MS5803-01BA

Miniature Variometer Module

The MS5803-01BA is a new generation of high resolution altimeter sensors from TE Connectivity with SPI and I²C bus interface. The MS5803-01BA HE is the high endurance pad technology version of the MS5803-01BA pressure sensor module. It is optimized for altimeters and variometers with an altitude resolution of 10 cm. The sensor module includes a high linearity 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 an altimeter/thermometer function without any additional sensor. The MS5803-01BA can be interfaced to virtually any microcontroller. The communication protocol is simple, without the need of programming internal registers in the device. The gel protection and antimagnetic stainless steel cap allows the use in 100m water resistant altimeter/compass watches. 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 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

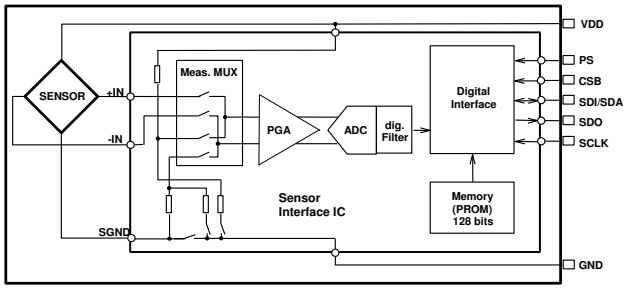
- High resolution module, 10cm
- Fast conversion down to 1 ms
- Low power, 1 µA (standby < 0.15 µA)
- Integrated digital pressure sensor (24 bit ΔΣ ADC)
- Supply voltage 1.8 to 3.6 V
- Operating range: 10 to 1300 mbar, -40 to +85 °C
- I2C and SPI interface (Mode 0, 3)
- No external components (Internal oscillator)
- Excellent long term stability
- Hermetically sealable for outdoor devices
- High Endurance (HE version)

APPLICATIONS

- Mobile altimeter / barometer systems
- Bike computers
- Adventure or multi-mode watches
- Variometers
- Dataloggers
- High endurance pad technology (HE version)

Sensor Performances (V_{DD} = 3 V)				
Pressure	**Min**	**Typ**	**Max**	**Unit**
Range	10		1300	mbar
ADC		24		bit
Resolution (1)		0.065 / 0.042 / 0.027 / 0.018 / 0.012		mbar
Accuracy 25°C, 750 to 1100 mbar	-1.5		+1.5	mbar
Accuracy -20°C to + 85°C, 300 to 1100 mbar (2)	-2.5		+2.5	mbar
Response time		0.5 / 1.1 / 2.1 / 4.1 / 8.22		ms
Long term stability		-1		mbar/yr
Temperature	**Min**	**Typ**	**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.	Typ.	Max	Unit
Supply voltage	V_{DD}		-0.3		+4.0	V
Storage temperature [3]	T_S		-40		+125	°C
Overpressure	P_{max}	ISO22810 [1]			10	bar
Maximum Soldering Temperature [2]	T_{max}	40 sec max			250	°C
ESD rating		Human Body Model	-4		+4	kV
Latch up		JEDEC standard No 78	-100		+100	mA

[1] Qualified referring to ISO 22810, pressure ramp up/down min 60s
[2] Refer to application note 808
[3] Storage in an environment of dry and non-corrosive gases

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			nF

ANALOG DIGITAL CONVERTER (ADC)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Output Word				24		bit
Conversion time [4]	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

[4] 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	300		1100	mbar
Extended Pressure Range	P_{ext}	Linear Range of ADC	10		1300	mbar
Absolute Accuracy, no autozero (1)	at 25°C, 700..1100 mbar at 0..50°C, 300..1100 mbar at -20..85°C, 300..1100 mbar at -40..85°C, 300..1100 mbar		-1.5 -2.0 -3.5 -6.0		+1.5 +2.0 +3.5 +6.0	mbar
Absolute Accuracy, autozero at one pressure point (1)	at 25°C, 700..1100 mbar at 0..50°C, 300..1100 mbar at -20..85°C, 300..1100 mbar at -40..85°C, 300..1100 mbar		-0.5 -1.0 -2.5 -5.0		+0.5 +1.0 +2.5 +5.0	mbar
Maximum error with supply voltage (3)	V_{DD} = 1.8 V … 3.6 V			+/- 2		mbar
Long-term stability (2)				-1		mbar/yr
Resolution RMS	OSR	4096 2048 1024 512 256		0.012 0.018 0.027 0.042 0.065		mbar

(1) Wet/dry cycle: sensor must be dried typically once a day.
(2) The long-term stability is measured with non-soldered devices.
(3) With autozero at 3V point

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

Parameter	Conditions		Min.	Typ.	Max	Unit
Absolute Accuracy	at 25°C -20..85°C -40..85°C		-0.8 -2.0 -4.0		+0.8 +2.0 +4.0	°C
Maximum error with supply voltage (4)	V_{DD} = 1.8 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

(4) With autozero at 3V point

PERFORMANCE SPECIFICATIONS (CONTINUED)

