overpressure	P <sub>max</sub>				6	bar
Maximum Soldering Temperature	T <sub>max</sub>	40 sec max			250	°C
ESD rating		Human Body Model	-4		+4	kV
Latch up		JEDEC standard No 78	-100		+100	mA

# **ELECTRICAL CHARACTERISTICS**

Parameter	Symbol	Conditions	Min.	Тур.	Max	Unit
Operating Supply voltage	$V_{DD}$		1.8	3.0	3.6	V
Operating Temperature	Т		-40	+25	+85	°C
		OSR 4096		12.5		
Cupply gurrant		2048		6.3		
Supply current	I <sub>DD</sub>	1024		3.2		μΑ
(1 sample per sec.)		512		1.7		
		256		0.9		
Peak supply current		during conversion		1.4		mA
Standby supply current		at 25°C		0.02	0.14	μΑ
VDD Capacitor		From VDD to GND	100			nF

# **ANALOG DIGITAL CONVERTER (ADC)**

Parameter	Symbol	Conditions	S	Min.	Тур.	Max	Unit
Output Word					24		bit
		OSR	4096	7.40	8.22	9.04	
			2048	3.72	4.13	4.54	
Conversion time	tc		1024	1.88	2.08	2.28	ms
			512	0.95	1.06	1.17	
			256	0.48	0.54	0.60	

# PERFORMANCE SPECIFICATIONS (CONTINUED)

# PRESSURE OUTPUT CHARACTERISTICS (V<sub>DD</sub> = 3 V, T = 25°C UNLESS OTHERWISE NOTED)

Parameter	Conditio	ons	Min.	Тур.	Max	Unit
Operating Pressure Range	Prange	Full Accuracy	300		1100	mbar
Extended Pressure Range	P <sub>ext</sub>	Linear Range of ADC	10		1200	mbar
Total Error band, no autozero	at 050°	at 25°C, 7001100 mbar at 050°C, 3001100 mbar at -2085°C, 3001100 mbar			+1.5 +2.0 +3.5	mbar
Total Error band, autozero at one pressure point	at 050°	at 25°C, 7001100 mbar at 050°C, 3001100 mbar at -2085°C, 3001100 mbar			+0.5 +1.0 +2.5	mbar
Maximum error with supply voltage	V <sub>DD</sub> = 1.8	3 V 3.6 V	-2.5		+2.5	mbar
Resolution RMS	OSR	4096 2048 1024 512 256		0.024 0.036 0.054 0.084 0.130		mbar
Long-term stability				±1		mbar/yr
Reflow soldering impact	IPC/JEDEC J-STD-020C (See application note AN808)			+0.4		mbar
Recovering time after reflow (1)				7		days

<sup>(1)</sup> Time to recovering at least 66% of the reflow impact

# TEMPERATURE OUTPUT CHARACTERISTICS ( $V_{DD} = 3 \text{ V}, T = 25^{\circ}\text{C}$ UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Тур.	Max	Unit
	at 25°C		-0.8		+0.8	
Absolute Accuracy	-2085°C		-2.0		+2.0	°C
	-4085°C		-4.0		+4.0	
Maximum error with supply voltage	V <sub>DD</sub> = 1.8 V 3.6 V		-0.5		+0.5	°C
	OSR	4096		0.002		
		2048		0.003		
Resolution RMS		1024		0.005		°C
		512		0.008		
		256		0.012		

# PERFORMANCE SPECIFICATIONS (CONTINUED)

# DIGITAL INPUTS (CSB, I<sup>2</sup>C, DIN, SCLK)

Parameter	Symbol	Conditions	Min.	Тур.	Max	Unit
Serial data clock	SCLK	SPI protocol			20	MHz
Seriai data ciock	SULK	I <sup>2</sup> C protocol			400	KHz
Input high voltage	V <sub>IH</sub>	Pins CSB	80% V <sub>DD</sub>		100% V <sub>DD</sub>	V
Input low voltage	VIL		0% V <sub>DD</sub>		20% V <sub>DD</sub>	V
Input leakage current	I <sub>leak25°C</sub>	at 25°C			0.15	
input leakage current	I <sub>leak85°</sub> C	at 25 G			0.15	μΑ
Input capacitance	C <sub>IN</sub>				6	pF

