RoHS

MS5840-02BA

Low profile, gel-filled, ultra-compact, water resistant digital pressure and temperature sensor

There is an increasing demand for sensor components that offer high performance and precision in small spaces. To meet this need TE Connectivity (TE) has designed the MS5840-02BA sensor module with one of the lowest profile footprints in the market (3.3 x 3.3 x 1.7 mm). This ultra-compact, gel-filled pressure and temperature sensor is optimized for applications with small space constraints.

TE is a global leader in developing sensor solutions for harsh and complex environments. Our MS5840-2BA is optimized for consumer devices such as fitness trackers, drones and wearables providing a robust sensor package to withstand the harsh environments often encountered in these applications.

This MEMS based sensor includes a high-linearity pressure sensor with low power (0.6µA), 24-bit digital output (I^2C) and an altitude resolution at sea level of 13 cm. This enables high resolution measurements such as counting flights of stairs. The board level design delivers sensing accuracy for both pressure (±0.5mbar) and temperature (±2ºC) measurements.

Our MS5840-02BA provides exceptional performance, reliability and accurate performance from a brand you can trust.

APPLICATIONS

- Fitness Trackers
- Swim Watches
- Shallow Diving Computers
- Drones / Underwater Drones
- Diving Equipment
- E-cigarettes
- Mobile Altimeter/Barometer Systems
- Wearables

FEATURES

- Ceramic and metal package: 3.3 x 3.3 x 1.7mm
- High-resolution module: 13cm
- Supply voltage: 1.5 to 3.6V
- Fast conversion down to 0.5ms
- Low power, 0.6µA (standby ≤ 0.1 µA at 25°C)
- Integrated digital pressure sensor (24-bit ΔΣ ADC)
- Operating range: 300 to 1200mbar, -20 to +85°C
- I^2C interface
- No external components (internal oscillator)
- Shielded metal lid
- Chlorine resistant option

PERFORMANCE SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Supply voltage	V_{DD}		-0.3		+4	V
Storage temperature	T_S		-40		+85	℃
Overpressure	P_{max}	ISO 22810 (1)			10	bar
Maximum Soldering Temperature (2)	T_{max}	40 sec. max			250	℃
ESD rating (lid to GND version)		Human Body Model	-2		+2	kV
Latch up		JEDEC JESD78 standard	-100		+100	mA

(1) Pressure ramp up/down min 60s
(2) Refer to application note 808

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Operating Supply voltage	V_{DD}			1.5	3.0	3.6	V
Operating Temperature	T			-20	+25	+85	℃
Supply current (1 sample per sec.)	I_{DD}	OSR	8192		20.09		µA
			4096		10.05		
			2048		5.02		
			1024		2.51		
			512		1.26		
			256		0.63		
Peak supply current		during conversion			1.25		mA
Standby supply current		at 25℃ (V_{DD} = 3.0 V)			0.01	0.1	µA
Power supply hold off for internal reset (3)		VDD < 0.1V		200			ms
VDD Capacitor		from VDD to GND		100	470		nF
Resistor value between the lid and the GND		Version 02BA2x, 02BA3x			1000		Ω

(3) Supply voltage power up must be continuous from GND to VDD without any step

ANALOG DIGITAL CONVERTER (ADC)

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Output Word					24		bit
ADC Conversion time (4)	t_c	OSR	8192		16.44	17.2	ms
			4096		8.22	8.61	
			2048		4.13	4.32	
			1024		2.08	2.17	
			512		1.06	1.10	
			256		0.54	0.56	

(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℃ UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Typ.	Max	Unit
Operating Pressure Range	P_{range}		300		1200	mbar
Extended Pressure Range	P_{ext}	Linear Range of ADC	10		2000	mbar
Relative Accuracy [1] [4]	600...1000 mbar, at 20℃ 300...1100 mbar, 0...60℃ 300...1100 mbar, -20...85℃		-0.5 -2 -4		+0.5 +2 +4	mbar
Resolution RMS	OSR	8192 4096 2048 1024 512 256		0.016 0.021 0.028 0.039 0.062 0.11		mbar
Maximum error with supply voltage [2]	V_{DD} = 1.5 V…3.6 V			±2		mbar
Long-term stability				±2		mbar/yr
Reflow soldering impact	IPC/JEDEC J-STD-020C (Refer to application note AN808)			±4		mbar
Recovering time after reflow [3]				7		days

