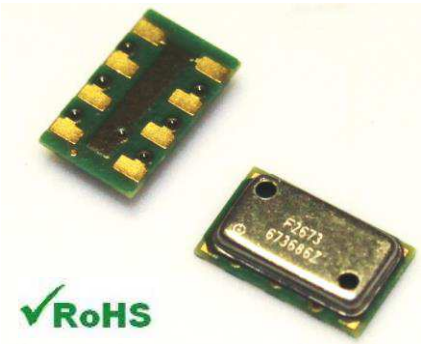


MS5607-12BA

Miniature 12 bar Industrial Pressure Sensor Module

The MS5607-12BA is a new generation of high resolution industrial pressure sensors from TE connectivity, with SPI and I^2C bus interface. It is optimized for air pressure measurement systems with a resolution of 2.5 mbar. The sensor module includes a highly linear pressure sensor and an ultra-low power 24 bit ΔΣ 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 a depth measurement systems and thermometer function without any additional sensor. The MS5607-12BA can be interfaced to virtually any microcontroller. The communication protocol is simple, without the need to programming internal registers in the device. The gold pad protection without gel and antimagnetic stainless steel cap protects the pressure die. This new sensor module generation is based on leading MEMS technology and latest benefits from TE proven experience and know-how in high volume manufacturing of pressure modules have been widely used for over a decade. This sensing principle employed leads to very low hysteresis and high stability of both pressure and temperature signal.

FEATURES

- High resolution module, 2.5mbar
- Fast conversion down to 1 ms
- Low power, 1 µA (standby < 0.15 µA)
- Integrated digital pressure sensor (24 bit ΔΣ ADC)
- Supply voltage 2.2 to 3.6 V
- Operating range: 0 to 12bar, -40 to +85 °C
- QFN package 5.0 x 3.0 x 1.0 mm3
- I2C and SPI interface (Mode 0, 3)
- No external components (Internal oscillator)
- Excellent long term stability

APPLICATIONS

- Industrial applications

PERFORMANCE SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Supply voltage	V_{DD}		-0.3		+3.6	V
Storage temperature	T_S		-20		+85	°C
Overpressure	P_{max}				30	bar
Maximum Soldering Temperature [1]	T_{max}	40 sec max			250	°C
ESD rating		Human Body Model	-2		+2	kV
Latch up		JEDEC standard No 78	-100		+100	mA

[1] Refer to application note 808

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Operating Supply voltage	V_{DD}			1.8	3.0	3.6	V
Operating Temperature	T			-40	+25	+85	°C
Supply current (1 sample per sec.)	I_{DD}	OSR	4096 2048 1024 512 256		12.5 6.3 3.2 1.7 0.9		µA
Peak supply current		during conversion			1.4		mA
Standby supply current		at 25°C			0.02	0.14	µA
VDD Capacitor		From VDD to GND		100	1000		nF

ANALOG DIGITAL CONVERTER (ADC)

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Output Word					24		bit
Conversion time [2]	t_c	OSR	4096 2048 1024 512 256	7.40 3.72 1.88 0.95 0.48	8.22 4.13 2.08 1.06 0.54	9.04 4.54 2.28 1.17 0.60	ms

[2] Maximum values must be used to determine waiting times in I2C communication

PERFORMANCE SPECIFICATIONS (CONTINUED)

PRESSURE OUTPUT CHARACTERISTICS (V_{DD} = 3 V, T = 25°C UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Typ.	Max	Unit
Operating Pressure Range	P_{range}	Full Accuracy	0		8	bar
Extended Pressure Range	P_{ext}	Linear Range of ADC	0		12	bar
Absolute Accuracy, Temperature range 0..40°C	0,2..9 bar		-60	±30	+60	mbar
Absolute Accuracy, Temperature range -5..70°C	0,2..9 bar		-70	±40	+60	mbar
Absolute Accuracy, Temperature range -40..85°C	1..8 bar		-160	±80	120	mbar
Absolute Accuracy, Temperature range 0..40°C	0,2..12 bar		-120	±60	+60	mbar
Absolute Accuracy, Temperature range -20..85°C			-180	±100	+100	mbar
Absolute Accuracy, Temperature range -40..85°C			-200	±100	+200	mbar
Maximum error with supply voltage	V_{DD} = 1.8 V … 3.6 V			±20		mbar
Resolution RMS	OSR	4096 2048 1024 512 256		0.2 0.3 0.4 0.6 1.0		mbar
Long-term stability				±20		mbar/yr
Reflow soldering impact	IPC/JEDEC J-STD-020C (See application note AN808)			-20		mbar
Recovering time after reflow (1)				1		days

(1) Time to recover at least 66% of the reflow impact

TEMPERATURE OUTPUT CHARACTERISTICS (V_{DD} = 3 V, T = 25°C UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Typ.	Max	Unit
Absolute Accuracy	-20..85°C -40..85°C		-5 -10	±2 ±4	+5 10	°C
Maximum error with supply voltage	V_{DD} = 2.2 V … 3.6 V			±0.5		°C
Resolution RMS	OSR	4096 2048 1024 512 256		0.002 0.003 0.005 0.008 0.012		°C

PERFORMANCE SPECIFICATIONS (CONTINUED)

DIGITAL INPUTS (PS, CSB, DIN, SCLK, SDA, SCL)

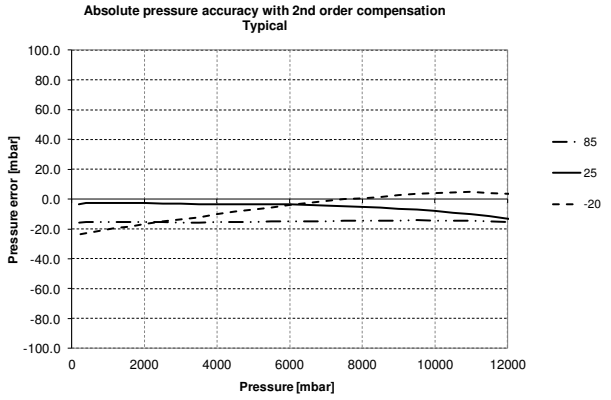
Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock	SCLK SCL	SPI protocol			10	MHz
		I^2C protocol			400	KHz
Input high voltage	V_{IH}	Pins CSB	80% V_{DD}		100% V_{DD}	V
Input low voltage	V_{IL}		0% V_{DD}		20% V_{DD}	V