# PRESSURE OUTPUTS (I<sup>2</sup>C, DOUT)

Parameter	Symbol	Conditions	Min.	Тур.	Max	Unit
Output high voltage	V <sub>OH</sub>	I <sub>source</sub> = 1.0 mA	80% V <sub>DD</sub>		100% V <sub>DD</sub>	V
Output low voltage	Vol	I <sub>sink</sub> = 1.0 mA	0% V <sub>DD</sub>		20% V <sub>DD</sub>	V
Load capacitance	CLOAD				16	pF

#### **FUNCTIONAL DESCRIPTION**

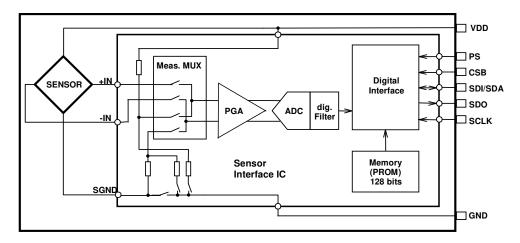


Figure 1: Block diagram of MS5607-02BA

#### **GENERAL**

The MS5607-02BA consists of a piezo-resistive sensor and a sensor interface IC. The main function of the MS5607-02BA is to convert the uncompensated analogue output voltage from the piezo-resistive pressure sensor to a 24-bit digital value, as well as providing a 24-bit digital value for the temperature of the sensor.

#### **FACTORY CALIBRATION**

Every module is individually factory calibrated at two temperatures and two pressures. As a result, 6 coefficients necessary to compensate for process variations and temperature variations are calculated and stored in the 128-bit PROM of each module. These bits (partitioned into 6 coefficients) must be read by the microcontroller software and used in the program converting D1 and D2 into compensated pressure and temperature values.

#### **SERIAL INTERFACE**

The MS5607-02BA has built in two types of serial interfaces: SPI and I<sup>2</sup>C. Pulling the Protocol Select pin PS to low selects the SPI protocol, pulling PS to high activates the I<sup>2</sup>C bus protocol.

Pin PS	Mode	Pins used
High	I <sup>2</sup> C	SDA
Low	SPI	SDI, SDO, CSB

#### SPI MODE

The external microcontroller clocks in the data through the input SCLK (Serial CLocK) and SDI (Serial Data In). In the SPI mode module can accept both mode 0 and mode 3 for the clock polarity and phase. The sensor responds on the output SDO (Serial Data Out). The pin CSB (Chip Select) is used to enable/disable the interface, so that other devices can talk on the same SPI bus. The CSB pin can be pulled high after the command is sent or after the end of the command execution (for example end of conversion). The best noise performance from the module is obtained when the SPI bus is idle and without communication to other devices during the ADC conversion.

#### I<sup>2</sup>C MODE

The external microcontroller clocks in the data through the input SCLK (Serial CLocK) and SDA (Serial DAta). The sensor responds on the same pin SDA which is bidirectional for the I<sup>2</sup>C bus interface. So this interface type uses only 2 signal lines and does not require a chip select, which can be favourable to reduce board space. In I<sup>2</sup>C-Mode the complement of the pin CSB (Chip Select) represents the LSB of the I<sup>2</sup>C address. It is possible to use two sensors with two different addresses on the I<sup>2</sup>C bus. The pin CSB shall be connected to VDD or GND (do not leave unconnected!).