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

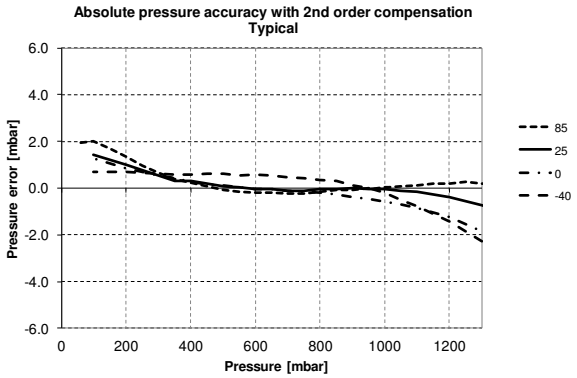
Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock	SCLK	SPI protocol			20	MHz
Serial data clock	SCL	I2C protocol			400	kHz
Input high voltage	V_{IH}	Pins CSB	80% V_{DD}		100% V_{DD}	V
Input low voltage	V_{IL}		0% V_{DD}		20% V_{DD}	V
Input leakage current	$I_{leak25°C}$	at 25°c			0.15	µA
CS low to first SCLK rising	t_{CSL}		21			ns
CS low from last SCLK falling	t_{CSH}		21			ns

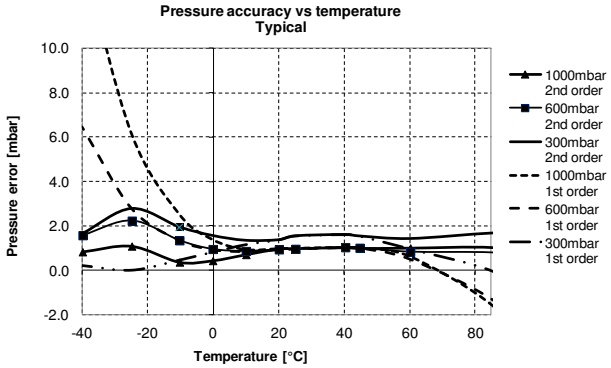
DIGITAL OUTPUTS (DOUT, SDA, SCL)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Output high voltage	V_{OH}	I_{source} = 0.6 mA	80% V_{DD}		100% V_{DD}	V
Output low voltage	V_{OL}	I_{sink} = 0.6 mA	0% V_{DD}		20% V_{DD}	V
Load capacitance	C_{LOAD}			16		pF