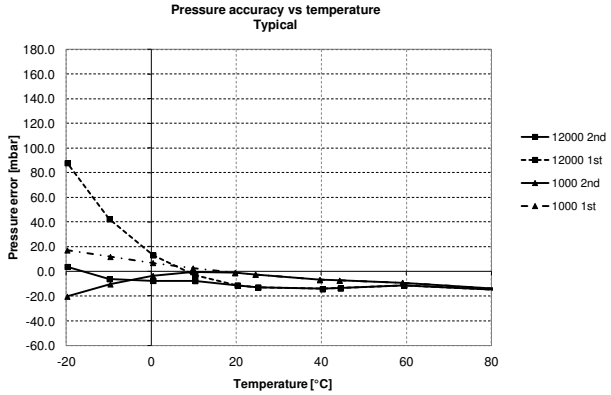
DIGITAL OUTPUTS (DOUT, SDA, SCL)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Output high voltage	V_{OH}	I_{source} = 1.0 mA	80% V_{DD}		100% V_{DD}	V
Output low voltage	V_{OL}	I_{sink} = 1.0 mA	0% V_{DD}		20% V_{DD}	V

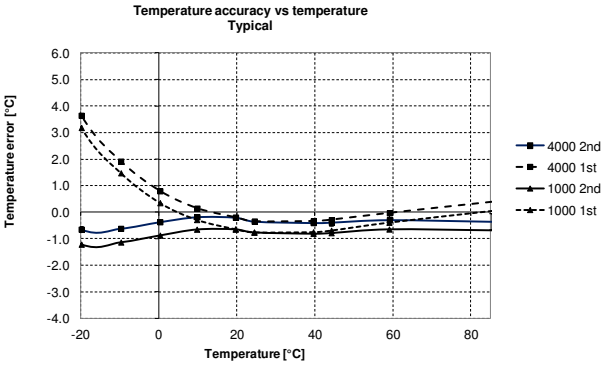
PERFORMANCE CHARACTERISTICS

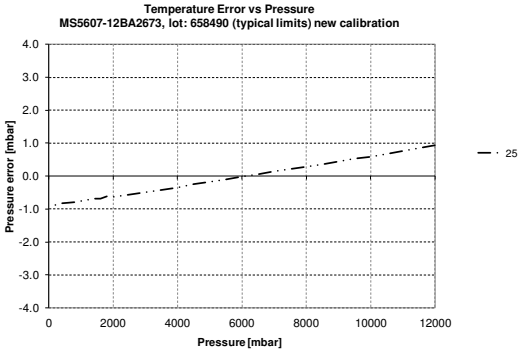
PRESSURE ERROR VS PRESSURE AND TEMPERATURE