[1] With autozero at one pressure point

[2] With autozero at 3V point

[3] Time to recover at least 66% of reflow impact

[4] Wet/dry cycle: sensor must be dried typically once a day

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

Parameter	Conditions		Min.	Typ.	Max	Unit
Relative Accuracy	0…60℃, 600…1100 mbar			±1		℃
	-20…85℃, 300…1100 mbar		-2		+2	℃
Maximum error with supply voltage	V_{DD} = 1.5 V…3.6 V			±0.3		℃
Resolution RMS	OSR	8192 4096 2048 1024 512 256		0.002 0.003 0.004 0.006 0.009 0.012		℃

DIGITAL INPUTS (SDA, SCL)

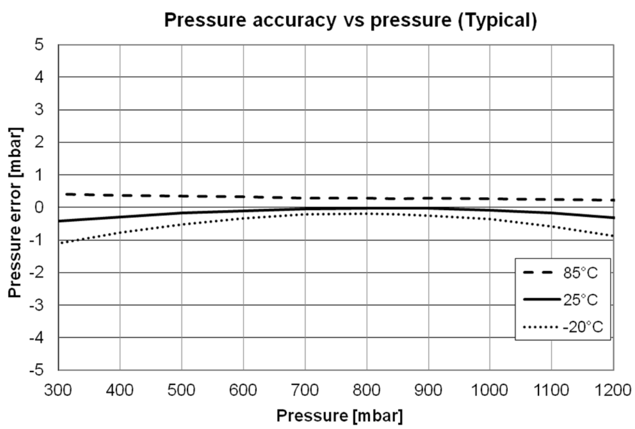
Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock	SCL				400	kHz
Input high voltage	V_{IH}		80% V_{DD}		100% V_{DD}	V
Input low voltage	V_{IL}		0% V_{DD}		20% V_{DD}	V
Input leakage current	I_{leak}	T = 25 ℃			0.1	µA

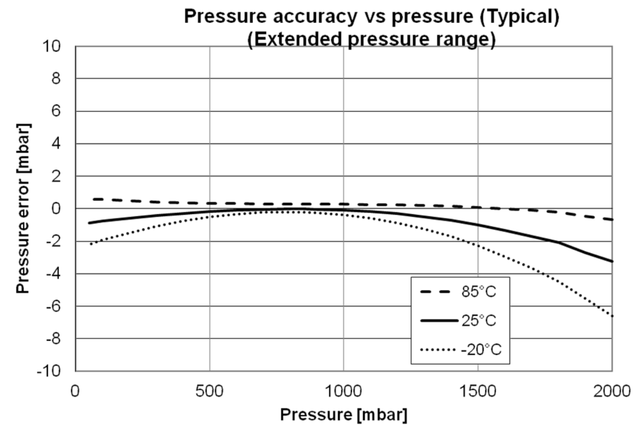
DIGITAL OUTPUTS (SDA)

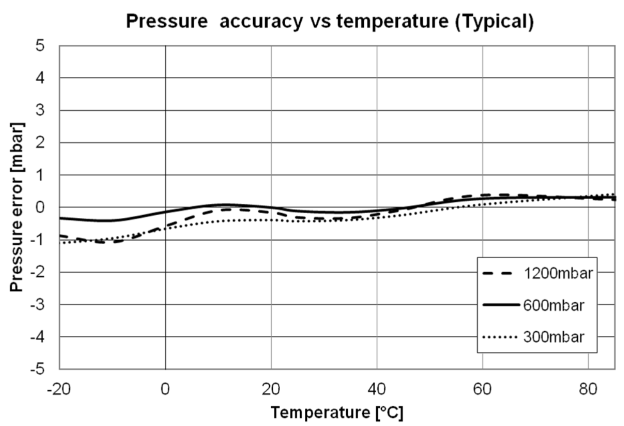
Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Output high voltage	V_{OH}	I_{source} = 1 mA	80% V_{DD}		100% V_{DD}	V
Output low voltage	V_{OL}	I_{sink} = 1 mA	0% V_{DD}		20% V_{DD}	V

TYPICAL PERFORMANCE CHARACTERISTICS

RELATIVE PRESSURE ERROR AND TEMPERATURE ERROR VS PRESSURE AND TEMPERATURE (TYPICAL VALUES)