#### **COMMANDS**

The MS5607-02BA has only five basic commands:

- 1. Reset
- 2. Read PROM (128 bit of calibration words)
- 3. D1 conversion
- 4. D2 conversion
- 5. Read ADC result (24 bit pressure / temperature)

#### PRESSURE AND TEMPERATURE CALCULATION

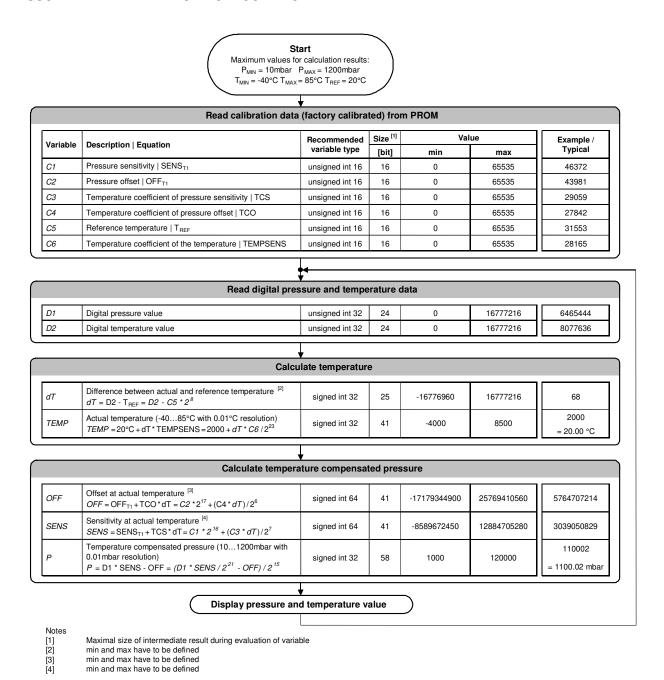


Figure 2: Flow chart for pressure and temperature reading and software compensation.

#### SECOND ORDER TEMPERATURE COMPENSATION

In order to obtain best accuracy over temperature range, particularly in low temperature, it is recommended to compensate the non-linearity over the temperature. This can be achieved by correcting the calculated temperature, offset and sensitivity by a second order correction factor and will be recalculated with the standard calculation. The second-order factors are calculated as follows:

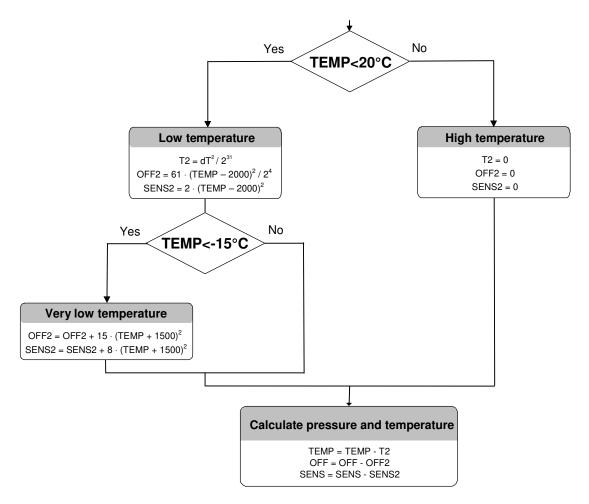


Figure 3: Flow chart for pressure and temperature to the optimum accuracy.

# SPI INTERFACE

#### **COMMANDS**

Size of each command is 1 byte (8 bits) as described in the table below. After ADC read commands the device will return 24 bit result and after the PROM read 16bit result. The address of the PROM is embedded inside of the PROM read command using the a2, a1 and a0 bits.

	Com	mand l	yte						hex value
Bit number	0	1	2	3	4	5	6	7	
Bit name	PR M	COV	-	Тур	Ad2/ Os2	Ad1/ Os1	Ad0/ Os0	Stop	
Command									
Reset	0	0	0	1	1	1	1	0	0x1E
Convert D1 (OSR=256)	0	1	0	0	0	0	0	0	0x40
Convert D1 (OSR=512)	0	1	0	0	0	0	1	0	0x42
Convert D1 (OSR=1024)	0	1	0	0	0	1	0	0	0x44
Convert D1 (OSR=2048)	0	1	0	0	0	1	1	0	0x46
Convert D1 (OSR=4096)	0	1	0	0	1	0	0	0	0x48
Convert D2 (OSR=256)	0	1	0	1	0	0	0	0	0x50
Convert D2 (OSR=512)	0	1	0	1	0	0	1	0	0x52
Convert D2 (OSR=1024)	0	1	0	1	0	1	0	0	0x54
Convert D2 (OSR=2048)	0	1	0	1	0	1	1	0	0x56
Convert D2 (OSR=4096)	0	1	0	1	1	0	0	0	0x58
ADC Read	0	0	0	0	0	0	0	0	0x00
PROM Read	1	0	1	0	Ad2	Ad1	Ad0	0	0xA0 to 0xAE