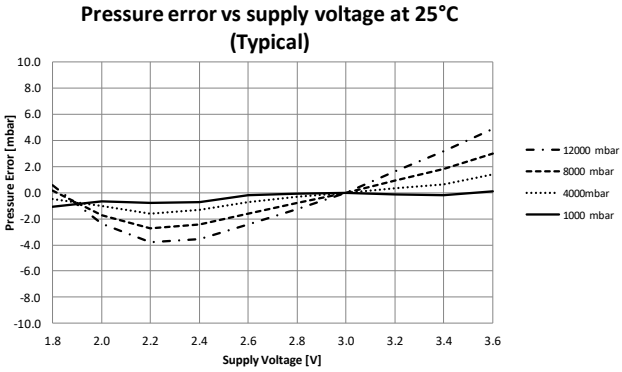


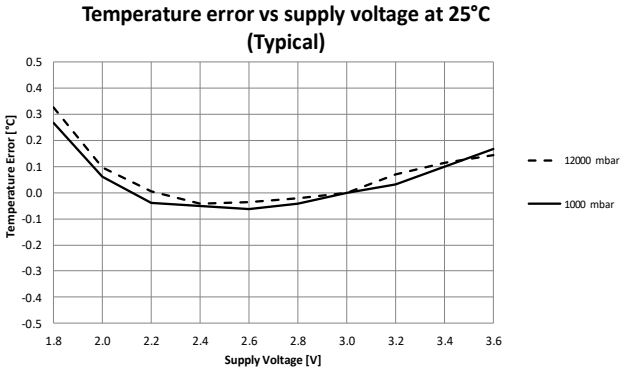
TEMPERATURE ERROR VS TEMPERATURE



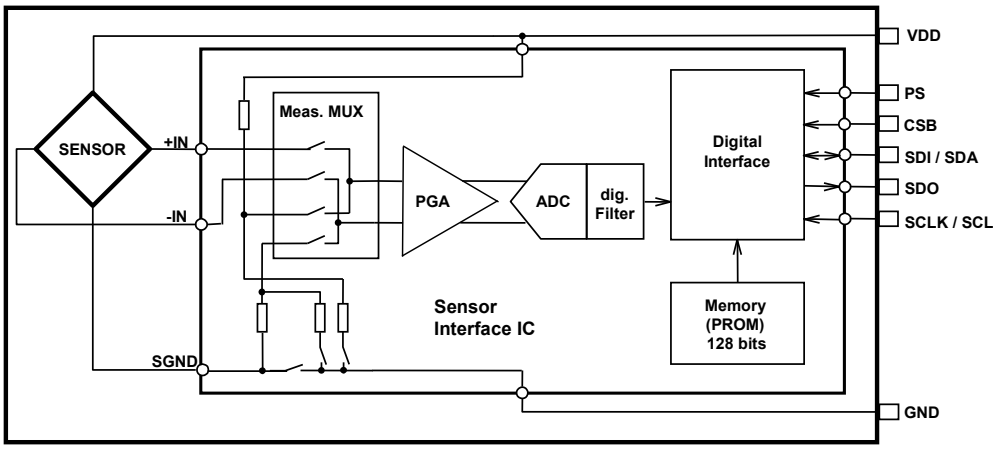


PRESSURE AND TEMPERATURE ERROR VS POWER SUPPLY





FUNCTIONAL DESCRIPTION



Block diagram of MS5607-12BA

GENERAL

The MS5607 consists of a piezo-resistive sensor and a sensor interface IC. The main function of the MS5607 is to convert the uncompensated analog 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 W1 to W6) must be read by the microcontroller software and used in the program converting D1 and D2 into compensated pressure and temperature values.
The 2 coefficients W0 and W7 are for factory configuration and CRC.

SERIAL INTERFACE

The MS5607 has built in two types of serial interfaces: SPI and I²C. Pulling the Protocol Select pin PS to low selects the SPI protocol, pulling PS to high activate the I²C bus protocol.

Pin PS	Mode	Pins used
High	I²C	SDA, SCL, CSB
Low	SPI	SDI, SDO, SCLK, 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.

I2C MODE

The external microcontroller clocks in the data through the input SCL (Serial CLocK) and SDA (Serial DAta). The sensor responds on the same pin SDA which is bidirectional for the I²C bus interface. So this interface type uses only 2 signal lines and does not require a chip select, which can be favorable to reduce board space. In I²C-Mode the complement of the pin CSB (Chip Select) represents the LSB of the I²C address. It is possible to use two sensors with two different addresses on the I²C bus. The pin CSB shall be connected to VDD or GND (do not leave unconnected!).

Pin CSB	**Address (7 bits)**
High	0x76 (1110110 b)
Low	0x77 (1110111 b)

COMMANDS

The MS5607 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)

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.

	Command byte								**hex value**
Bit number	0	1	2	3	4	5	6	7	
Bit name	PRM	COV	-	Typ	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

Command structure

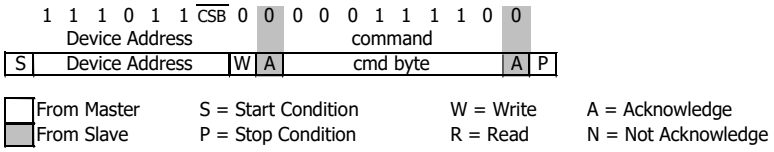
I²C INTERFACE

COMMANDS

Each I²C communication message starts with the start condition and it is ended with the stop condition. The MS5607 address is 111011Cx, where C is the complementary value of the pin CSB (CSB=1, C=0 and CSB=0, C=1). Since the IC does not have a microcontroller inside, the commands for I²C and SPI are quite similar.

RESET SEQUENCE

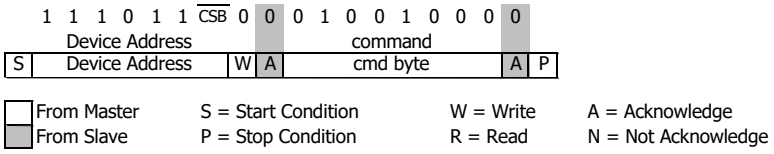
The reset can be sent at any time. In the event that there is not a successful power on reset this may be caused by the SDA being blocked by the module in the acknowledge state. The only way to get the MS5607 to function is to send several SCLKs followed by a reset sequence or to repeat power on reset.



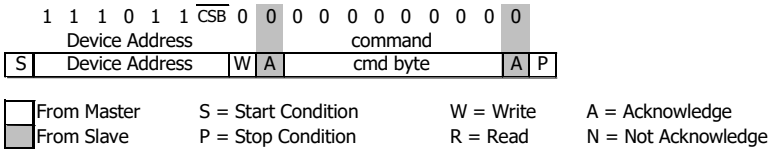
I²C Reset Command

CONVERSION SEQUENCE

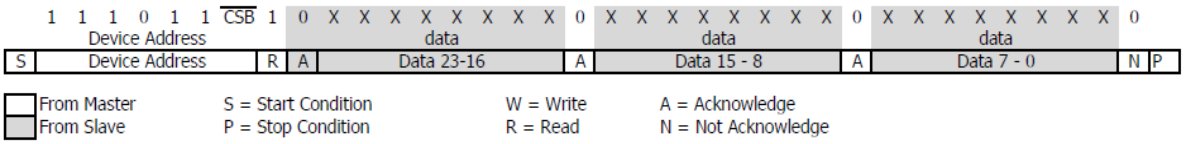
A conversion can be started by sending the command to MS5607. When command is sent to the system it stays busy until conversion is done. When conversion is finished the data can be accessed by sending a Read command, when an acknowledge appears from the MS5607, 24 SCLK cycles may be sent to receive all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



I²C Command to initiate a pressure conversion (OSR=4096, typ=D1)



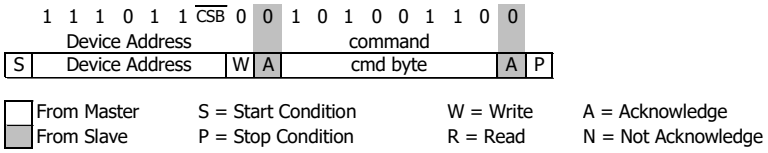
I²C ADC read sequence



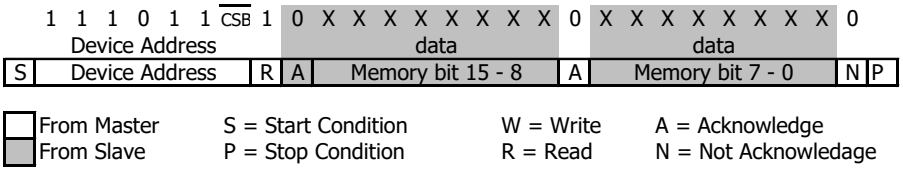
I²C answer from MS5607

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.