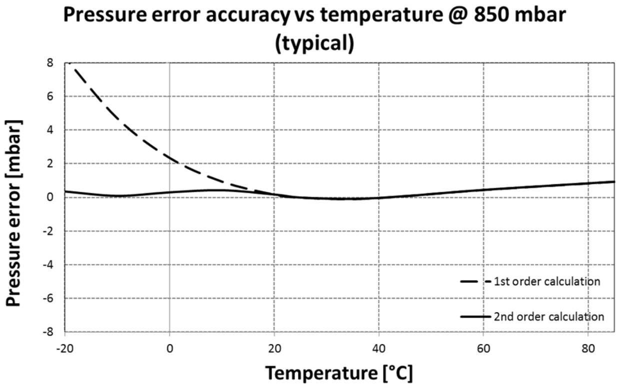


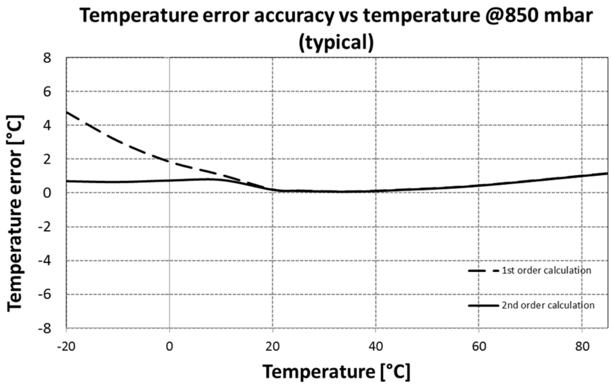




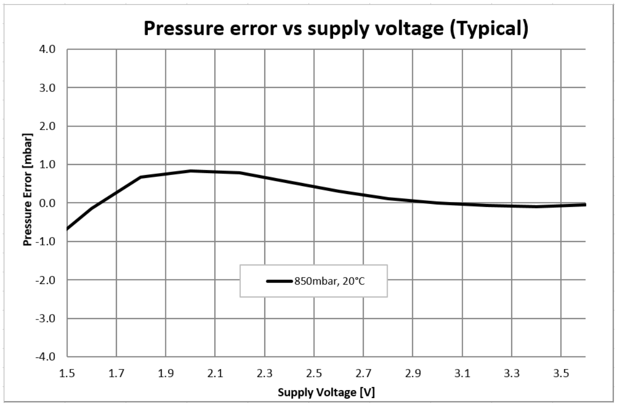
TYPICAL PERFORMANCE CHARACTERISTICS

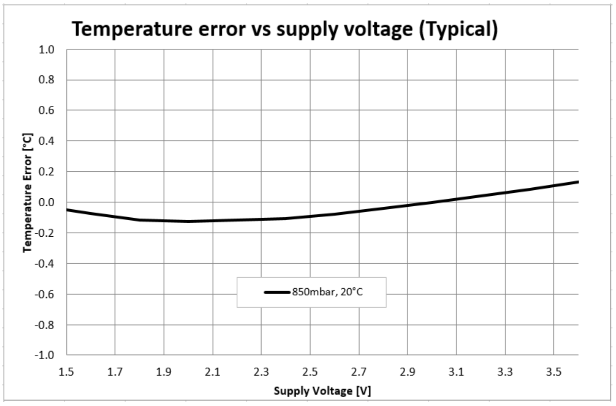
RELATIVE PRESSURE AND TEMPERATURE ERROR VS TEMPERATURE (1ST ORDER AND 2ND ORDER ALGORITHM, TYPICAL VALUES)





RELATIVE PRESSURE AND TEMPERATURE ERROR VS POWER SUPPLY (TYPICAL VALUES)





PRESSURE AND TEMPERATURE CALCULATION

GENERAL

The MS5840 consists of a piezo-resistive sensor and a sensor interface integrated circuit. The main function of the MS5840 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, 8 coefficients necessary to compensate for process and temperature variations are calculated and stored in the 112 bits PROM of each module. These bits (stored in 16 bits word from W0 to W6) must be read and used together with the D1 and D2 values to get the compensated pressure and temperature values.

The coefficient W0 contains also factory configuration bits and a CRC, as represented in '' Figure 10 : Version number in Word 0'' below.

SERIAL I^{2}C INTERFACE

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 I^{2}C bus interface. This interface type uses only 2 signal lines and does not require a chip select.