Figure 4: Command structure

#### **RESET SEQUENCE**

The Reset sequence shall be sent once after power-on to make sure that the calibration PROM gets loaded into the internal register. It can be also used to reset the device ROM from an unknown condition

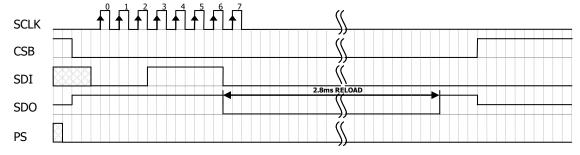


Figure 5: Reset command sequence SPI mode 0

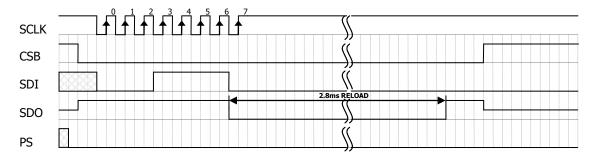


Figure 6: Reset command sequence SPI mode 3

#### **CONVERSION SEQUENCE**

The conversion command is used to initiate uncompensated pressure (D1) or uncompensated temperature (D2) conversion. The chip select can be disabled during this time to communicate with other devices.

After the conversion, using ADC read command the result is clocked out with the MSB first. If the conversion is not executed before the ADC read command, or the ADC read command is repeated, it will give 0 as the output result. If the ADC read command is sent during conversion the result will be 0, the conversion will not stop and the final result will be wrong. Conversion sequence sent during the already started conversion process will yield incorrect result as well.

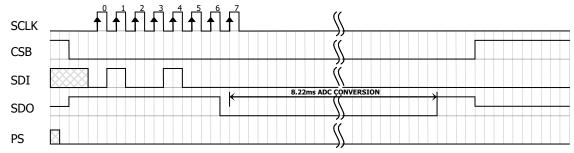


Figure 7: Conversion out sequence, Typ=d1, OSR = 4096

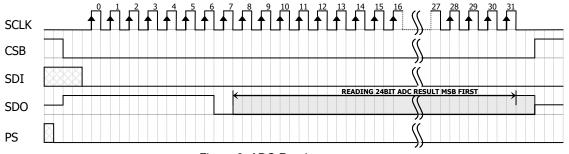


Figure 8: ADC Read sequence

# **PROM READ SEQUENCE**

The read command for PROM shall be executed once after reset by the user to read the content of the calibration PROM and to calculate the calibration coefficients. There are in total 8 addresses resulting in a total memory of 128 bit. Address 0 contains factory data and the setup, addresses 1-6 calibration coefficients and address 7 contains the serial code and CRC. The command sequence is 8 bits long with a 16 bit result which is clocked with the MSB first.

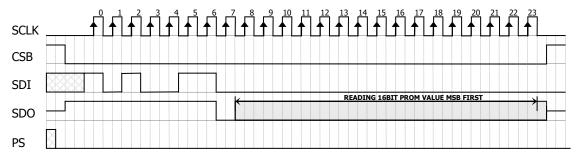


Figure 9: PROM Read sequence, address = 011 (Coefficient 3).

#### I<sup>2</sup>C INTERFACE

#### **COMMANDS**

Each I<sup>2</sup>C communication message starts with the start condition and it is ended with the stop condition. The MS5607-02BA address is 111011Cx, where C is the complementary value of the pin CSB. Since the IC does not have a microcontroller inside, the commands for I<sup>2</sup>C and SPI are quite similar.