I²C Command to read memory address= 011 (Coefficient 3)

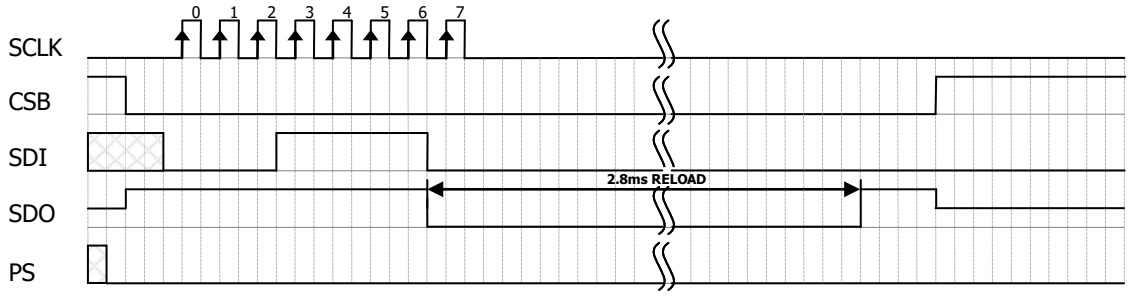


I²C answer from MS5607

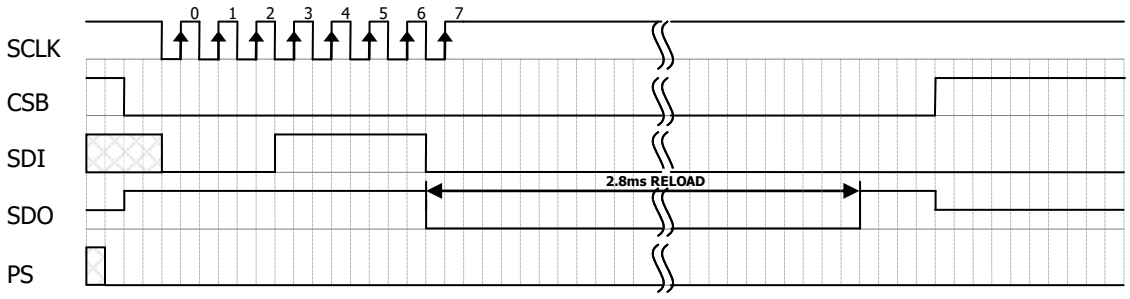
SPI INTERFACE

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



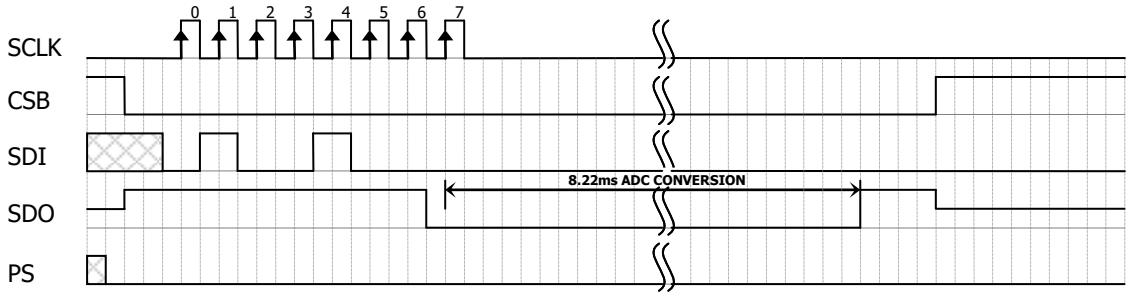
Reset command sequence SPI (mode 0)



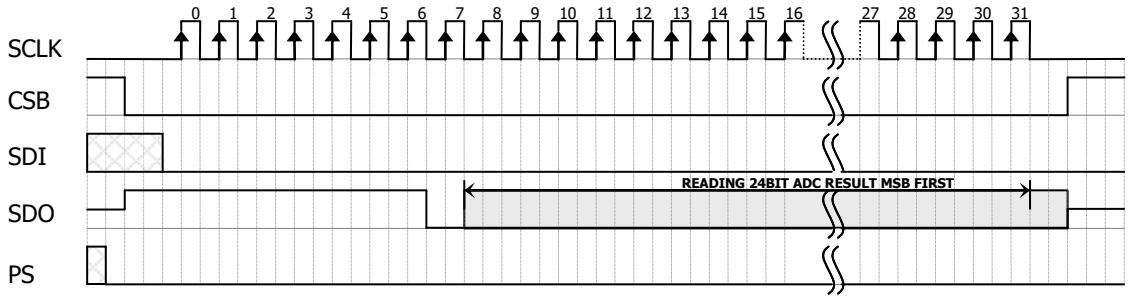
Reset command sequence SPI (mode 3)

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.



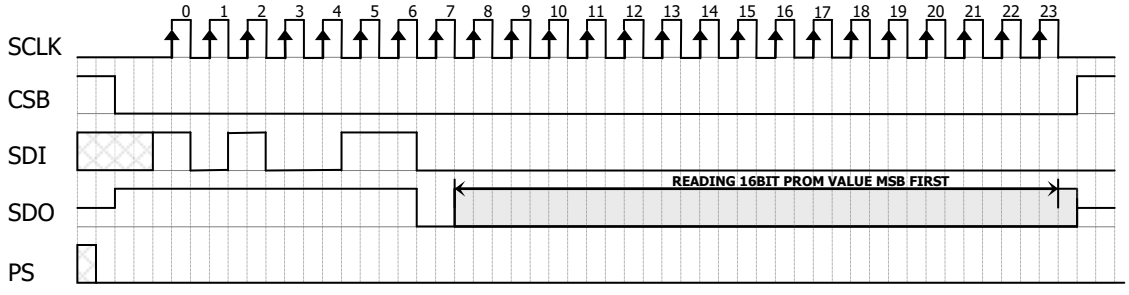
Conversion out sequence, Typ=d1, OSR = 4096



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.