Module ref	Mode	Pins used	Address (7 bits)
MS5840-02BA	I^{2}C	SDA, SCL	0x76 (1110110 b)

FIRST ORDER PRESSURE AND TEMPERATURE CALCULATION

Start
Maximum values for calculation results:
P_{MIN} = 10mbar P_{MAX} = 2000mbar
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	65335	46372
C2	Pressure offset | OFF_{T1}	unsigned int 16	16	0	65335	43981
C3	Temperature coefficient of pressure sensitivity | TCS	unsigned int 16	16	0	65335	29059
C4	Temperature coefficient of pressure offset | TCO	unsigned int 16	16	0	65335	27842
C5	Reference temperature | T_{REF}	unsigned int 16	16	0	65335	31553
C6	Temperature coefficient of the temperature | TEMPSENS	unsigned int 16	16	0	65335	28165

Read digital pressure and temperature data

Variable	Description | Equation	Recommended variable type	Size[1] [bit]	Value min	Value max	Example / Typical
D1	Digital pressure value	unsigned int 32	24	0	16777215	6464444
D2	Digital temperature value	unsigned int 32	24	0	16777215	8077636

Calculate temperature

Variable	Description | Equation	Recommended variable type	Size[1] [bit]	Value min	Value max	Example / Typical
dT	Difference between actual and reference temperature [2] $dT = D2 - T_{REF} = D2 - C5 * 2^{8}$	signed int 32	25	-16776960	16777216	68
TEMP	Actual temperature (-40…85°C with 0.01°C resolution) $TEMP = 20°C + dT * TEMPSENS = 2000 + dT * C6 / 2^{23}$	signed int 32	25	-4000	8500	2000 = 20.00°C

Calculate temperature compensated pressure

Variable	Description | Equation	Recommended variable type	Size[1] [bit]	Value min	Value max	Example / Typical
OFF	Offset at actual temperature [2] $OFF = OFF_{T1} + TCO * dT = C2 * 2^{17} + dT * C4 / 2^{6}$	signed int 64	41	-17179344900	25769410560	5764707214
SENS	Sensitivity at actual temperature [2] $SENS = SENS_{T1} + TCS * dT = C1 * 2^{16} + dT * C3 / 2^{7}$	signed int 64	41	-8589672450	12884705280	303950829
P	Temperature compensated pressure (10…1200mbar with 0.01mbar resolution) $P = (D1 * SENS / 2^{21} - OFF) / 2^{15}$	signed int 32	58	1000	120000	110002 = 1100.02 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

Figure 1 : Pressure and temperature first order

SECOND ORDER TEMPERATURE COMPENSATION

The results of the first order calculation are used as described in the following chart to obtain the 2nd order pressure and temperature compensated values.

