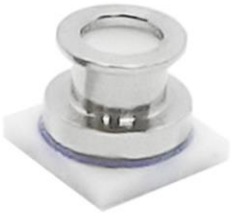


# MS5839-02BA

## Ultra-compact, chlorine resistant, digital pressure and temperature sensor

Miniaturization, performance and precision are key for sensors embedded in consumer devices like swim watches and diving equipment. Expanding on TE Connectivity's (TE) portfolio of ultra-compact digital altimeters, our MS5839 2 bar model is designed to meet the next generation of device manufacturer designs and challenges.

TE's MS5839 is an ultra-compact (3.3 x 3.3 x 2.75 mm) digital altimeter that is optimized for applications where chlorine and saline are present. The robust, gel-filled design of the MS5839 enables operation in harsh media environments while providing accurate and reliable digital measurements.

This MEMS based sensor offers advanced water resistance, chlorine resistance, shielding, low power consumption and digital interconnectivity in an ultra-compact, low profile package. The board level design delivers sensing accuracy for both pressure (±0.5mbar) and temperature (±2ºC) measurements.

Take your devices to the next level with the MS5839-02BA.

## APPLICATIONS

- Shallow Diving Computers
- Swim Watches
- Fitness Trackers
- Underwater Vehicles
- Diving Equipment
- Diving Computers

## FEATURES

- Ceramic and metal package: 3.3 x 3.3 x 2.75mm
- High resolution module: 13 cm
- Supply voltage: 1.5 to 3.6 V
- Low power: 0.6 µA (standby ≤ 0.1 µA at 25°C)
- Integrated digital pressure sensor (24-bit ΔΣ ADC)
- Operating range: 300 to 1,200 mbar, -20 to +85 °C
- $I^2C$ interface
- No external components (internal oscillator)
- Water resistant sealing with 1.8 x 0.8mm O-ring
- Chlorine resistant
- Shielded metal lid

# PREFORMANCE SPECIFCIATIONS

## ABSOLUTE MAXIMUM RATINGS

| Parameter | Symbol | Conditions | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Supply voltage | $V_{DD}$ | | -0.3 | | +3.6 | V |
| Storage temperature | $T_S$ | | -40 | | +85 | °C |
| Overpressure | $P_{max}$ | ISO 22810[1] | | | 10 | bar |
| Maximum Soldering Temperature [2] | $T_{max}$ | 40 sec. max | | | 250 | °C |
| 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 | °C |
| Supply current (1 sample per sec.) | $I_{DD}$ | OSR | 8192<br>4096<br>2048<br>1024<br>512<br>256 | | 20.09<br>10.05<br>5.02<br>2.51<br>1.26<br>0.63 | | µA |
| Peak supply current | | during conversion | | | 1.25 | | mA |
| Standby supply current | | at 25°C ($V_{DD}$ = 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 | | | | | 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<br>4096<br>2048<br>1024<br>512<br>256 | | 16.44<br>8.22<br>4.13<br>2.08<br>1.06<br>0.54 | 17.2<br>8.61<br>4.32<br>2.17<br>1.10<br>0.56 | ms |

[4] Maximum values must be used to determine waiting times in $I^2C$ 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 | $P_{range}$ | | 300 | | 1200 | mbar |
| Extended Pressure Range | $P_{ext}$ | Linear Range of ADC | 10 | | 2000 | mbar |
| Relative Accuracy [1] [4] | 600...1000 mbar, at 20°C<br>300...1100 mbar, 0...60°C<br>300...1100 mbar, -20...85°C | | -0.5<br>-2<br>-4 | | +0.5<br>+2<br>+4 | mbar |
| Resolution RMS | OSR | 8192<br>4096<br>2048<br>1024<br>512<br>256 | | 0.016<br>0.021<br>0.028<br>0.039<br>0.062<br>0.11 | | mbar |
| Maximum error with supply voltage [2] | $V_{DD}$ = 1.5 V…3.6 V | | | ±2 | | mbar |
| Long-term stability | | | | ±1 | | mbar/yr |
| Reflow soldering impact | IPC/JEDEC J-STD-020C<br>(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°C UNLESS OTHERWISE NOTED)