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

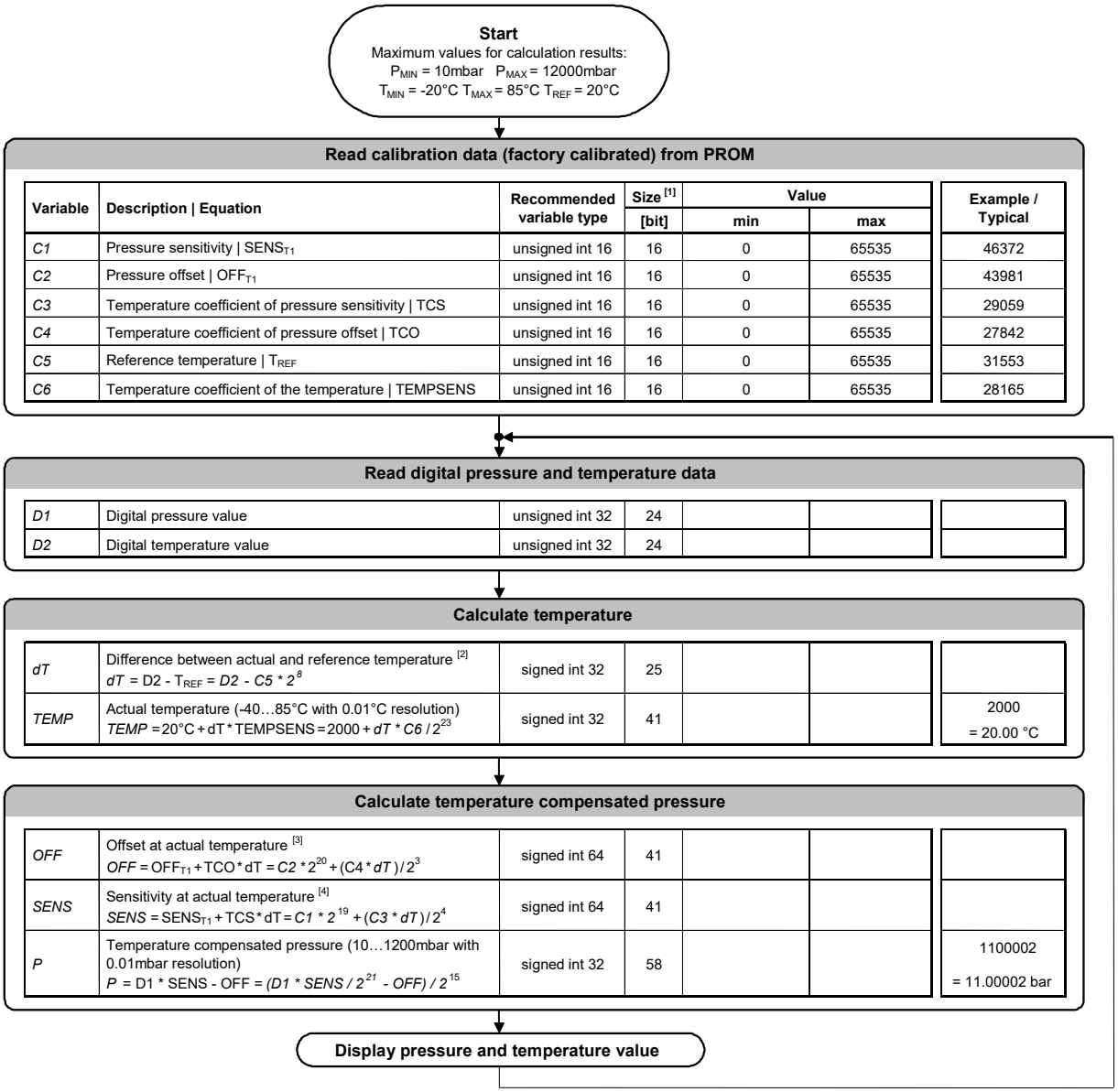
CYCLIC REDUNDANCY CHECK (CRC)

MS5607 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.

Add	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	16 bit reserved for manufacturer															
1	Coefficient 1 (16 bit unsigned)															
2	Coefficient 2 (16 bit unsigned)															
3	Coefficient 3 (16 bit unsigned)															
4	Coefficient 4 (16 bit unsigned)															
5	Coefficient 5 (16 bit unsigned)															
6	Coefficient 6 (16 bit unsigned)															
7													CRC			