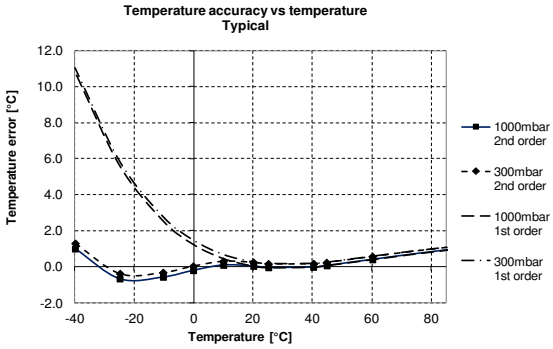
PERFORMANCE CHARACTERISTICS

PRESSURE ERROR VS PRESSURE AND TEMPERATURE

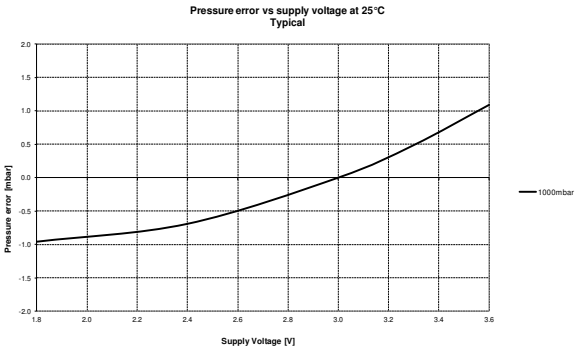


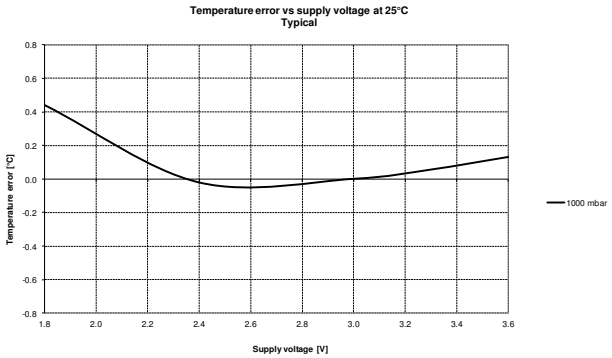


TEMPERATURE ERROR VS TEMPERATURE



PRESSURE AND TEMPERATURE ERROR VS SUPPLY VOLTAGE





FUNCTIONAL DESCRIPTION

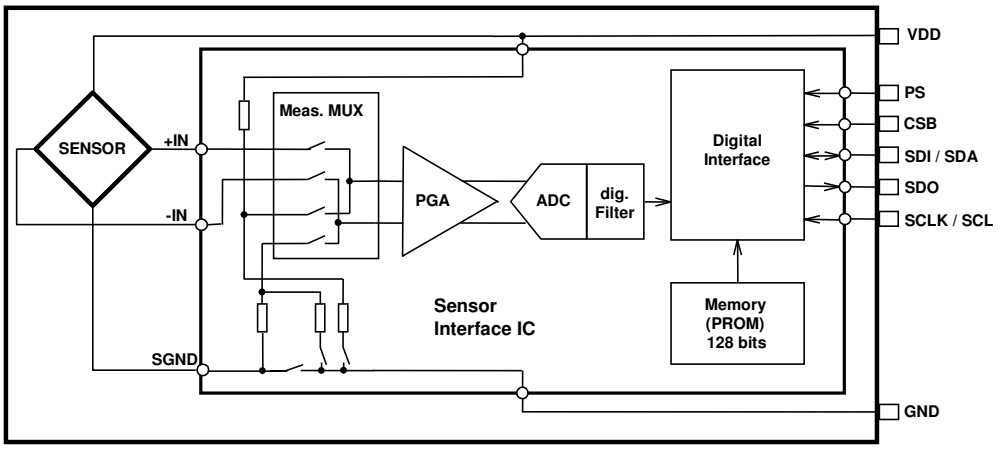


Figure 1: Block diagram of MS5803-01BA

GENERAL

The MS5803-01BA consists of a piezo-resistive sensor and a sensor interface IC. The main function of the MS5803-01BA 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 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 MS5803-01BA has built in two types of serial interfaces: SPI and I^2C. Pulling the Protocol Select pin PS to low selects the SPI protocol, pulling PS to high activates the I^2C bus protocol.

Pin PS	Mode	Pins used
High	I^2C	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 SCLK (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 MS5803-01BA 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

Figure 2: Command structure

I²C INTERFACE

COMMANDS

Each I²C communication message starts with the start condition and it is ended with the stop condition. The MS5803-01BA 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 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 MS5803-01BA to function is to send several SCLKs followed by a reset sequence or to repeat power on reset.

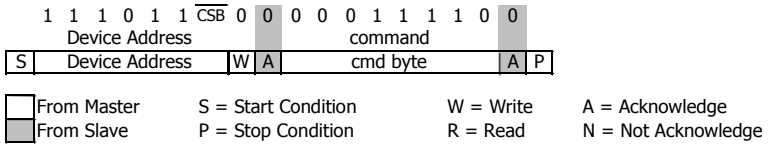


Figure 3: I²C Reset Command

CONVERSION SEQUENCE

A conversion can be started by sending the command to MS5803-01BA. 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 MS5803-01BA, 24 SCLK cycles may be sent to receive all result bits. Every 8 bit the system waits for an acknowledge signal.

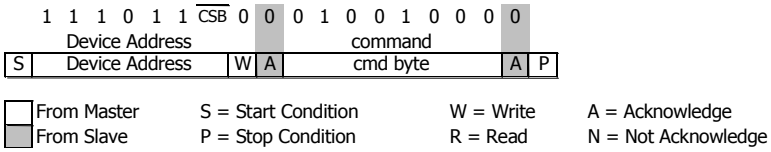


Figure 4: I²C Command to initiate a pressure conversion (OSR=4096, typ=D1)

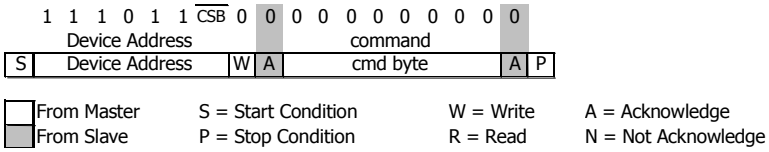


Figure 5: I²C ADC read sequence

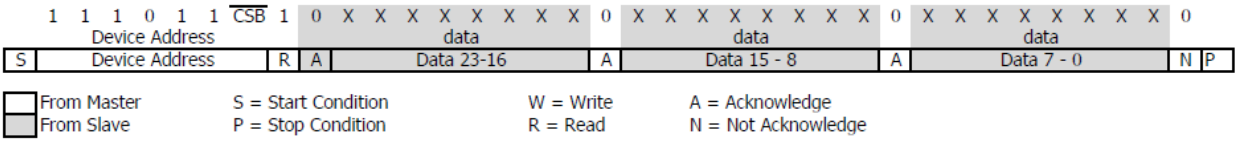


Figure 6: I²C pressure response (D1) on 24 bit from MS5803-01BA

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.

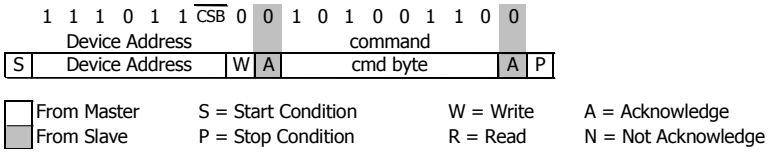


Figure 7: I²C Command to read memory address= 011 (Coefficient 3)