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

### DIGITAL INPUTS (SDA, SCL)

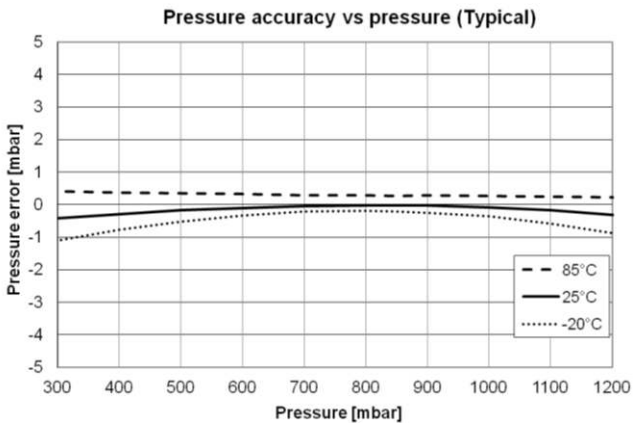
| Parameter | Symbol | Conditions | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Serial data clock | SCL | | | | 400 | kHz |
| Input high voltage | $V_{IH}$ | | 80% $V_{DD}$ | | 100% $V_{DD}$ | V |
| Input low voltage | $V_{IL}$ | | 0% $V_{DD}$ | | 20% $V_{DD}$ | V |
| Input leakage current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

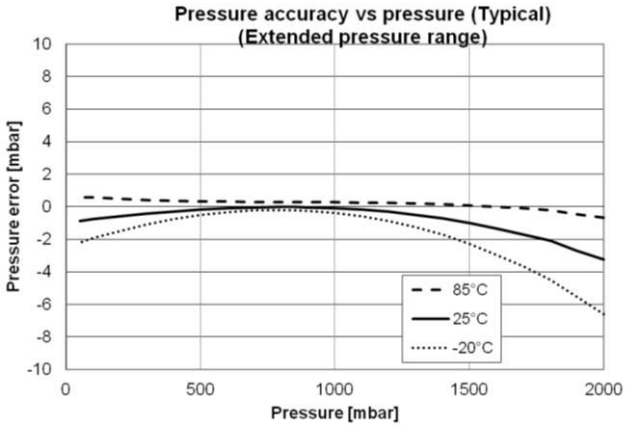
### DIGITAL OUTPUTS (SDA)

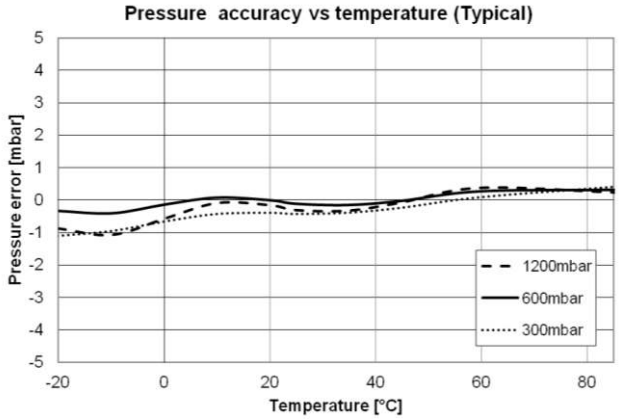
| Parameter | Symbol | Conditions | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Output high voltage | $V_{OH}$ | $I_{source}$ = 1 mA | 80% $V_{DD}$ | | 100% $V_{DD}$ | V |
| Output low voltage | $V_{OL}$ | $I_{sink}$ = 1 mA | 0% $V_{DD}$ | | 20% $V_{DD}$ | V |

