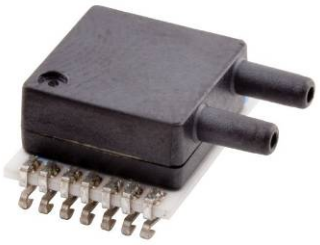
MS5701 Low Pressure Module



RoHS

- **Wide range of pressure ranges available**
  gage: +3.75, +5, +7.5, +10, +20, +50 mbar
  (+1.5, +2, +3, +4, +8, +20 in H_2O)
  differential: ±2.5, ±3.75, ±5, ±10, ±25 mbar
  (±1, ±1.5, ±2, ±4, ±10 in H_2O)
- **High resolution module, 0.001 mbar (0.0004 In H_20)**
- **Fast conversion, 0.54 ms**
- **Supply voltage 1.8 to 3.6 V**
- **Integrated pressure sensor (24 bit ΔΣ ADC)**
- **Temperature range: -20°C to 85°C**
- **I^2C or SPI interface up to 20 MHz**
- **No external components (Internal oscillator)**

DESCRIPTION

The MS5701 is a new generation SMD-hybrid device from Measurement Specialties including a high resolution differential pressure sensor with SPI and I2C bus interface. The sensor module includes a high 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 thermometer function without any additional sensor. The MS5701 can be interfaced to virtually any microcontroller. The communication protocol is simple, without the need to programming internal registers in the device. This new sensor module generation is based on leading MEMS technology and latest benefits from MEAS proven experience and know how in high volume manufacturing of pressure sensors 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.

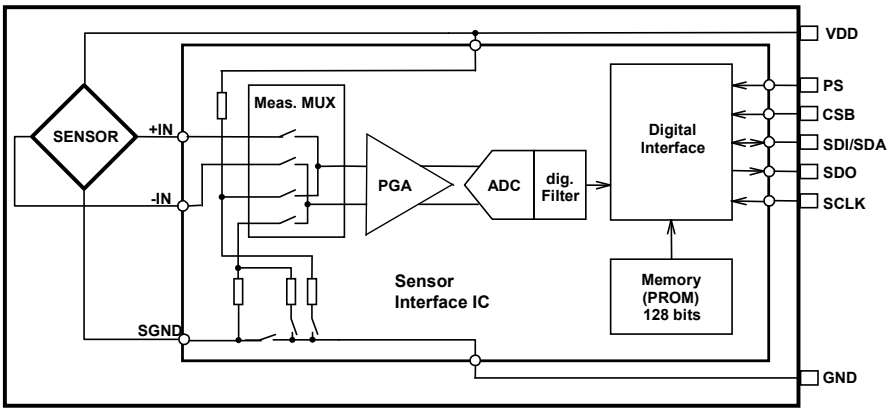
FEATURES

- Low power, 1 µA (standby < 0.15µA)
- High Stability, insensitive to mechanical stress
- Temperature range, -20°C to +85°C

APPLICATIONS

- HVAC (Heating ventilation and air conditioning)
- Respirators/Ventilators
- CPAP/Sleep Apnea Instruments
- Leak Detection
- Liquid level metering

BLOCK DIAGRAM



MS5701 Low Pressure Module

PRESSURE UNITS CONVERSION

mm H_2O	in H_2O	mm Hg	kPa	bar	mbar	PSI	atm
509.87	20.073	37.503	5.0	0.05	50.0	0.7252	0.04934

PERFORMANCE SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Supply voltage	V_{DD}		-0.3		+4.0	V
Storage temperature	T_S		-40		+125	°C
Overpressure	P_{max}				Tbd	bar In H_20
	P_{max}				2 800	bar In H_20
Maximum Soldering Temperature	T_{max}	40 sec max			250	°C
ESD rating		Human Body Model	-4		+4	kV
Latch up		JEDEC standard No 78	-100		+100	mA

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Operating Supply voltage	V_{DD}		1.8	3.0	3.6	V
Operating Temperature	T		-20	+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	t_c	OSR 4096	7.40	8.22	9.04	ms
		2048	3.72	4.13	4.54	
		1024	1.88	2.08	2.28	
		512	0.95	1.06	1.17	
		256	0.48	0.54	0.60	

PERFORMANCE SPECIFICATIONS (CONTINUED)