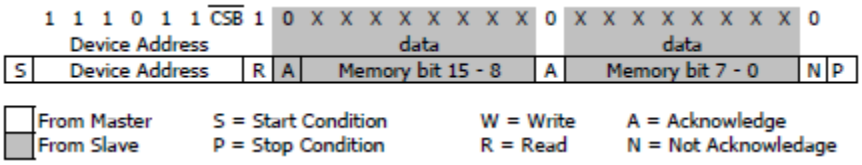


Figure 8: I²C answer from MS5803-01BA

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

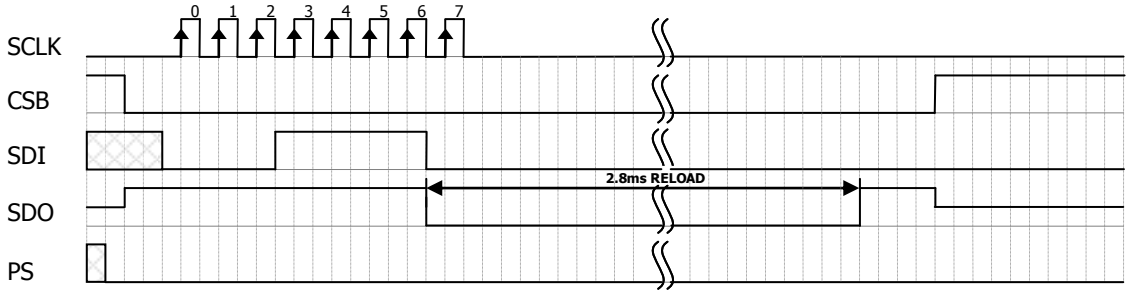


Figure 9: Reset command sequence SPI mode 0

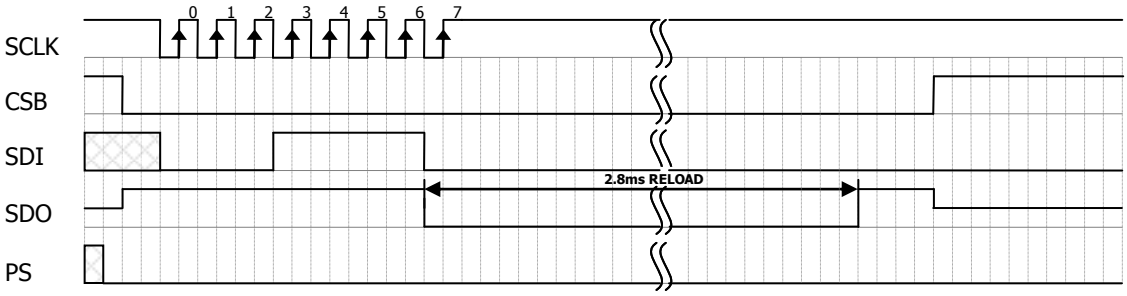


Figure 10: Reset command sequence SPI mode 3

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.

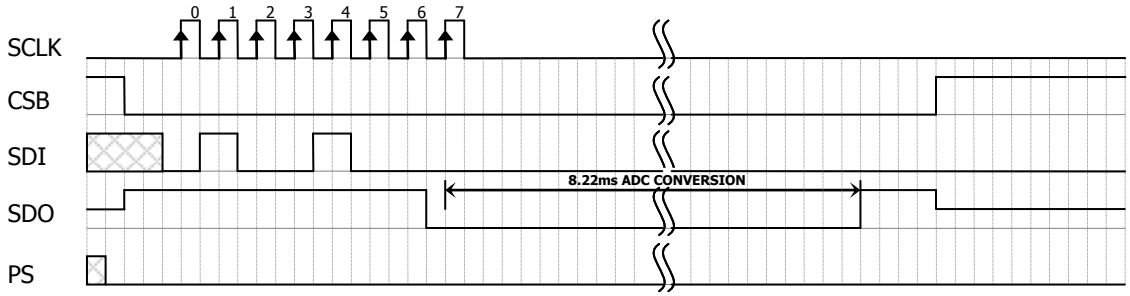


Figure 11: Conversion out sequence, Typ=d1, OSR = 4096

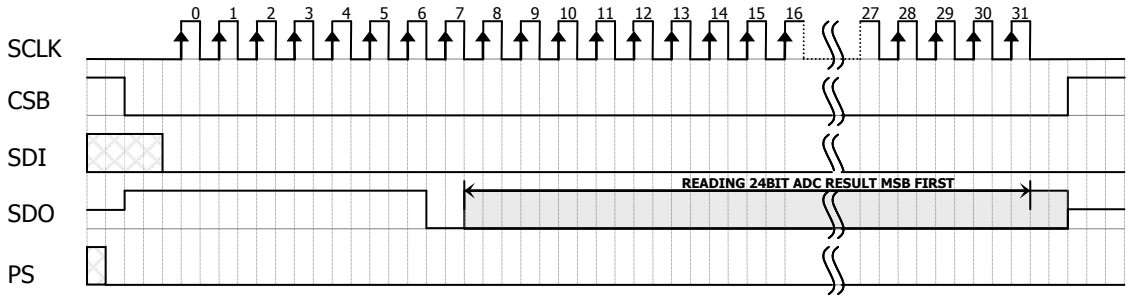


Figure 12: ADC Read sequence

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.