## TYPICAL PERFORMANCE CHARACTERISTICS

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

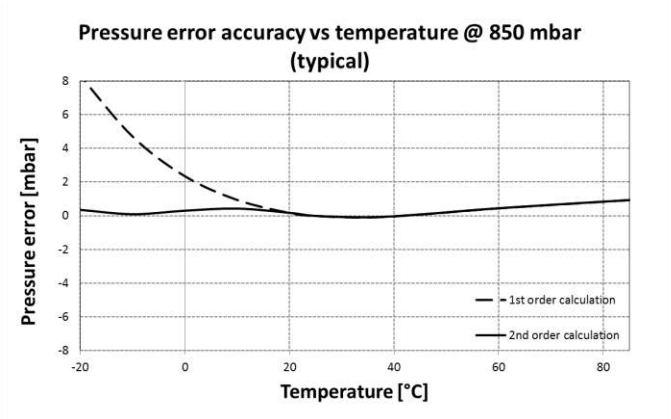


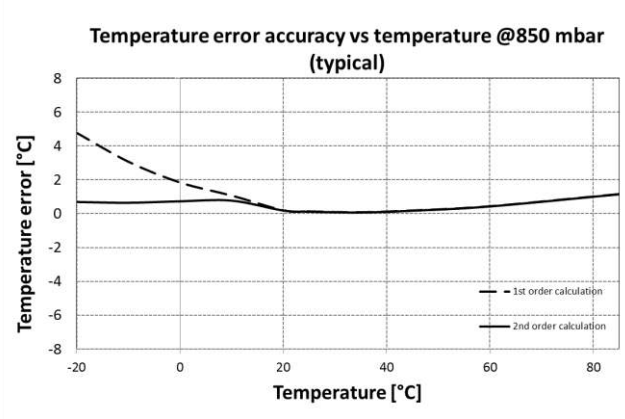



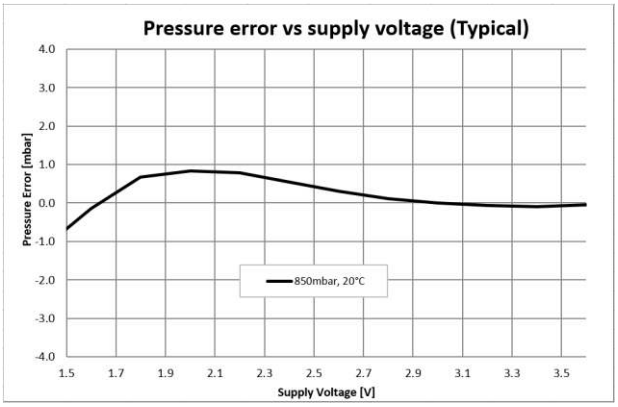
## TYPICAL PERFORMANCE CHARACTERISTICS

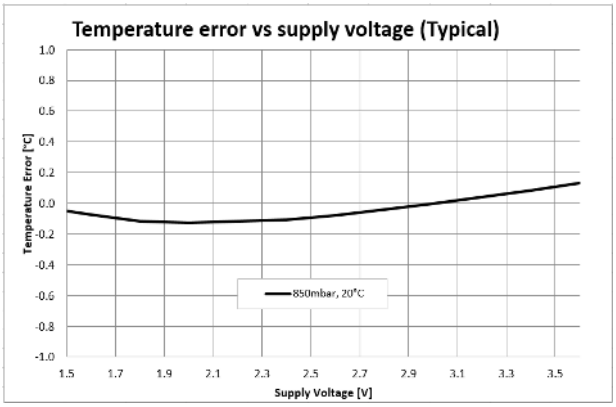
### RELATIVE PRESSURE AND TEMPERATURE ERROR VS TEMPERATURE (1ST ORDER AND 2ND ORDER ALGORITHM, TYPICAL VALUES)




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



## PRESSURE AND TEMPERATURE CALCULATION

### GENERAL

The MS5839 consists of a piezo-resistive sensor and a sensor interface integrated circuit. The main function of the MS5839 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 112-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.