#### **RESET SEQUENCE**

The reset can be sent at any time. In the event that there is not a successful power on reset this may be caused by the SDA being blocked by the module in the acknowledge state. The only way to get the MS5607-02BA to function is to send several SCLKs followed by a reset sequence or to repeat power on reset.

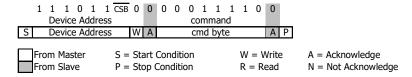


Figure 10: I2C Reset Command

#### **PROM READ SEQUENCE**

The PROM Read command consists of two parts. First command sets up the system into PROM read mode. The second part gets the data from the system.

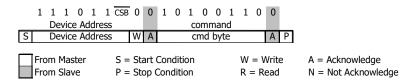


Figure 11: I<sup>2</sup>C Command to read memory address= 011 (Coefficient 3)

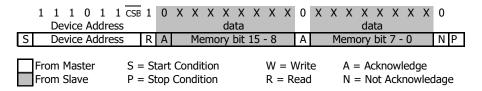


Figure 12: I2C answer from MS5607-02BA

#### **CONVERSION SEQUENCE**

A conversion can be started by sending the command to MS5607-02BA. When command is sent to the system it stays busy until conversion is done. When conversion is finished the data can be accessed by sending a Read command, when an acknowledge appears from the MS5607-02BA, 24 SCLK cycles may be sent to receive all result bits. Every 8 bit the system waits for an acknowledge signal.

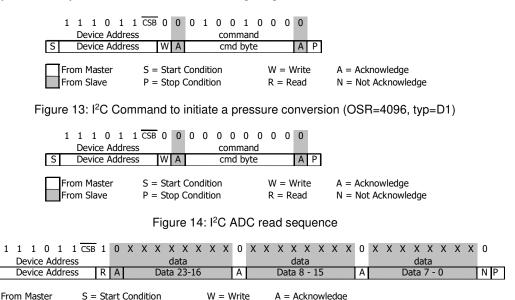


Figure 15: I2C answer from MS5607-02BA

N = Not Acknowledge

R = Read

#### **CYCLIC REDUNDANCY CHECK (CRC)**

From Slave

P = Stop Condition

MS5607-02BA contains a PROM memory with 128-Bit. A 4-bit CRC has been implemented to check the data validity in memory. The application note AN520 describes in detail CRC-4 code used.

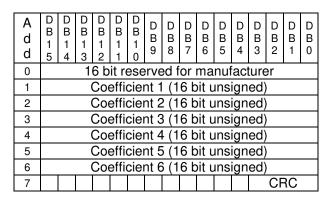
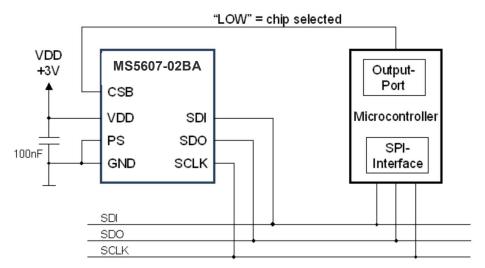


Figure 16: Memory PROM mapping

# **APPLICATION CIRCUIT**

The MS5607-02BA is a circuit that can be used in conjunction with a microcontroller in mobile altimeter applications. It is designed for low-voltage systems with a supply voltage of 3 V.

# SPI protocol communication



# I<sup>2</sup>C protocol communication

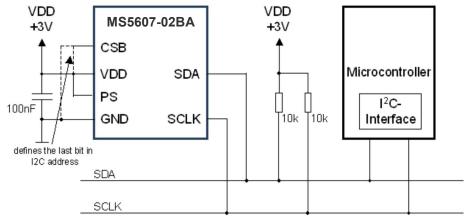
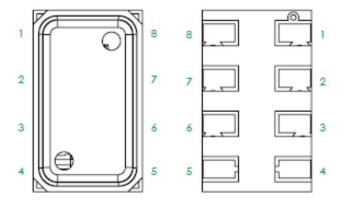