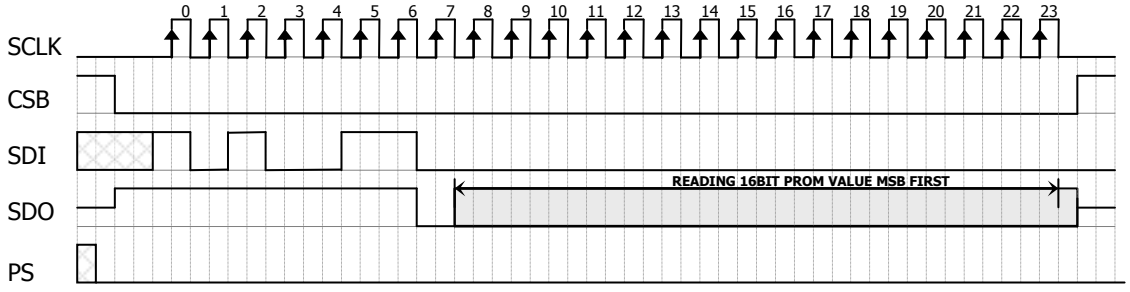


Figure 13: PROM Read sequence, address = 011 (Coefficient 3).

CYCLIC REDUNDANCY CHECK (CRC)

MS5803-01BA 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			

Figure 14: Memory PROM mapping

PRESSURE AND TEMPERATURE CALCULATION

Start
Maximum values for calculation results:
P_{MIN} = 10mbar P_{MAX} = 1300mbar
T_{MIN} = -40°C T_{MAX} = 85°C T_{REF} = 20°C

Read calibration data (factory calibrated) from PROM

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	40127
C2	Pressure offset | OFF_{T1}	unsigned int 16	16	0	65535	36924
C3	Temperature coefficient of pressure sensitivity | TCS	unsigned int 16	16	0	65535	23317
C4	Temperature coefficient of pressure offset | TCO	unsigned int 16	16	0	65535	23282
C5	Reference temperature | T_{REF}	unsigned int 16	16	0	65535	33464
C6	Temperature coefficient of the temperature | TEMPSENS	unsigned int 16	16	0	65535	28312

Read digital pressure and temperature data

D1	Digital pressure value	unsigned int 32	24	0	16777216	9085466
D2	Digital temperature value	unsigned int 32	24	0	16777216	8569150

Calculate temperature

dT	Difference between actual and reference temperature [2] $dT = D2 - T_{REF} = D2 - C5 * 2^8$	signed int 32	25	-16776960	16777216	2366
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	-4000	8500	2007 = 20.07 °C

Calculate temperature compensated pressure

OFF	Offset at actual temperature [3] $OFF = OFF_{T1} + TCO * dT = C2 * 2^{16} + (C4 * dT) / 2^7$	signed int 64	41	-8589672450	12884705280	2420281617
SENS	Sensitivity at actual temperature [4] $SENS = SENS_{T1} + TCS * dT = C1 * 2^{15} + (C3 * dT) / 2^8$	signed int 64	41	-4294836225	6442352640	1315097036
P	Temperature compensated pressure (10…1300mbar with 0.01mbar resolution) $P = D1 * SENS - OFF = (D1 * SENS / 2^{21} - OFF) / 2^{15}$	signed int 32	58	1000	130000	100009 = 1000.09 mbar

Display pressure and temperature value

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

Figure 15: Flow chart for pressure and temperature reading and software compensation.