### COMMUNICATION INTERFACE

The MS5839 has been built with $I^2C$ serial interface.

| Module ref | Mode | Pins used |
|---|---|---|
| MS5839-02BA36 | $I^2C$ | SDA, SCL |

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

## 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**

| | | | | | | |
|---|---|---|---|---|---|---|
| *D1* | Digital pressure value | unsigned int 32 | 24 | 0 | 16777215 | 6464444 |
| *D2* | Digital temperature value | unsigned int 32 | 24 | 0 | 16777215 | 8077636 |

**Calculate temperature**

| | | | | | | |
|---|---|---|---|---|---|---|
| *dT* | Difference between actual and reference temperature [2]<br>$dT = D2 - T_{REF} = D2 - C5 * 2^8$ | signed int 32 | 25 | -16776960 | 16777216 | 68 |
| *TEMP* | Actual temperature (-40...85°C with 0.01°C resolution)<br>$TEMP = 20°C + dT * TEMPSENS = 2000 + dT * C6 / 2^{23}$ | signed int 32 | 25 | -4000 | 8500 | 2000<br>= 20.00°C |

**Calculate temperature compensated pressure**

| | | | | | | |
|---|---|---|---|---|---|---|
| OFF | Offset at actual temperature [2]<br>$OFF = OFF_{T1} + TCO * dT = C2 * 2^{17} + dT * C4 / 2^6$ | signed int 64 | 41 | -17179344900 | 25769410560 | 5764707214 |
| SENS | Sensitivity at actual temperature [2]<br>$SENS = SENS_{T1} + TCS * dT = C1 * 2^{16} + dT * C3 / 2^7$ | signed int 64 | 41 | -8589672450 | 12884705280 | 303950829 |
| P | Temperature compensated pressure (10...1200mbar with 0.01mbar resolution)<br>$P = (D1 * SENS / 2^{21} - OFF) / 2^{15}$ | signed int 32 | 58 | 1000 | 120000 | 110002<br>= 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.