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

Parameter		Conditions		Min.	Typ.	Max	Unit
Optimized Operating Pressure Range		MS5701-03MG		0		3.75	mbar
		MS5701-05MG		0		5	mbar
		MS5701-07MG		0		7.5	mbar
		MS5701-10MG		0		10	mbar
		MS5701-20MG		0		20	mbar
		MS5701-50MG		0		50	mbar
		MS5701-05MD		-2.5		2.5	mbar
		MS5701-07MD		-3.75		3.75	mbar
		MS5701-10MD		-5		5	mbar
		MS5701-20MD		-10		10	mbar
		MS5701-50MD		-25		25	mbar
Absolute Accuracy on pressure range (autozero at one pressure point)		MS5701-03MG	25°C -20…85°C	-0.03 Tbd		0.03 Tbd	mbar
		MS5701-05MG	25°C -20…85°C	-0.1 -0.25		0.1 0.25	mbar
		MS5701-07MG	25°C -20…85°C	-0.12 -0.3		0.12 0.3	mbar
		MS5701-10MG	25°C -20…85°C	-0.15 -0.4		0.15 0.4	mbar
		MS5701-20MG	25°C -20…85°C	-0.25 -0.7		0.25 0.7	mbar
		MS5701-50MG	25°C -20…85°C	-0.5 -1		0.5 1	mbar
		MS5701-05MD	25°C -20…85°C	-0.1 -0.25		0.1 0.25	mbar
		MS5701-07MD	25°C -20…85°C	-0.12 -0.3		0.12 0.3	mbar
		MS5701-10MD	25°C -20…85°C	-0.15 -0.4		0.15 0.4	mbar
		MS5701-20MD	25°C -20…85°C	-0.25 -0.7		0.25 0.7	mbar
		MS5701-50MD	25°C -20…85°C	-0.5 -1		0.5 1	mbar
Maximum error with supply voltage		V_{DD} = 1.8 V … 3.6 V			Tbd		mbar
Long-term stability					Tbd		mbar/yr
Resolution RMS	MS5701-03MG	OSR	4096 2048 1024 512 256		0.0005 0.0008 0.0012 0.0017 0.0026		mbar
	Others	OSR	4096 2048 1024 512 256		0.0010 0.0015 0.0023 0.0034 0.0051		mbar

PERFORMANCE SPECIFICATIONS (CONTINUED)

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

Parameter		Conditions		Min.	Typ.	Max	Unit
Optimized Operating Pressure Range		MS5701-03MG		0		1.5	In H_20
		MS5701-05MG		0		2	In H_20
		MS5701-07MG		0		3	In H_20
		MS5701-10MG		0		4	In H_20
		MS5701-20MG		0		8	In H_20
		MS5701-50MG		0		20	In H_20
		MS5701-05MD		-1		1	In H_20
		MS5701-07MD		-1.5		1.5	In H_20
		MS5701-10MD		-2		2	In H_20
		MS5701-20MD		-4		4	In H_20
		MS5701-50MD		-10		10	In H_20
Absolute Accuracy on pressure range (autozero at one pressure point)		MS5701-03MG	25°C -20…85°C	-0.012 Tbd		0.012 Tbd	In H_20
		MS5701-05MG	25°C -20…85°C	-0.04 -0.1		0.04 0.1	In H_20
		MS5701-07MG	25°C -20…85°C	-0.048 -0.12		0.048 0.12	In H_20
		MS5701-10MG	25°C -20…85°C	-0.06 -0.16		0.06 0.16	In H_20
		MS5701-20MG	25°C -20…85°C	-0.1 -0.28		0.1 0.28	In H_20
		MS5701-50MG	25°C -20…85°C	-0.2 -0.4		0.2 0.4	In H_20
		MS5701-05MD	25°C -20…85°C	-0.04 -0.1		0.04 0.1	In H_20
		MS5701-07MD	25°C -20…85°C	-0.048 -0.12		0.048 0.12	In H_20
		MS5701-10MD	25°C -20…85°C	-0.06 -0.16		0.06 0.16	In H_20
		MS5701-20MD	25°C -20…85°C	-0.1 -0.28		0.1 0.28	In H_20
		MS5701-50MD	25°C -20…85°C	-0.2 -0.4		0.2 0.4	In H_20
Maximum error with supply voltage		V_{DD} = 1.8 V … 3.6 V			Tbd		In H_20
Long-term stability					Tbd		In H_20/yr
Resolution RMS	MS5701-03MG	OSR	4096 2048 1024 512 256		0.0002 0.0003 0.0005 0.0007 0.0010		In H_20
	Others	OSR	4096 2048 1024 512 256		0.0004 0.0006 0.0009 0.0014 0.0020		In H_20