Figure 17: Typical application circuit with SPI / I<sup>2</sup>C protocol communication

# PIN CONFIGURATION

Pin	Name	Туре	Function
1	VDD	Р	Positive supply voltage
2	PS	I	Protocol select PS high (VDD) → I <sup>2</sup> C PS low (GND) → SPI
3	GND	G	Ground
4 5	CSB	ı	Chip select (active low), internal connection
6	SDO	0	Serial data output
7	SDI / SDA	1/10	Serial data input / I <sup>2</sup> C data IO
8	SCLK	I	Serial data clock



# **DEVICE PACKAGE OUTLINE**

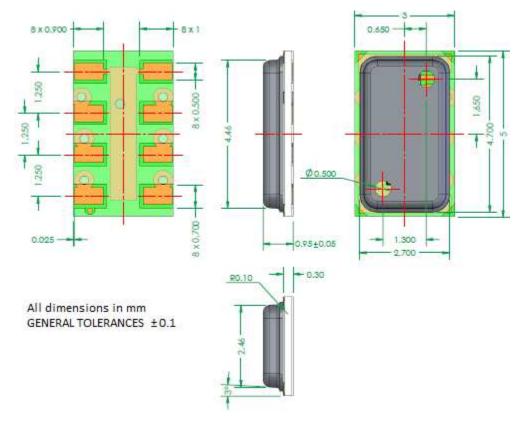
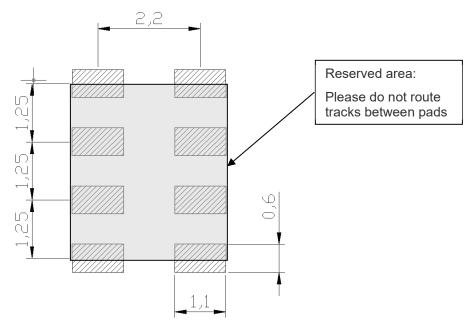


Figure 18: MS5607-02BA03 package outline

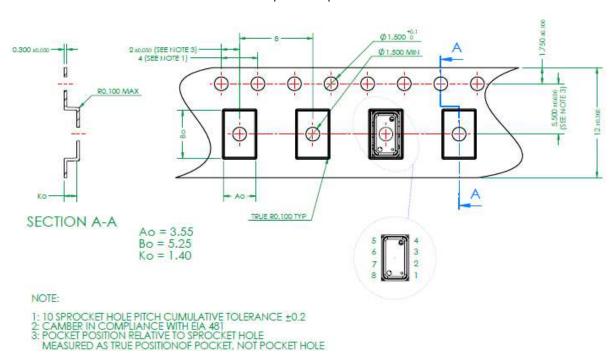
# RECOMMENDED PAD LAYOUT

Pad layout for bottom side of the MS5607-02BA soldered onto printed circuit board.



# SHIPPING PACKAGE





#### MOUNTING AND ASSEMBLY CONSIDERATIONS

#### **SOLDERING**

Please refer to the application note AN808 available on our website for all soldering issues.

#### **MOUNTING**

The MS5607-02BA can be placed with automatic Pick & Place equipment using vacuum nozzles. It will not be damaged by the vacuum. Due to the low stress assembly the sensor does not show pressure hysteresis effects. It is important to solder all contact pads.

#### CONNECTION TO PCB

The package outline of the module allows the use of a flexible PCB for interconnection. This can be important for applications in watches and other special devices.

#### **CLEANING**

The MS5607-02BA has been manufactured under cleanroom conditions. It is therefore recommended to assemble the sensor under class 10'000 or better conditions. Should this not be possible, it is recommended to protect the sensor opening during assembly from entering particles and dust. To avoid cleaning of the PCB, solder paste of type "no-clean" shall be used. Cleaning might damage the sensor!