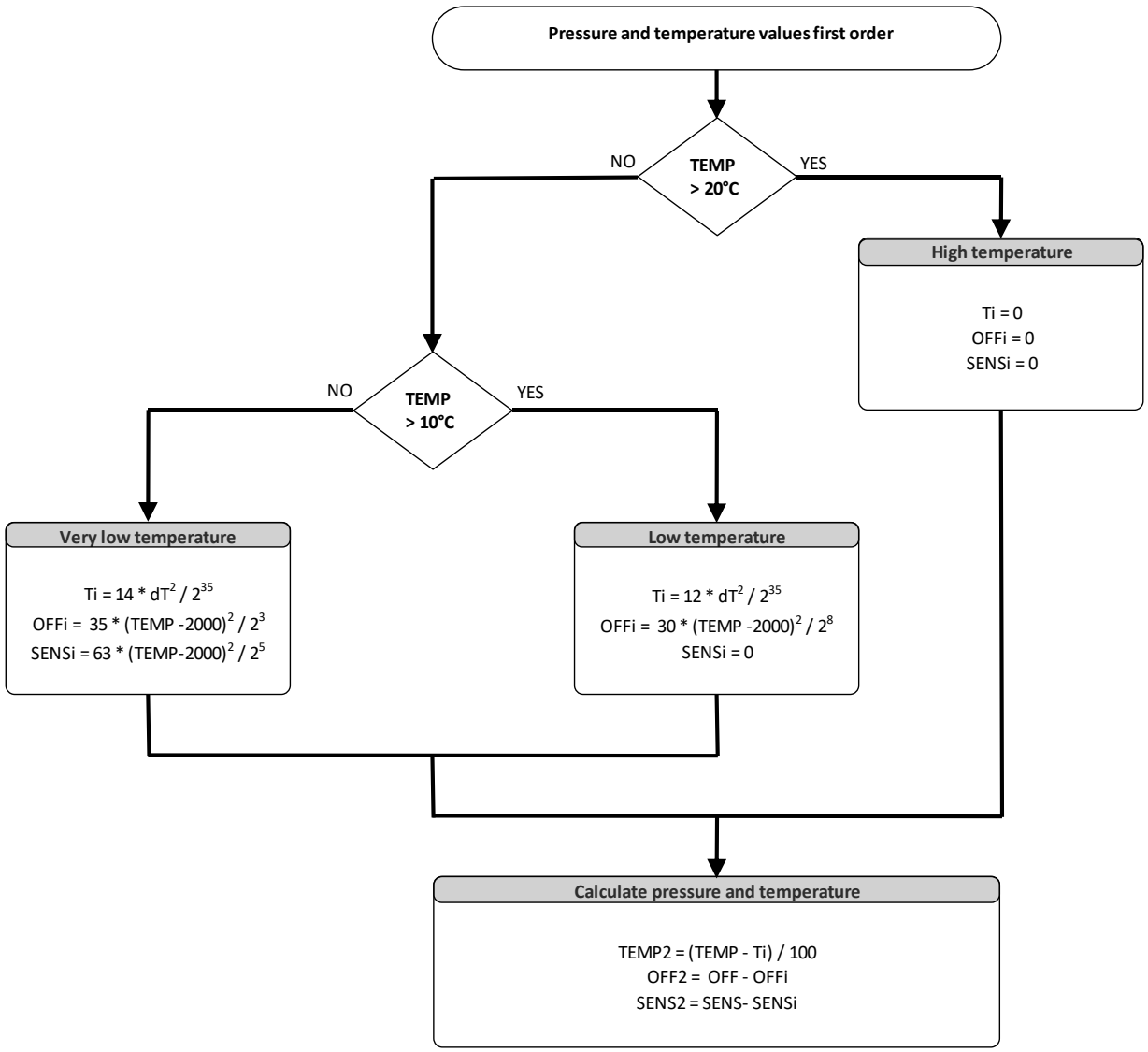



*Figure 2 :* Second order compensation flowchart

## I²C INTERFACE

### COMMANDS

The MS5839 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)

Each I²C communication message starts with the start condition and it is ended with the stop condition. The MS5839 address is 1110110x (write: x=0, read: x=1).

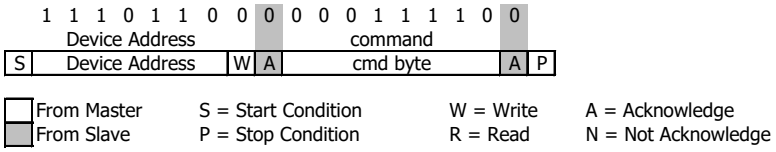
Size of each command is 1 byte (8 bits) as described in the table below. After ADC read commands, the device will return 24 bit result and after the PROM read 16 bit results. The address of the PROM is embedded inside of the PROM read command using the a2, a1 and a0 bits.

| | **Command byte** | | | | | | | | **hex value** |
|---|---|---|---|---|---|---|---|---|---|
| Bit number | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Bit name | PROM | CONV | - | 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 D1 (OSR=8192) | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0x4A |
| 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 |
| Convert D2 (OSR=8192) | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0x5A |
| 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

## RESET SEQUENCE

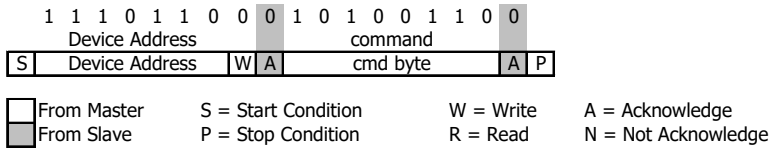
The Reset sequence shall be sent once after power-on to make sure that the calibration PROM gets loaded into the internal register. It can be also used to reset the device PROM from an unknown condition.
The reset can be sent at any time. In the event that there is not a successful power on reset this may be caused by the SDA being blocked by the module in the acknowledge state. The only way to get the MS5839 to function is to send several SCLs followed by a reset sequence or to repeat power on reset.



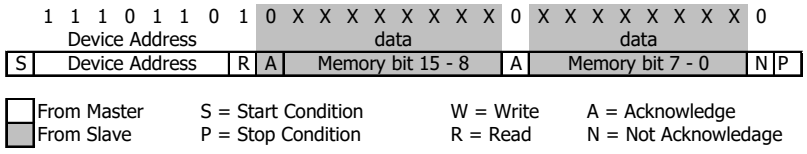

I²C Reset Command

## 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 7 addresses resulting in a total memory of 112 bit. Addresses contain factory data and the setup, calibration coefficients, the serial code and CRC. The command sequence is 8 bits long with a 16 bit result which is clocked with the MSB first. 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.