PERFORMANCE SPECIFICATIONS (CONTINUED)

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	-0.8 -2.0		+0.8 +2.0	°C
Maximum error with supply voltage	V_{DD} = 1.8 V … 3.6 V	Tbd		Tbd	°C
Resolution RMS	OSR 4096 2048 1024 512 256		0.002 0.003 0.005 0.008 0.012		°C

DIGITAL INPUTS (CSB, I²C, DIN, SCLK)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock	SCLK	SPI protocol			20	MHz
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	$I_{leak25°C}$ $I_{leak85°C}$	at 25°C			0.15	µA
Input capacitance	C_{IN}				6	pF

PRESSURE OUTPUTS (I²C, DOUT)

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
Load capacitance	C_{LOAD}				16	pF

FUNCTIONAL DESCRIPTION

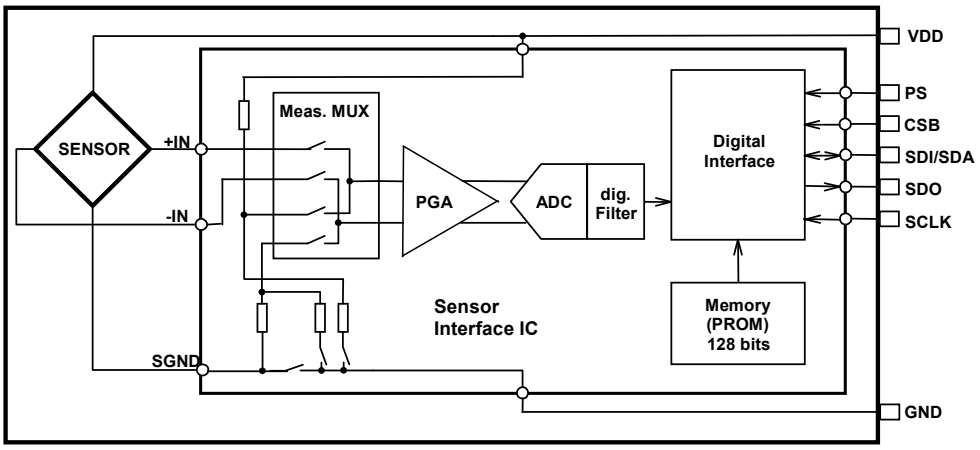


Figure 1: Block diagram of MS5701

GENERAL

The MS5701 consists of a piezo-resistive sensor and a sensor interface IC. The main function of the MS5701 is to convert the uncompensated analogue output voltage from the piezo-resistive pressure sensor to a 24-bit digital value, as well as providing a 24-bit digital value for the temperature of the sensor.

FACTORY CALIBRATION

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

SERIAL INTERFACE

The MS5701 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
Low	SPI	SDI, SDO, CSB

SPI MODE

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

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 favourable 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!).

COMMANDS

The MS5701 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)

MS5701 Low Pressure Module

PRESSURE AND TEMPERATURE CALCULATION

Start
Maximum values for calculation results:

T_{MIN} = -20°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	30343
C2	Pressure offset | OFF_{T1}	unsigned int 16	16	0	65535	32322
C3	Temperature coefficient of pressure sensitivity | TCS	unsigned int 16	16	0	65535	40838
C4	Temperature coefficient of pressure offset | TCO	unsigned int 16	16	0	65535	39805
C5	Reference temperature | T_{REF}	unsigned int 16	16	0	65535	34295
C6	Temperature coefficient of the temperature | TEMPSENS	unsigned int 16	16	0	65535	29546

Read digital pressure and temperature data

D1	Digital pressure value	unsigned int 32	24	0	16777216	9064442
D2	Digital temperature value	unsigned int 32	24	0	16777216	9393126

Calculate temperature

dT	Difference between actual and reference temperature [2] $dT = D2 - T_{REF} = D2 - C5 * 2^8$	signed int 32	25			613606
TEMP	Actual temperature (-20…85°C with 0.01°C resolution) $TEMP = 20°C + dT * TEMPSENS = 2000 + dT * C6 / 2^{23}$	signed int 32	41	-2000	8500	4161 = 41.61 °C