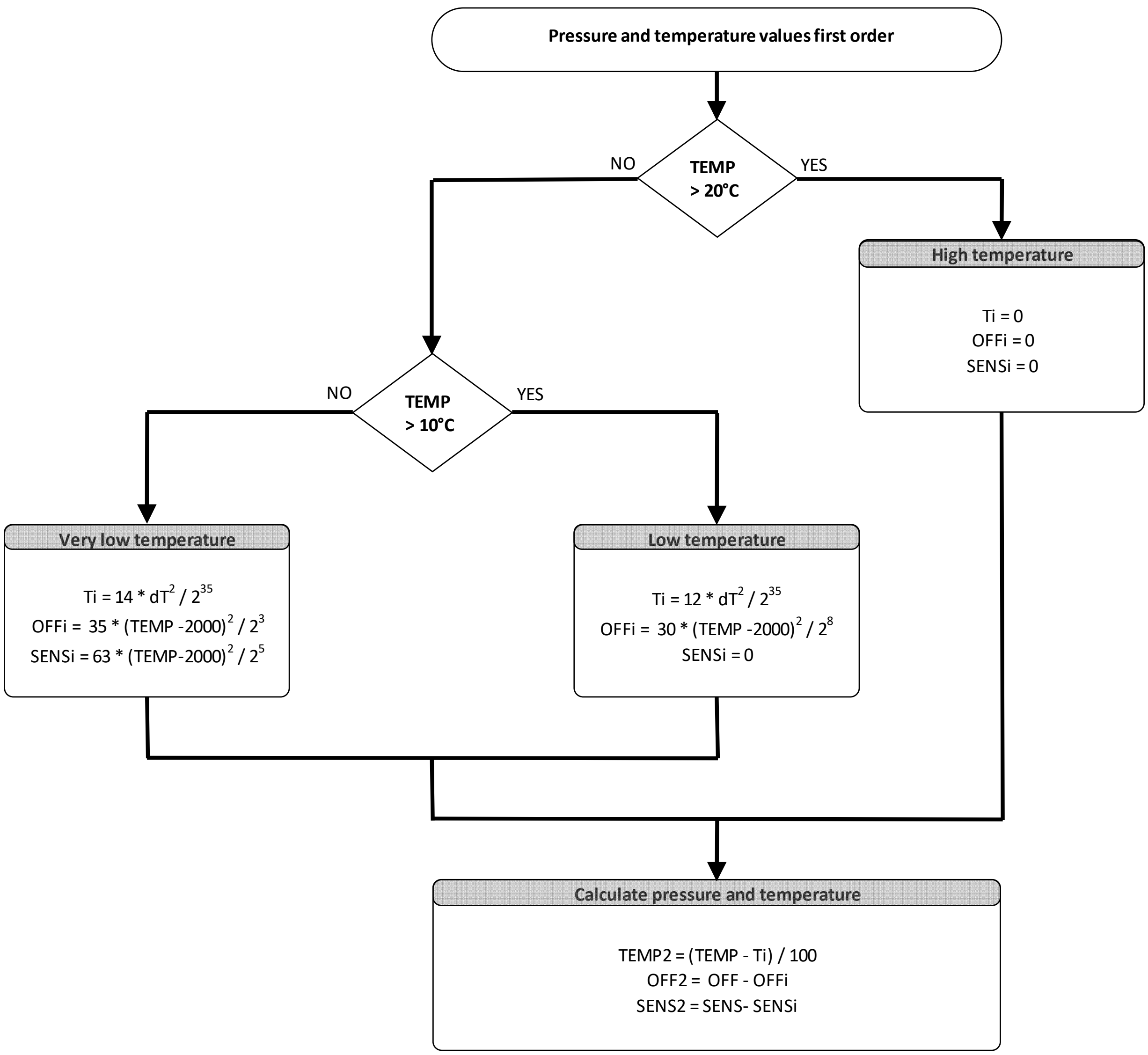


Figure 2 : Second order compensation flowchart

I²C INTERFACE

COMMANDS

The MS5840 has only five basic commands:

1. Reset
2. Read PROM (112 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 ''Figure 3 : Command structure'' below.
After the PROM read command, sensor responds with 16 bits word. Bits A2, A1 and A0 select PROM addresses.
Conversion is started after a "Convert D1" or "Convert D2" with the requested OSR is issued. Conversion time depends on the OSR as shown in the table specifications. Maximum waiting time values need to be used to ensure finished operation.
ADC read command will return 24 bits result of the above requested finished conversion.

	Command byte								**hex value**
Bit number	0	1	2	3	4	5	6	7	
Bit name	PRM	COV	-	Typ	A2/Os2	A1/Os1	A0/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	A2	A1	A0	0	0xA0 to 0xAC

Figure 3 : Command structure

RESET SEQUENCE

At power on, an internal reset circuitry ensures calibration PROM data gets loaded into the internal register. Reset sequence can be sent once to make sure this operation is successfully done. It can be also used to reset the device PROM from an unknown condition.
The reset can be sent at any time. In the event that there is no successful power on reset, maybe caused by the SDA being blocked by the module in the acknowledge state, the only way to get the MS5840 back to function, is to send several SCLs until SDA release, followed by a reset sequence, or to perform a power OFF-ON cycle.

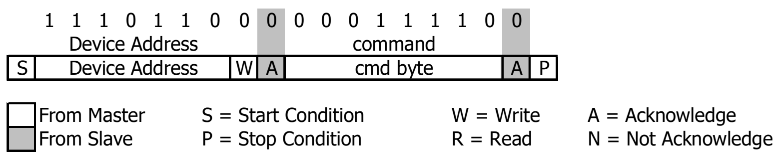


Figure 4 : I²C Reset Command

PROM READ SEQUENCE

The read command for PROM must be executed once after reset by the user software to read the content of the calibration PROM and extract / store the calibration coefficients. There are 7 addresses resulting in a total memory content of 112 bits. Memory words contain: factory data, calibration coefficients and CRC. Command sequence is 8 bits wide and slave responses will send back 16 bits result which is clocked with the MSB first.
The PROM read command is divided in two parts. Firstly, ASIC is set into PROM read mode and address of the requested word is issued. Then, content of addressed memory word is read.