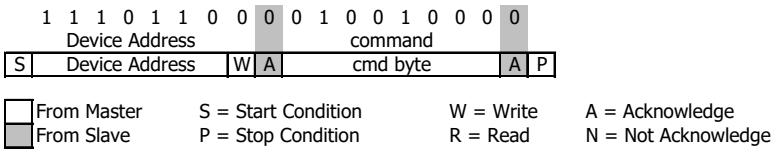

I²C Command to read memory address= 011



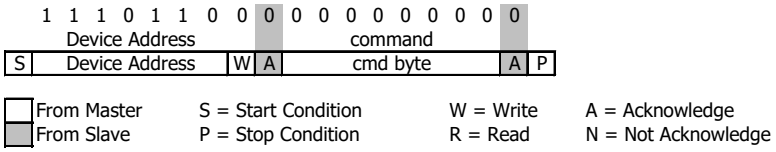

I²C answer from MS5839

## CONVERSION SEQUENCE

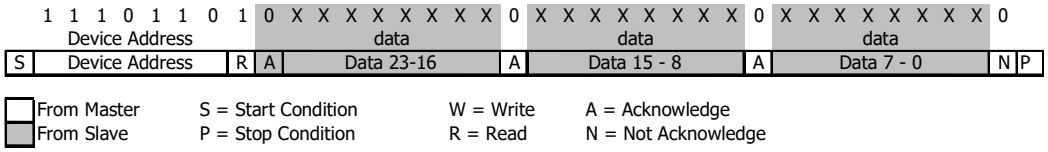
The conversion command is used to initiate uncompensated pressure (D1) or uncompensated temperature (D2) conversion. After the conversion, using ADC read command the result is clocked out with the MSB first. If the conversion is not executed before the ADC read command, or the ADC read command is repeated, 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. A conversion can be started by sending the command to MS5839. 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 is sent from the MS5839, 24 SCL cycles may be sent to receive all result bits. Every 8 bits 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 MS5839

## VERSION PROM WORD 0 PROGRAMMING

For product type, the bits [11:5] of memory address 0 must be programmed with the following fixed values:

MS5839-02BA36

| 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 settings* | | | | |

## CYCLIC REDUNDANCY CHECK (CRC)

MS5839 contains a PROM memory with 112-Bit. A 4-bit CRC has been implemented to check the data validity in memory.

| MS5839-02BA | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Add | DB15 | DB14 | DB13 | DB12 | DB11 | DB10 | DB9 | DB8 | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 |
| 0 | CRC | | | | Version defined | | | | | | | Factory defined | | | | |
| 1 | C1 | | | | | | | | | | | | | | | |
| 2 | C2 | | | | | | | | | | | | | | | |
| 3 | C3 | | | | | | | | | | | | | | | |
| 4 | C4 | | | | | | | | | | | | | | | |
| 5 | C5 | | | | | | | | | | | | | | | |
| 6 | C6 | | | | | | | | | | | | | | | |

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

The MS5839 is a circuit that can be used in conjunction with a microcontroller in mobile altimeter applications.