Memory PROM mapping

PRESSURE AND TEMPERATURE CALCULATION



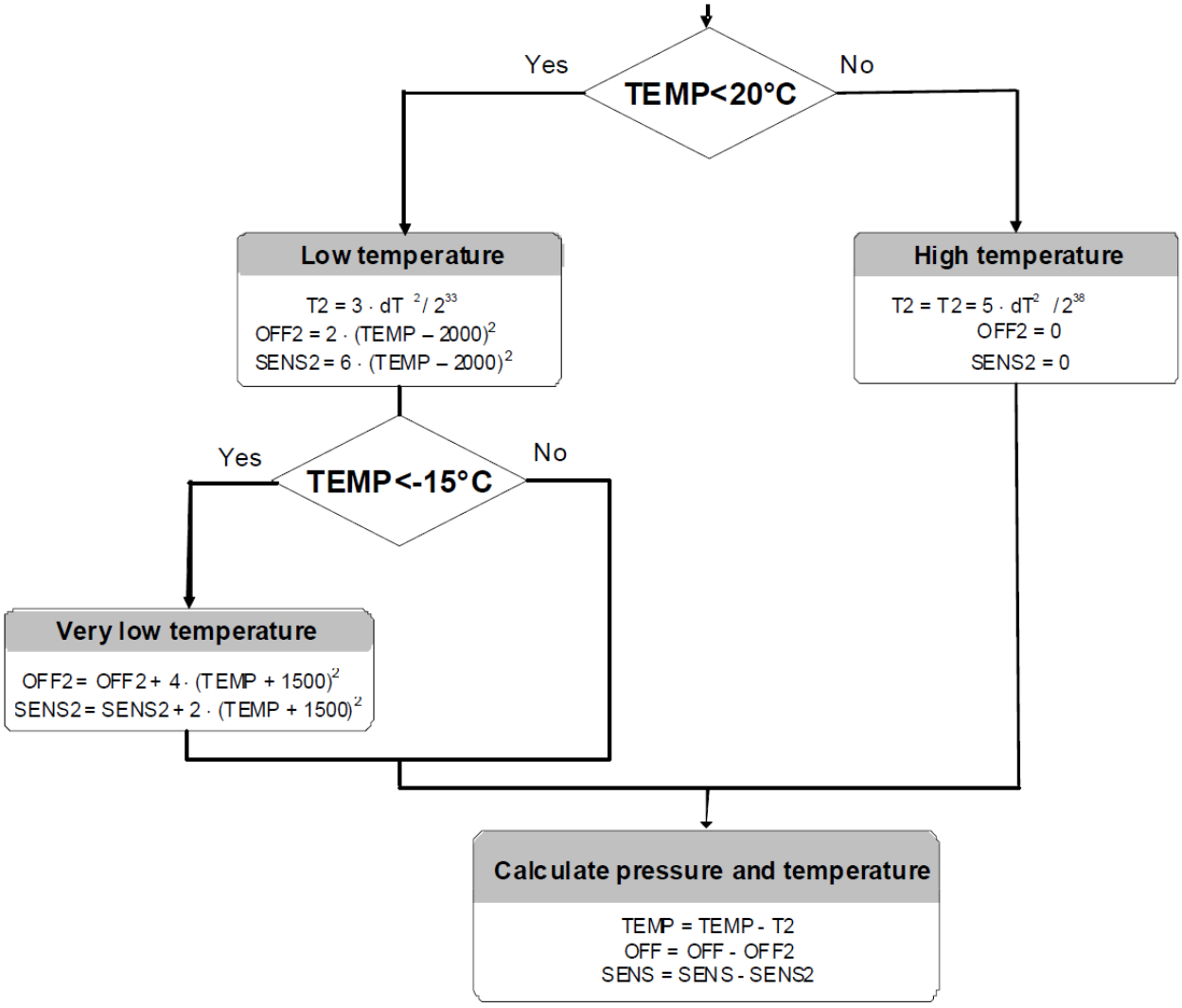
Variable	Description | Equation	Recommended variable type	Size [1] [bit]	Value min	Value max	Example / Typical
C1	Pressure sensitivity | $SENS_{T1}$	unsigned int 16	16	0	65535	46372
C2	Pressure offset | OFF_{T1}	unsigned int 16	16	0	65535	43981
C3	Temperature coefficient of pressure sensitivity | TCS	unsigned int 16	16	0	65535	29059
C4	Temperature coefficient of pressure offset | TCO	unsigned int 16	16	0	65535	27842
C5	Reference temperature | T_{REF}	unsigned int 16	16	0	65535	31553
C6	Temperature coefficient of the temperature | TEMPSENS	unsigned int 16	16	0	65535	28165
D1	Digital pressure value	unsigned int 32	24			
D2	Digital temperature value	unsigned int 32	24			
dT	Difference between actual and reference temperature [2] $dT = D2 - T_{REF} = D2 - C5 * 2^8$	signed int 32	25			
TEMP	Actual temperature (-40…85°C with 0.01°C resolution) $TEMP = 20°C + dT * TEMPSENS = 2000 + dT * C6 / 2^{23}$	signed int 32	41			2000 = 20.00 °C
OFF	Offset at actual temperature [3] $OFF = OFF_{T1} + TCO * dT = C2 * 2^{20} + (C4 * dT) / 2^3$	signed int 64	41			
SENS	Sensitivity at actual temperature [4] $SENS = SENS_{T1} + TCS * dT = C1 * 2^{19} + (C3 * dT) / 2^4$	signed int 64	41			
P	Temperature compensated pressure (10…1200mbar with 0.01mbar resolution) $P = D1 * SENS - OFF = (D1 * SENS / 2^{21} - OFF) / 2^{15}$	signed int 32	58			1100002 = 11.00002 bar

Notes
[1] Maximal size of intermediate result during evaluation of variable
[2] min and max have to be defined
[3] min and max have to be defined
[4] min and max have to be defined

Flow chart for pressure and temperature reading and software compensation.