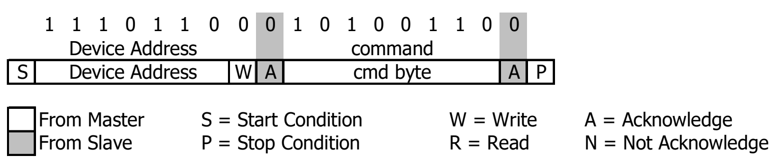


Figure 5 : I²C Command to read memory address= 011

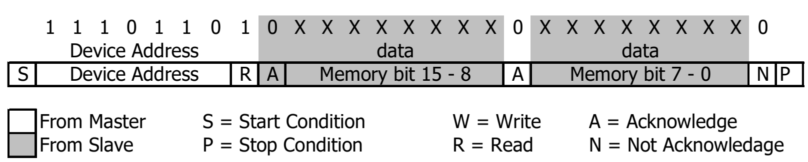


Figure 6 : I²C answer from MS5840

CONVERSION SEQUENCE

The conversion command is used to initiate uncompensated pressure (D1) or uncompensated temperature (D2) conversion. Once finished, raw values are read using "ADC read command". Result is clocked out with MSB first. If conversion is not finished before sending the "ADC read command", or the "ADC read command" is repeated, conversion will not stop but issued result will be wrong. Conversion sequence command sent during the already started conversion process will yield incorrect result as well.

Once command issued, the ADC will start converting the values from the sensing element into digital 24-bit format. Conversion time is dependent from selected OSR (page 2).
After the conversion is performed, the data can be accessed by sending a read command as shown below.

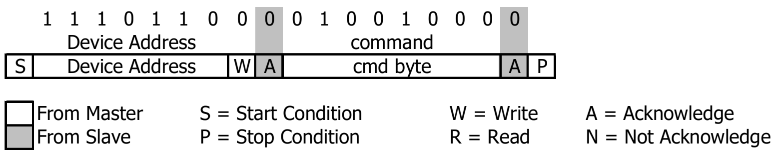


Figure 7 : I²C command to initiate a pressure conversion (OSR=4096, typ=D1)

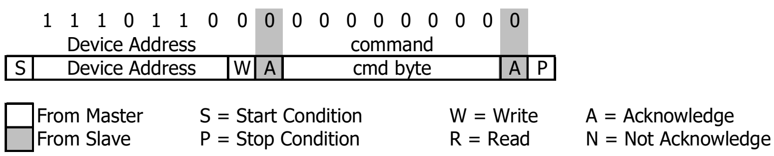


Figure 8 : I²C ADC read sequence

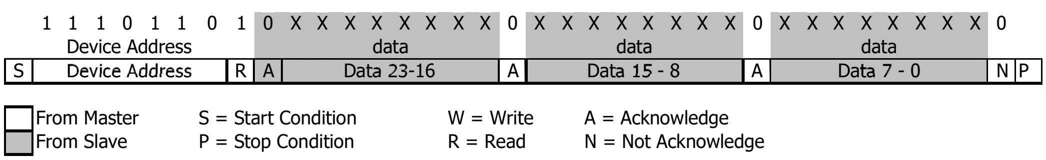


Figure 9 : I²C answer from MS5840

VERSION IDENTIFICATION NUMBER (WORD 0)

Depending on product version, bits [11:5] of memory address 0 are programmed with the following fixed values:

MS5840-02BA21

Address	*15*	*14*	*13*	*12*	11	10	9	8	7	6	5	*4*	*3*	2	*1*	*0*
0	*crc*				**0**	**0**	**1**	**0**	**1**	**0**	**1**	*factory configuration bits*				

MS5840-02BA36

Address	*15*	*14*	*13*	*12*	11	10	9	8	7	6	5	*4*	*3*	2	*1*	*0*
0	*crc*				**0**	**1**	**0**	**0**	**1**	**0**	**0**	*factory configuration bits*				

Figure 10 : Version number in Word 0

CYCLIC REDUNDANCY CHECK (CRC)

A 4-bits CRC has been implemented to check the data validity in memory. The CRC read in the first four bits of W0 must be equal to the CRC calculated (see algorithm below) with all other PROM bits to ensure memory content integrity.