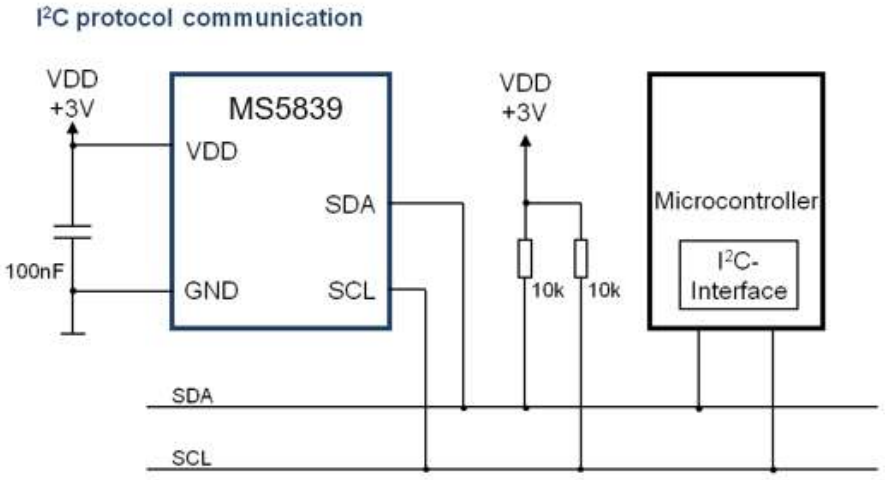
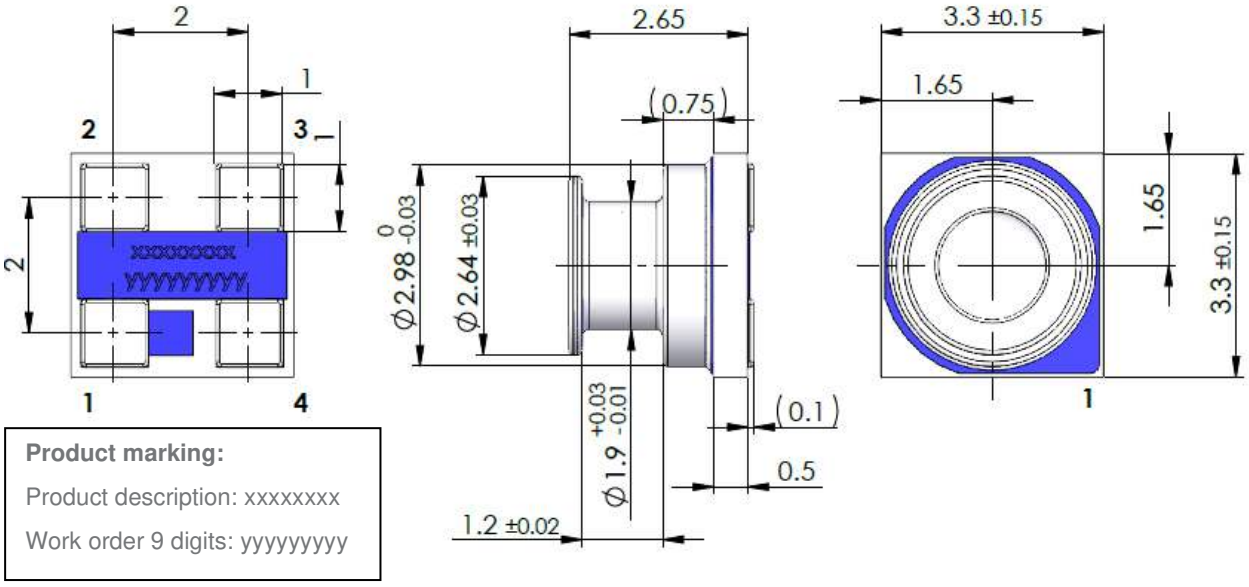