SECOND ORDER TEMPERATURE COMPENSATION

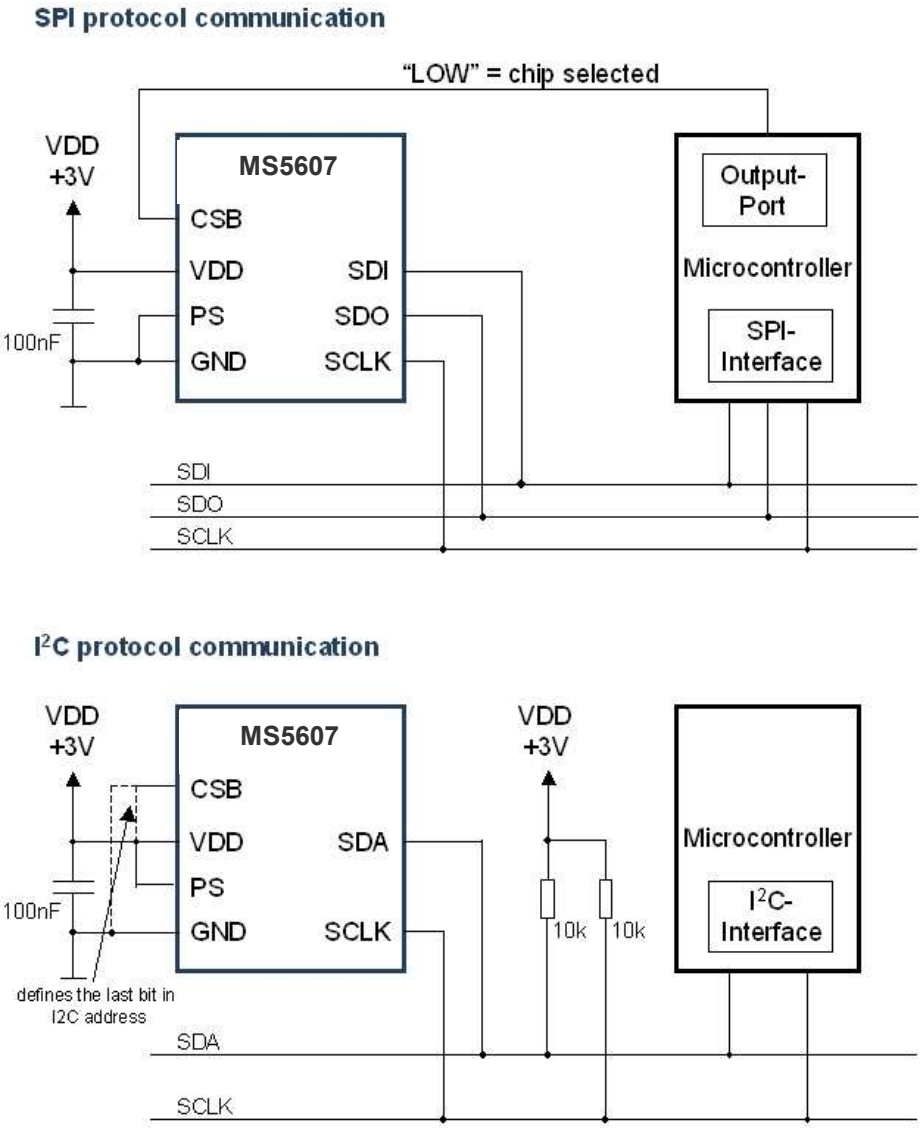
In order to obtain best accuracy over temperature range, particularly in low temperature, it is recommended to compensate the non-linearity over the temperature. This can be achieved by correcting the calculated temperature, offset and sensitivity by a second order correction factor and will be recalculated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



Flow chart for pressure and temperature to the optimum accuracy.

APPLICATION CIRCUIT

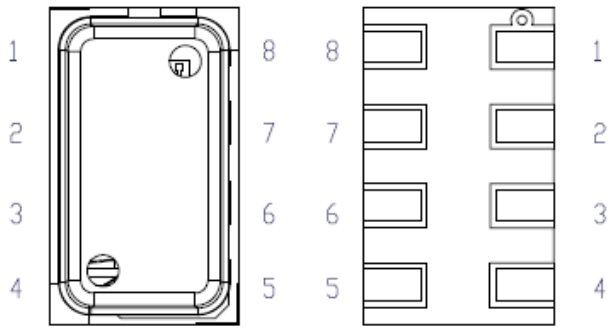
The MS5607 is a circuit that can be used in conjunction with a microcontroller in industrial pressure applications. It is designed for low-voltage systems with a supply voltage of 3 V.



Typical application circuit with SPI / I²C protocol communication

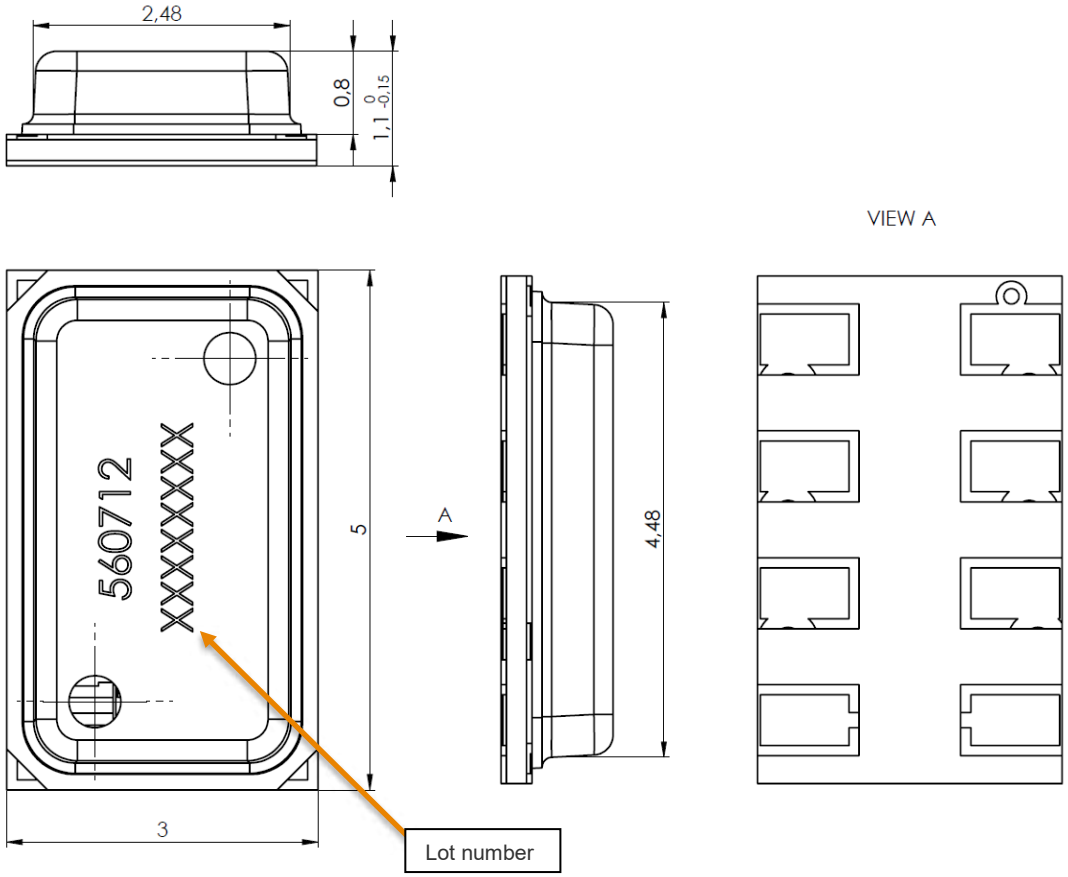
PIN CONFIGURATION

Pin	Name	Type	Function
1	VDD	P	Positive supply voltage
2	PS	I	Protocol select PS high (VDD) → I²C PS low (GND) → SPI
3	GND	G	Ground
4	CSB	I	Chip select (active low), internal connection
5			
6	SDO	O	Serial data output
7	SDI / SDA	I / IO	Serial data input / I²C data IO
8	SCLK / SCL	I	Serial data clock