	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	CRC				Version number							Factory configuration bits				
1	C1															
2	C2															
3	C3															
4	C4															
5	C5															
6	C6															

Figure 11 : Memory PROM mapping

C CODE EXAMPLE FOR CRC-4 CALCULATION:

```
unsigned char crc4(unsigned int n_prom[])                    // n_prom defined as 8x unsigned int (n_prom[8])
{
int cnt;                                                     // simple counter
unsigned int n_rem=0;                                        // crc remainder
unsigned char n_bit;
        n_prom[0]=((n_prom[0]) & 0x0FFF);                    // CRC byte is replaced by 0
        n_prom[7]=0;                                         // Subsidiary value, set to 0
        for (cnt = 0; cnt < 16; cnt++)                       // operation is performed on bytes
                {                                            // choose LSB or MSB
                if (cnt%2==1)       n_rem ^= (unsigned short) ((n_prom[cnt>>1]) & 0x00FF);
                else                n_rem ^= (unsigned short) (n_prom[cnt>>1]>>8);
                for (n_bit = 8; n_bit > 0; n_bit--)
                        {
                        if (n_rem & (0x8000))       n_rem = (n_rem << 1) ^ 0x3000;
                        else                        n_rem = (n_rem << 1);
                        }
                }
        n_rem= ((n_rem >> 12) & 0x000F);                     // final 4-bit remainder is CRC code
        return (n_rem ^ 0x00);
}
```

APPLICATION CIRCUIT

MS5840 is a sensor that can be used in conjunction with a microcontroller in mobile altimeter applications. A typical application circuit is presented in ''Figure 12 : *Typical application circuit*''

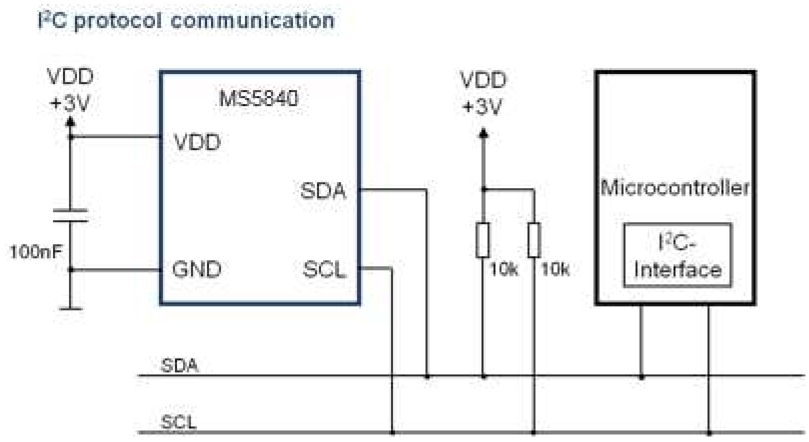
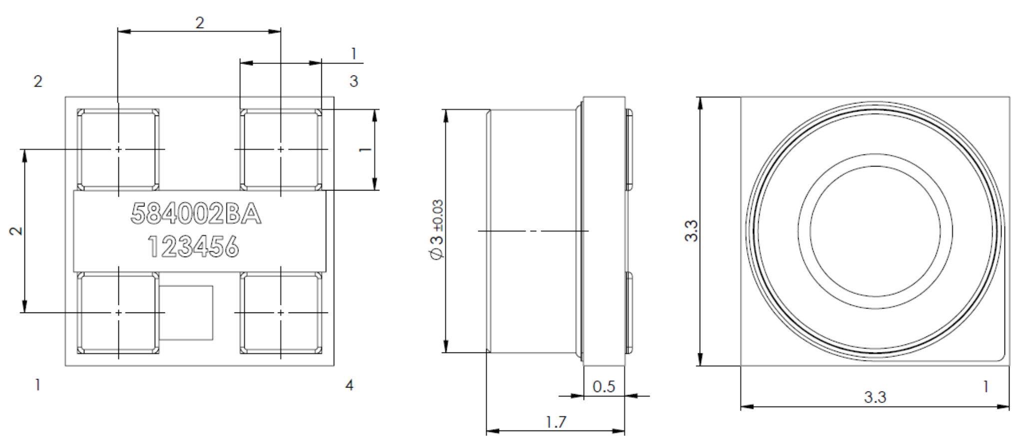


Figure 12 : Typical application circuit

PIN CONFIGURATION AND DEVICE PACKAGE OUTLINE.



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS. GENERAL TOLERANCE ± 0.15mm

1	GND	GROUND
2	VDD	POSITIVE SUPPLY
3	SCL	I²C CLOCK
4	SDA	I²C DATA

Figure 13 : Package outlines and pin configuration

RECOMMENDED PAD LAYOUT

Pad layout for bottom side of the MS5840 soldered onto printed circuit board.