Calculate temperature compensated pressure

OFF	Offset at actual temperature [3] $OFF = OFF_{T1} + TCO * dT = C2 * 2^{17} + (C4 * dT) / 2^7$	signed int 64	41			4427326268
SENS	Sensitivity at actual temperature [4] $SENS = SENS_{T1} + TCS * dT = C1 * 2^{15} + (C3 * dT) / 2^9$	signed int 64	41			1043221693
P	Temperature compensated pressure $P = D1 * SENS - OFF = (D1 * SENS / 2^{21} - OFF) / 2^{15}$	signed int 32	58			2494
P	Convert the pressure in unity - In imperial unit: $P * 100 / 249082$ - In metric unit: $P / 1000$	float				= 1.001 in H_2O = 2.494 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 2: Flow chart for pressure and temperature reading and software compensation.

SECOND ORDER TEMPERATURE COMPENSATION

To improve the accuracy of the MS5701 over the temperature, it is possible to use the following calculation:

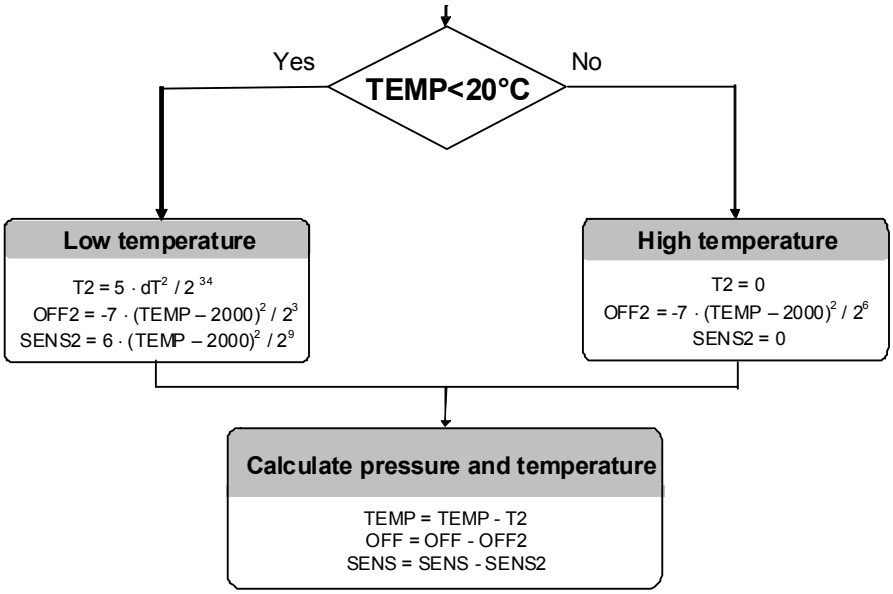


Figure 3: Flow chart for pressure and temperature to the optimum accuracy.

This calculation correct the quadratic error of the TCO and TCS already calibrated in the sensor. A correction of the temperature has also been introduced, if it is necessary. Note, TEMP is in 0.01°C (ex:4000 for 40°C).

The OFF and SENS recalculated with the above calculation must be used in the standard calculation described on previous page.

SPI INTERFACE

COMMANDS

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

	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 Add0	1	0	1	0	0	0	0	0	0xA0
PROM Read Add1	1	0	1	0	0	0	1	0	0xA2
PROM Read Add2	1	0	1	0	0	1	0	0	0xA4
PROM Read Add3	1	0	1	0	0	1	1	0	0xA6
PROM Read Add4	1	0	1	0	1	0	0	0	0xA8
PROM Read Add5	1	0	1	0	1	0	1	0	0xAA
PROM Read Add6	1	0	1	0	1	1	0	0	0xAC
PROM Read Add7	1	0	1	0	1	1	1	0	0xAE