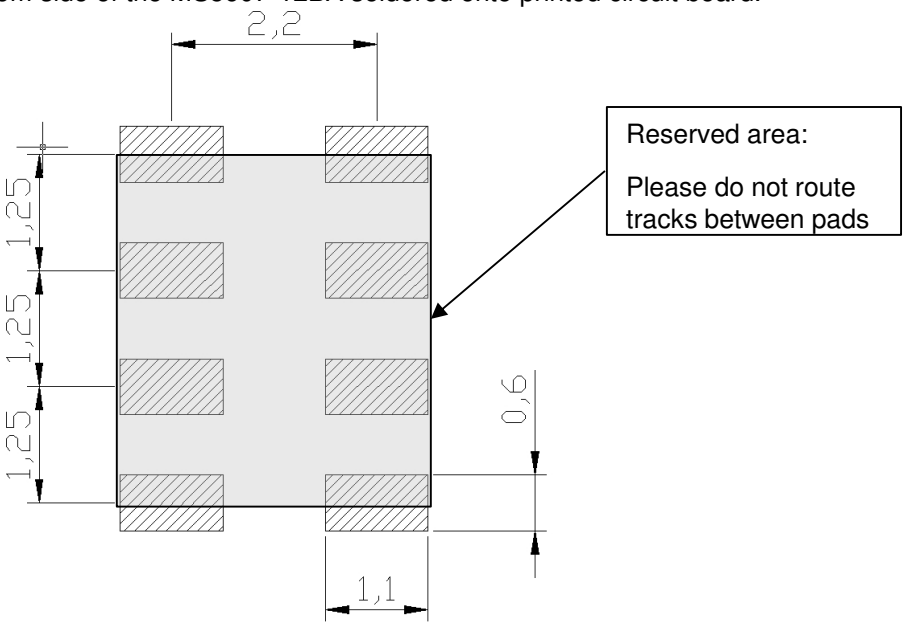
DEVICE PACKAGE OUTLINE

MS5607-12BA package outline

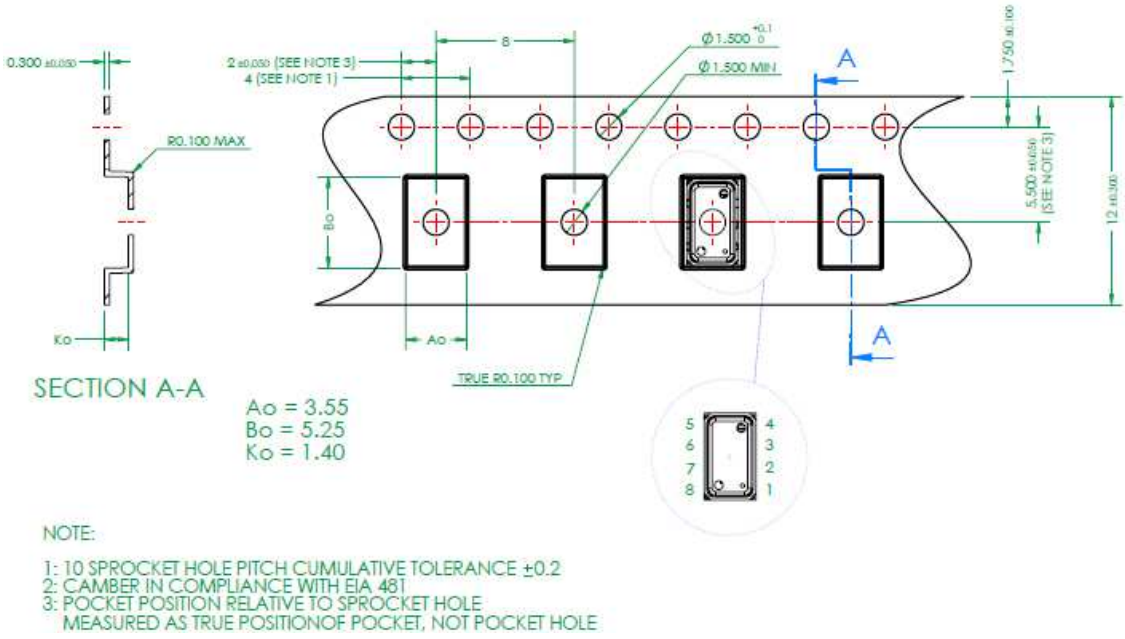


RECOMMENDED PAD LAYOUT

Pad layout for bottom side of the MS5607-12BA soldered onto printed circuit board.



SHIPPING PACKAGE



TAPE & REEL

MOUNTING AND ASSEMBLY CONSIDERATIONS

SOLDERING

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

MOUNTING

The MS5607 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 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 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 minimum 100nF ceramic capacitor must be placed as close as possible to the MS5607 VDD pin. This capacitor will stabilize the power supply during data conversion and thus, provide the highest possible accuracy.

ORDERING INFORMATION

PART NUMBER	DESCRIPTION	Delivery Form
20024250-50	MS5607-12BA INDUS AL PADS WITH GEL T&R	Tape & Reel

PRODUCT DESCRIPTION

MS5607__BA

Pressure Range

12	12 bar