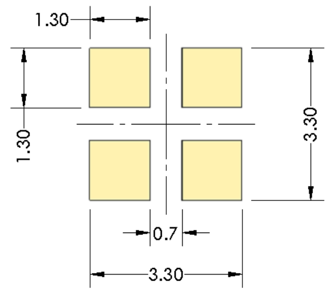
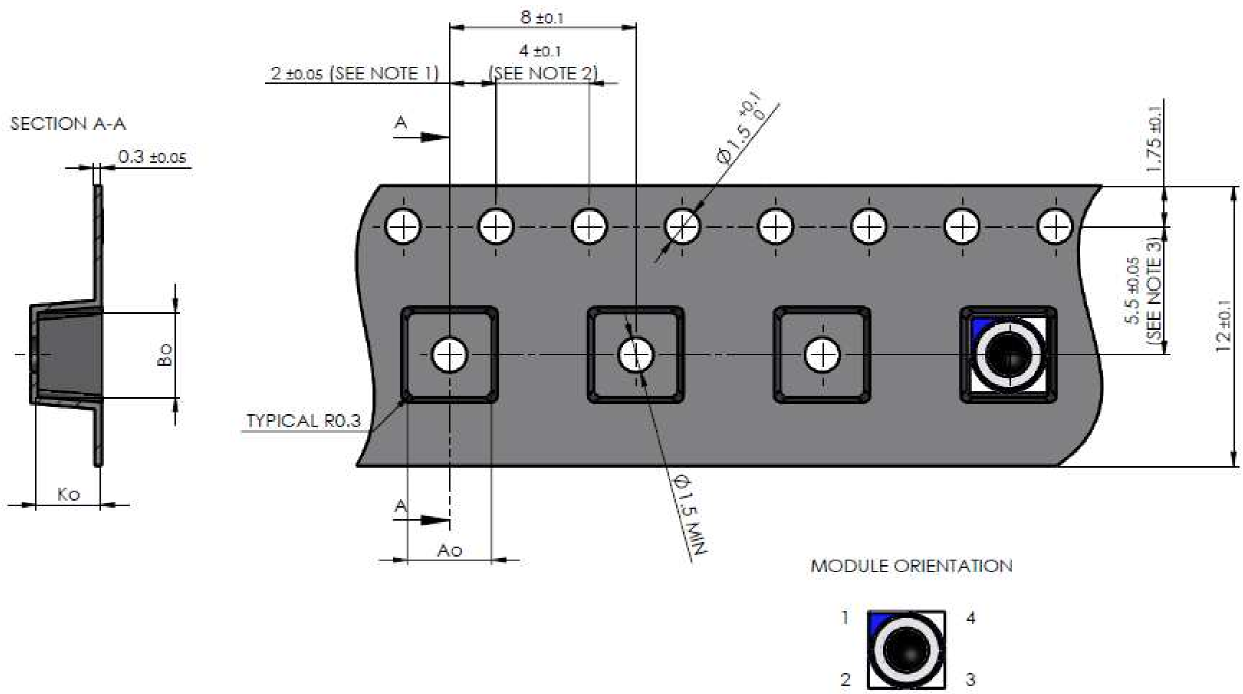


Figure 14 : PCB footprint

SHIPPING PACKAGE



Ao	3.6±0.1
Bo	3.6±0.1
Ko	2.75±0.1

Figure 15 : Tape dimensions

MOUNTING AND ASSEMBLY CONSIDERATIONS

SOLDERING

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

MOUNTING

The MS5840 can be processed 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. Gel must stay free of external physical contact when manipulation.

CONNECTION TO PCB

The package outline of the module allows the use of a flexible PCB. This is ideal for small-sized applications.

SEALING

In applications such as outdoor watches the electronics must be protected against direct water or humidity. For such applications the MS5840 provides the possibility to seal with a gasket or an O-ring.

CLEANING

The MS5840 has been manufactured under clean-room 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. Warning: cleaning might damage the sensor.

ESD PRECAUTIONS

The electrical contact pads are protected against ESD up to 2 kV HBM (human body model). It is therefore essential to ground machines and personal properly during assembly and handling of the device. The MS5840 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 of 100nF ceramic capacitor must be placed as close as possible to the MS5840 VDD pin. This capacitor will stabilize the power supply during data conversion and thus, provide the highest possible accuracy.

ORDERING INFORMATION

PART NUMBER	DESCRIPTION	SHIELDING	CHLORINE RESISTANT
20000980-00	MS5840-02BA21 LP PRESS SENSOR T&R	X	
20000982-00	MS5840-02BA36 LP PRESS SENSOR T&R	X	X

NORTH AMERICA
TEsensors-CCmeas@te.com

EUROPE
tess-ic-tlse@te.com

ASIA
customercare.shzn@te.com

te.com/sensorsolutions

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