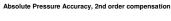
#### **ESD PRECAUTIONS**

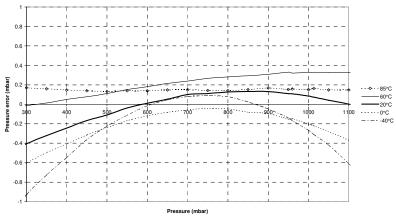
The electrical contact pads are protected against ESD up to 4 kV HBM (human body model). It is therefore essential to ground machines and personnel properly during assembly and handling of the device. The MS5607-02BA is shipped in antistatic transport boxes. Any test adapters or production transport boxes used during the assembly of the sensor shall be of an equivalent antistatic material.

#### **DECOUPLING CAPACITOR**

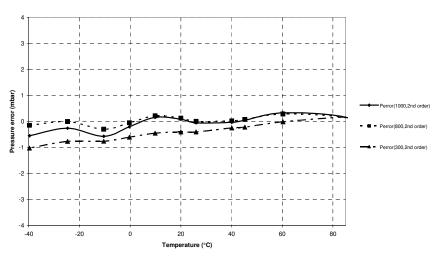
Particular care must be taken when connecting the device to the power supply. A 100 nF ceramic capacitor must be placed as close as possible to the MS5607-02BA VDD pin. This capacitor will stabilize the power supply during data conversion and thus, provide the highest possible accuracy.

# TYPICAL PERFORMANCE CHARACTERISTICS

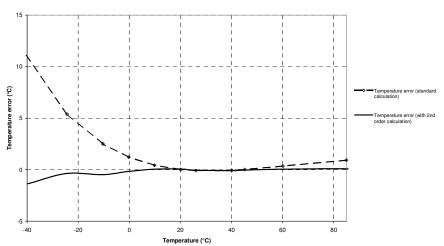




#### Pressure Error Accuracy vs temperature

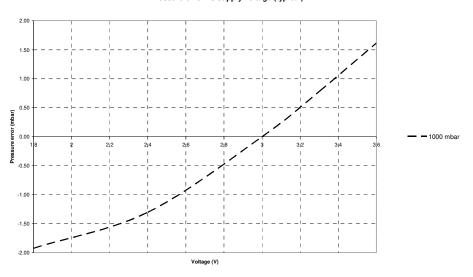


# Temperature Error Accuracy vs temperature

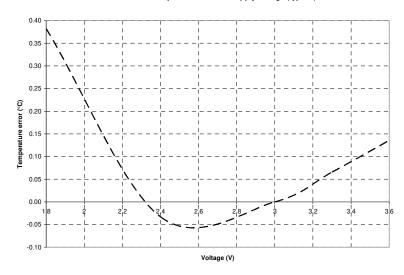


# TYPICAL PERFORMANCE CHARACTERISTICS (CONTINUED)

#### Pressure error vs supply voltage (typical)



#### Temperature error vs supply voltage (typical)



#### ORDERING INFORMATION

Product Code	Product	Art. No	Delivery Form
MS5607-02BA03	Barometric Pressure Sensor Thin Metal Cap	MS560702BA03-00	Waffle pack
MS5607-02BA03	Barometric Pressure Sensor Thin Metal Cap	MS560702BA03-50	Tape and reel

**NORTH AMERICA** 

Tel: 1-800-899-9783 Email: TEsensors-CCmeas@te.com **EUROPE** 

Email: tess-ic-tlse@te.com

ASIA

Email: customercare.shzn@te.com

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6407-249V-17343P 6407-250V-09273P 80527-25.0H2-05 80541-B00000150-01 80541-B00000200-05 80554-00700100-05 8056800300050-01 93.631.4253.0 93.731.4353.0 93.932.4553.0 136PC150G2 136PC15A1 142PC95AW71 142PC05DW70 15PSI-G-4V 180501A-L0N-B 26PCBKT 26PCCFA6D26 26PCCFS2G 26PCCVA6D 93.632.7353.0 93.731.3653.0 93.931.4853.0 93.932.4853.0 SCDA120XSC05DC 185PC30DH 20INCH-G-MV-MINI 26PCAFJ3G 26PCCEP5G24 26PCDFA3G 26PCJEU5G19 30INCH-D1-MV-MINI
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