SECOND ORDER TEMPERATURE COMPENSATION

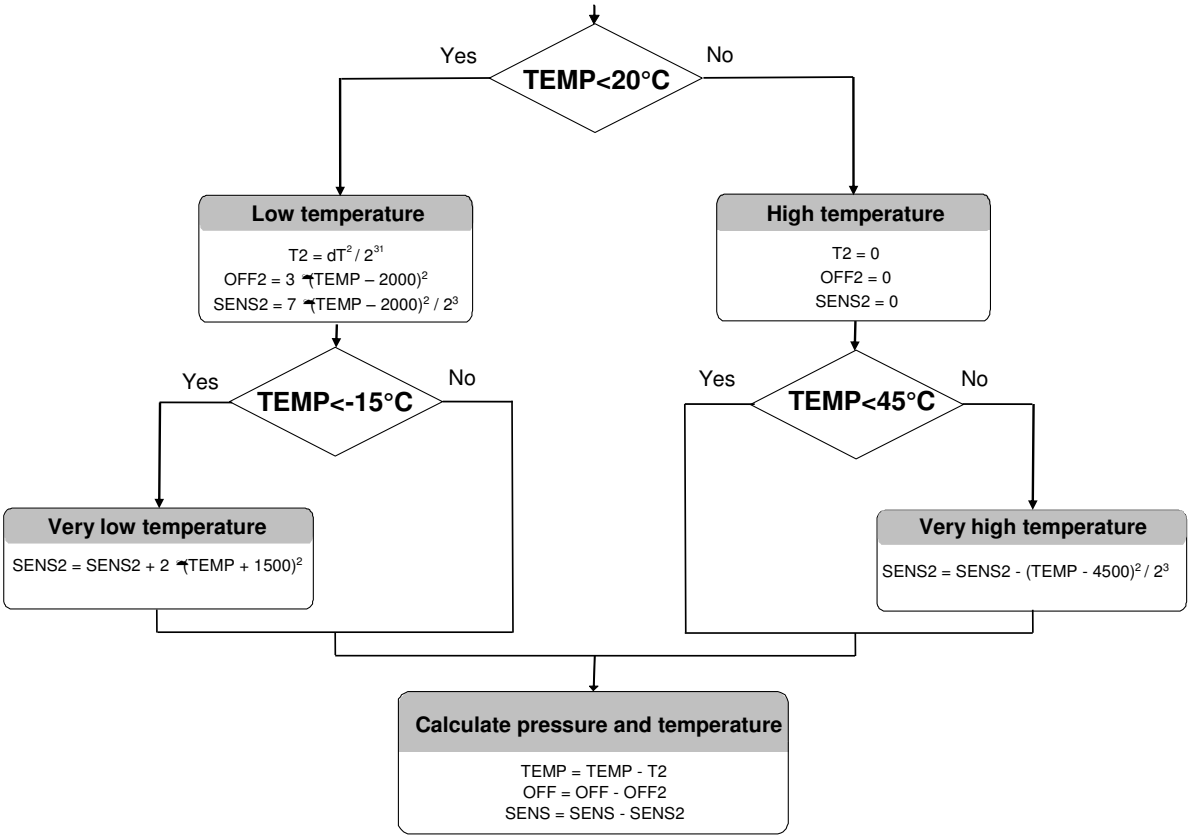


Figure 16: Flow chart for pressure and temperature to the optimum accuracy.

APPLICATION CIRCUIT

The MS5803-01BA 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.

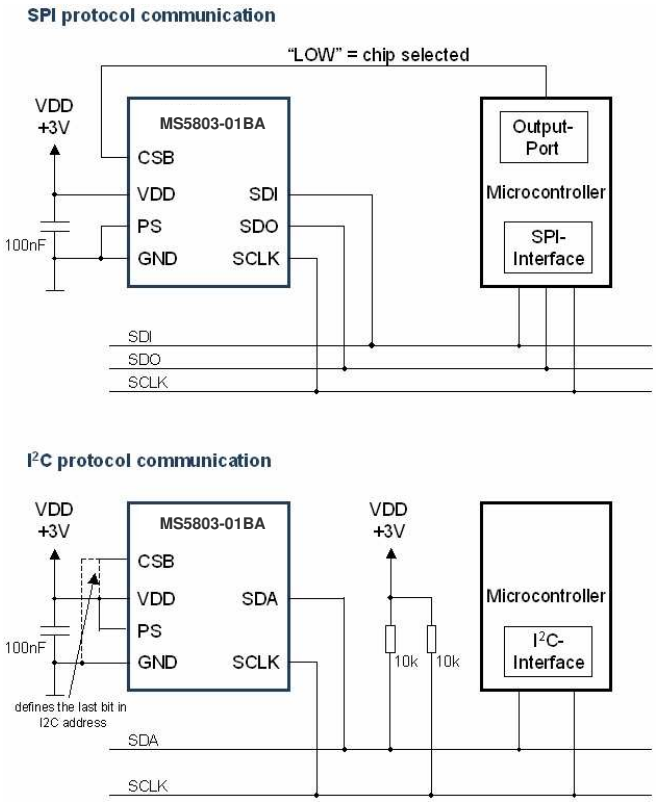
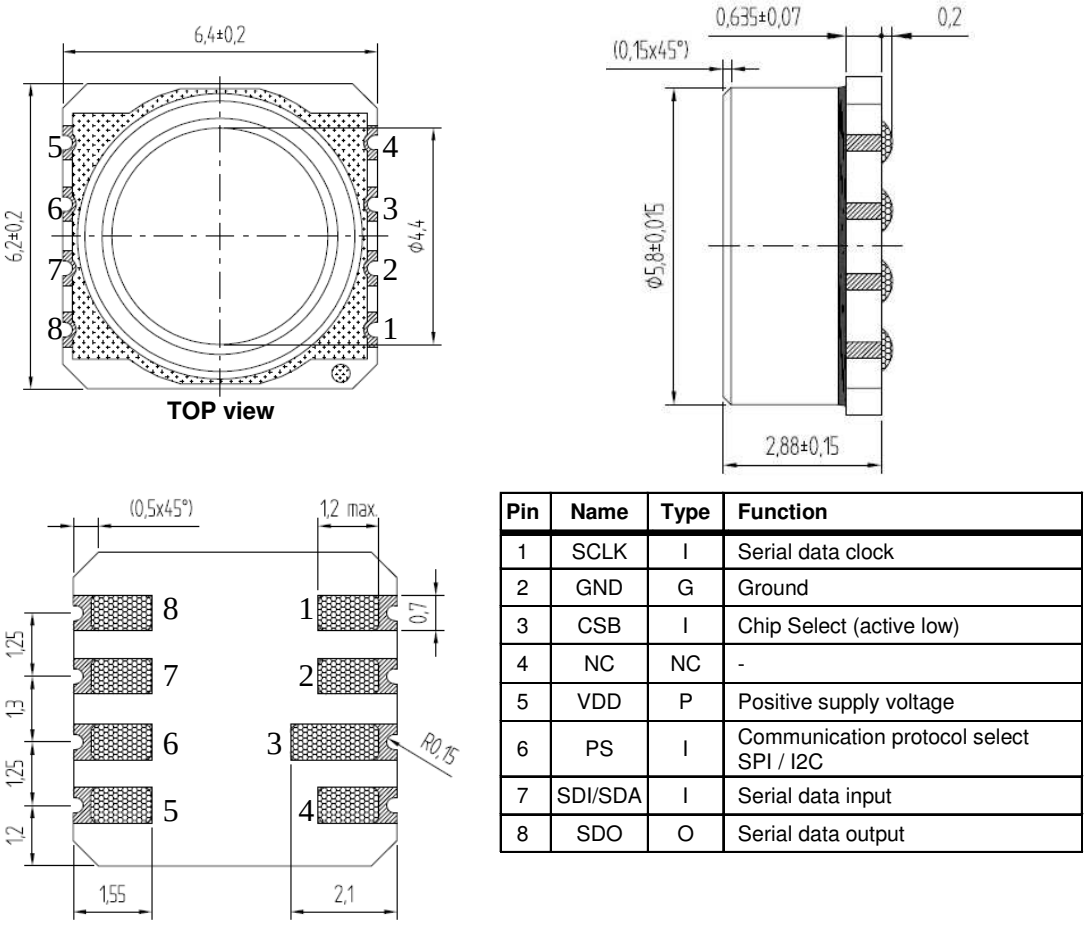