Figure 4: Command structure

RESET SEQUENCE

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

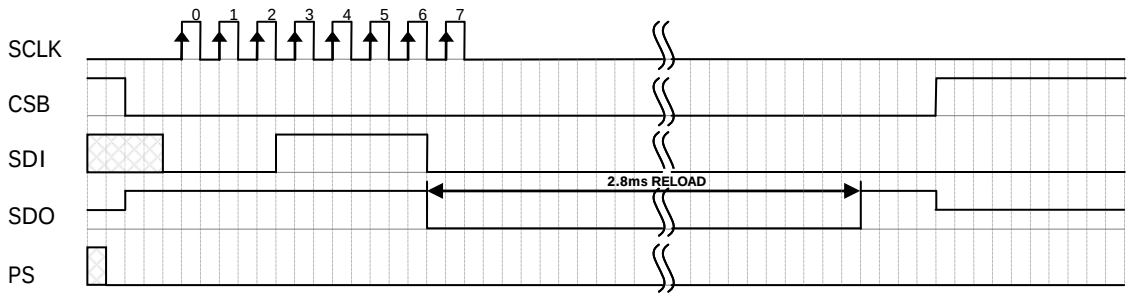


Figure 5: Reset command sequence SPI mode 0

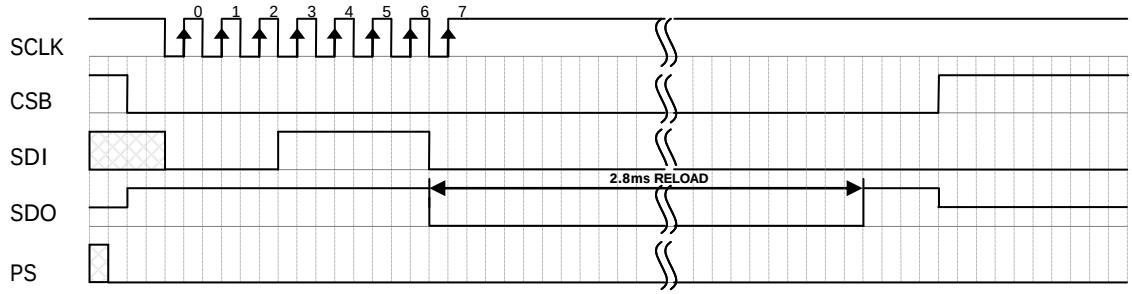


Figure 6: Reset command sequence SPI mode 3

CONVERSION SEQUENCE

The conversion command is used to initiate uncompensated pressure (D1) or uncompensated temperature (D2) conversion. The chip select can be disabled during this time to communicate with other devices.
After the conversion, using ADC read command the result is clocked out with the MSB first. If the conversion is not executed before the ADC read command, or the ADC read command is repeated, it will give 0 as the output result. If the ADC read command is sent during conversion the result will be 0, the conversion will not stop and the final result will be wrong. Conversion sequence sent during the already started conversion process will yield incorrect result as well.