Figure: Typical application circuit

## PIN CONFIGURATION AND DEVICE PACKAGE OUTLINE

**UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS. GENERAL TOLERANCE ± 0.1mm**




**Product marking:**

Product description: xxxxxxxx

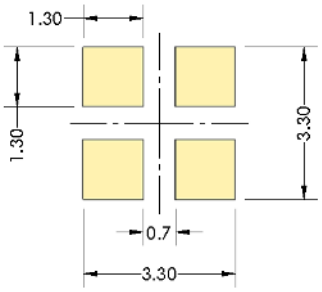
Work order 9 digits: yyyyyyyyy

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

Figure: Package outlines and Pin configuration

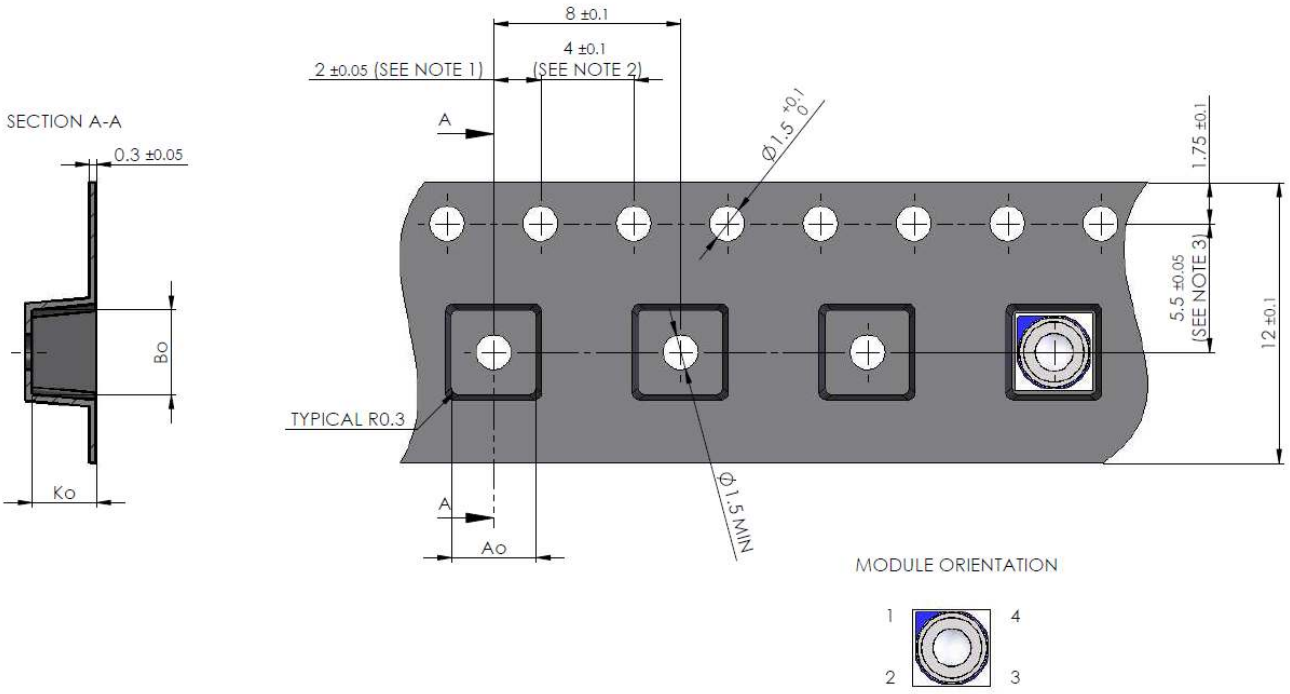
## RECOMMENDED PAD LAYOUT

Pad layout for bottom side of the MS5839 soldered onto printed circuit board.




Figure

## SHIPPING PACKAGE




| | |
|---|---|
| Ao | 3.6±0.1 |
| Bo | 3.6±0.1 |
| Ko | 2.75±0.1 |

NOTE:

1: Measured from centerline of sprocket hole to centerline of pocket
2: Cumulative tolerance of 10 sprocket holes is ±0.2mm
3: Measured from centerline of sprocket hole to centerline of pocket

## MOUNTING AND ASSEMBLY CONSIDERATIONS

### SOLDERING

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

### MOUNTING

The MS5839 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. 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 for interconnection. This can be important for applications in watches and other special devices.

### SEALING WITH O-RINGS

In applications such as outdoor watches the electronics must be protected against direct water or humidity. For such applications the MS5839 provides the possibility to seal with an O-ring. The O-ring shall be placed at the groove location, i.e. the small outer diameter of the metal lid. The following O-ring / housing dimensions are recommended:

| | |
|---|---|
| O-ring inner diameter | 1.8 ± 0.05 mm |
| O-ring cross-section diameter | 0.8 ± 0.03 mm |
| Housing bore diameter | 3.07 ± 0.03 mm |

Please refer to the application note AN523 available on our website for O-ring mounting recommendations.

### CLEANING

The MS5839 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. It is therefore essential to ground machines and personnel properly during assembly and handling of the device. The MS5839 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 minimum ceramic capacitor must be placed as close as possible to the MS5839 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 |
|---|---|---|---|
| 20008669-50 | MS5839-02BA36 CL RESISTANT LS T&R SEN | X | X |

**NORTH AMERICA**
Tel +1 800 522 6752
customercare.frmt@te.com

**EUROPE**
Tel +31 73 624 6999
customercare.bevx@te.com

**ASIA**
Tel +86 0400 820 6015
customercare.shzn@te.com

**te.com/sensorsolutions**