Figure 17: Typical application circuit with SPI / I²C protocol communication

PACKAGE OUTLINE AND PIN CONFIGURATION

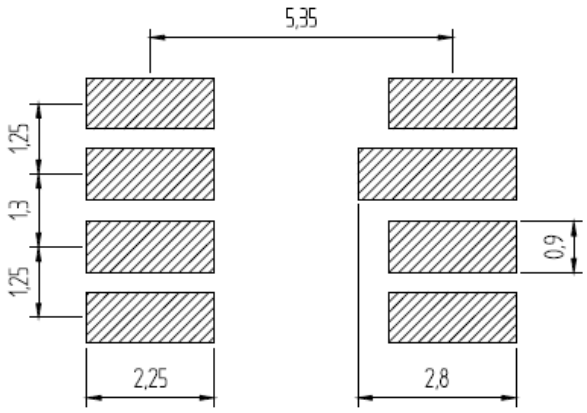


Pin	Name	Type	Function
1	SCLK	I	Serial data clock
2	GND	G	Ground
3	CSB	I	Chip Select (active low)
4	NC	NC	-
5	VDD	P	Positive supply voltage
6	PS	I	Communication protocol select SPI / I2C
7	SDI/SDA	I	Serial data input
8	SDO	O	Serial data output

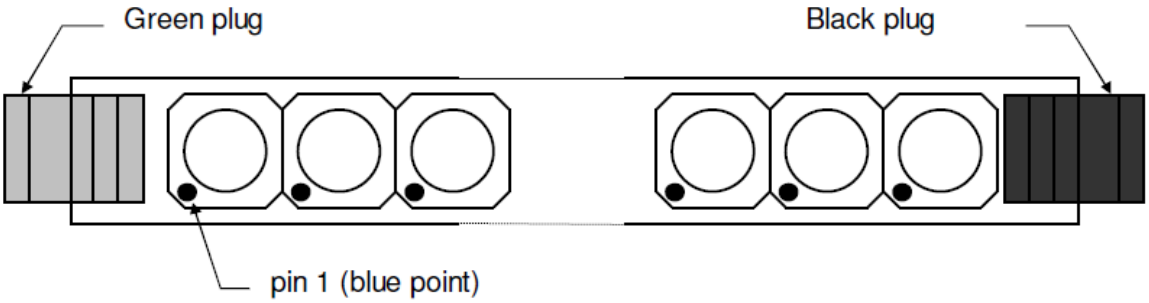
Figure 18: MS5803-01BA package outlines, pin configuration and description

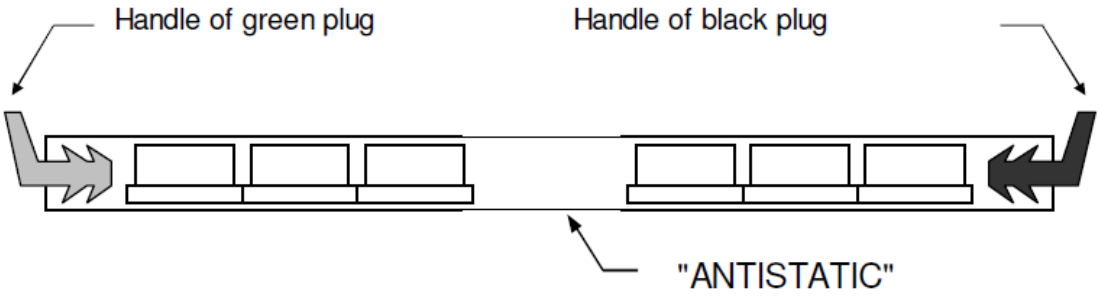
Notes: (1) Dimensions in mm
(2) General tolerance ±0.1
(3) Cap centering ± 0.15 from center of the ceramic

RECOMMENDED PAD LAYOUT

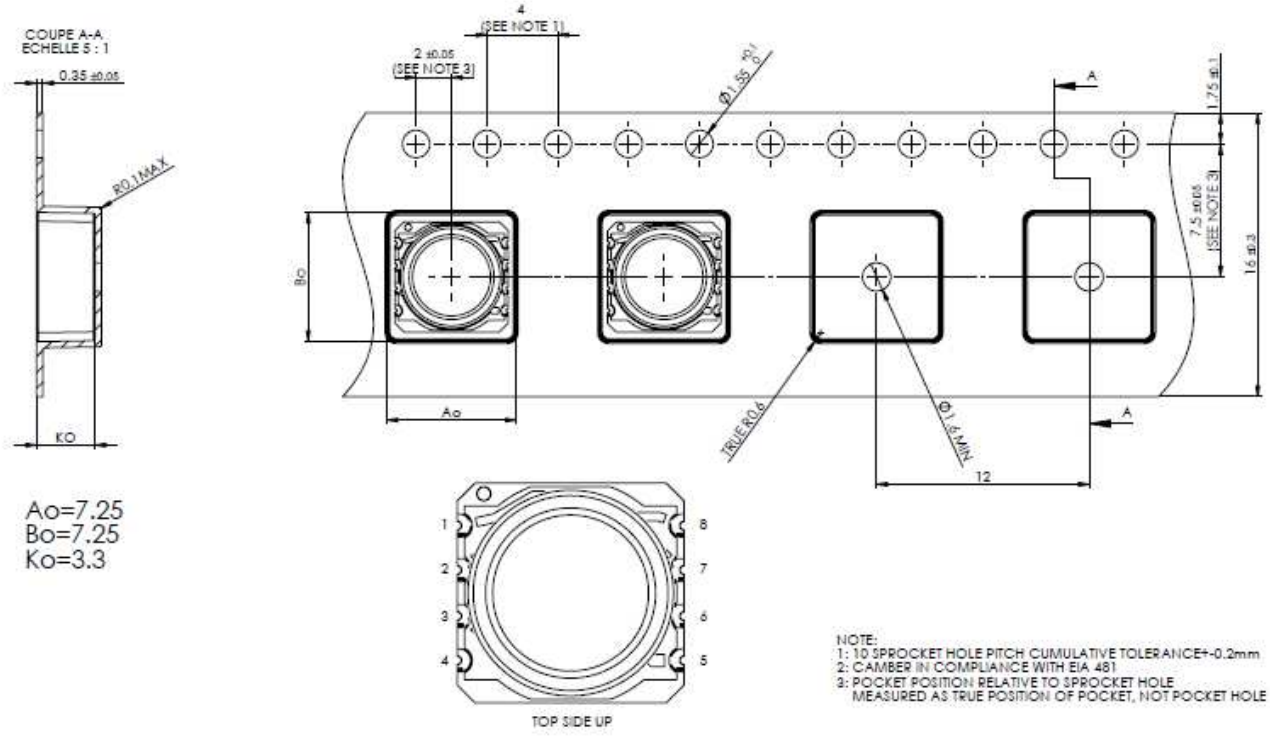


SHIPPING PACKAGE





Tube



Tape & reel

MOUNTING AND ASSEMBLY CONSIDERATIONS

SOLDERING

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

MOUNTING

The MS5803-01BA 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.

SEALING WITH O-RINGS

In products like outdoor watches the electronics must be protected against direct water or humidity. For those products the MS5803-01BA provides the possibility to seal with an O-ring. The protective cap of the MS5803-01BA is made of special anticorrosive stainless steel with a polished surface. In addition to this the MS5803-01BA is filled with silicone gel covering the sensor and the bonding wires. The O-ring (or O-rings) shall be placed at the outer diameter of the metal cap. This method avoids mechanical stress because the sensor can move in vertical direction.

CLEANING

The MS5803-01BA 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 MS5803-01BA 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 100nF ceramic capacitor must be placed as close as possible to the MS5803-01BA 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
MS580301BA01-00	MS5803-01BA 1BAR White Gel	Tube
MS580301BA01-50	MS5803-01BA 1BAR White Gel T&R	Tape & Reel TOP-UP
MS580301BA06-00	MS5803-01BA1BAR White Gel HE	Tube
MS580301BA06-50	MS5803-01BA 1BAR White Gel HE T&R	Tape & Reel TOP-UP
MS580301BA06-10	MS5803-01BA 1BAR White Gel P-Caps (Protective cap)	Tray
MS580301BA06-60	MS5803-01BA 1BAR White Gel HE T&R P-Caps (Protective cap)	Tape & Reel TOP-UP

PRODUCT DESCRIPTION

MS5803__BA__

Pressure Range

01	1 bar

Version

00	Standard
06	High Endurance