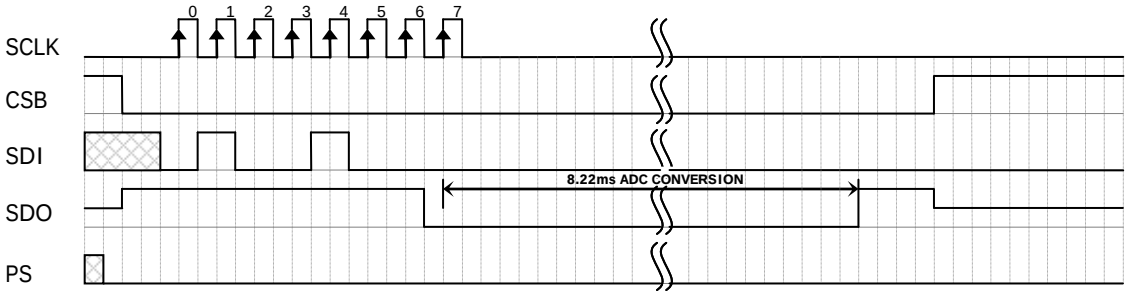


Figure 7: Conversion out sequence, Typ=d1, OSR = 4096

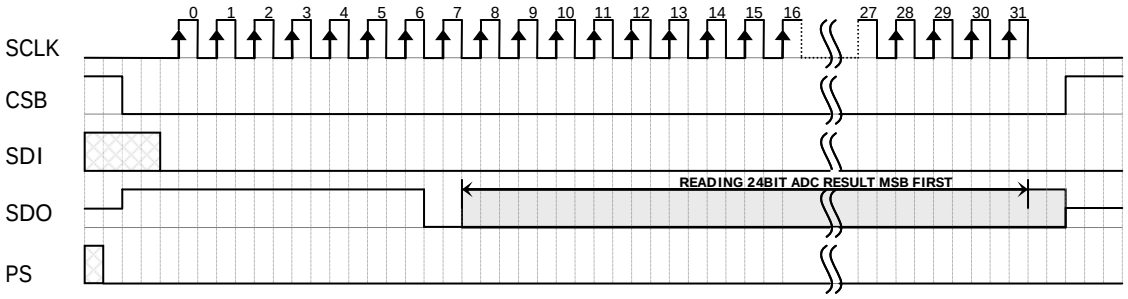


Figure 8: ADC Read sequence

PROM READ SEQUENCE

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

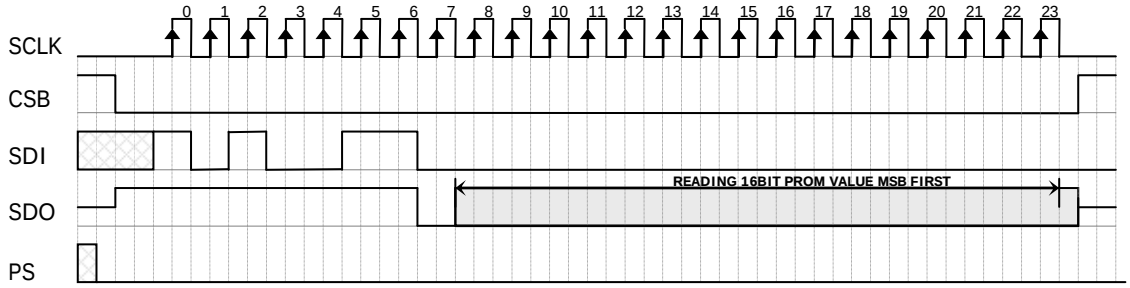


Figure 9: PROM Read sequence, address = 011 (Coefficient 3).

I²C INTERFACE

COMMANDS

Each I²C communication message starts with the start condition and it is ended with the stop condition. The MS5701 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 MS5701 to function is to send several SCLKs followed by a reset sequence or to repeat power on reset.

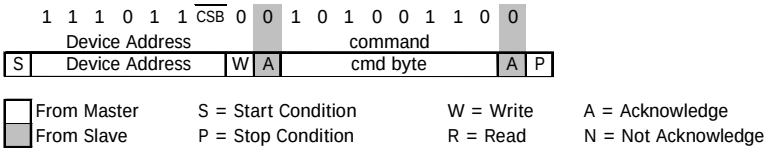


Figure 10: I²C Reset Command

PROM READ SEQUENCE

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

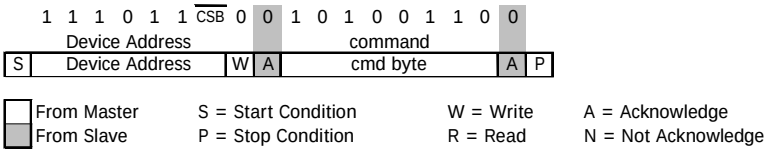


Figure 11: I²C Command to read memory address= 011 (Coefficient 3)

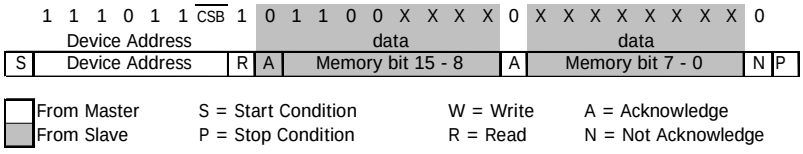


Figure 12: I²C answer from MS5701

CONVERSION SEQUENCE

A conversion can be started by sending the command to MS5701. 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 MS5701, 24 SCLK cycles may be sent to receive all result bits. Every 8 bit the system waits for an acknowledge signal.

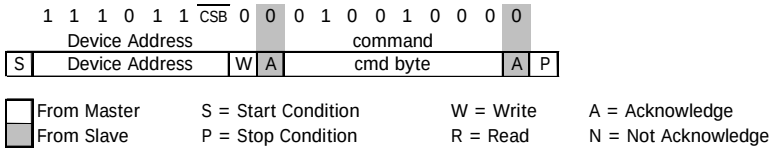


Figure 13: I²C Command to initiate a pressure conversion (OSR=4096, typ=D1)

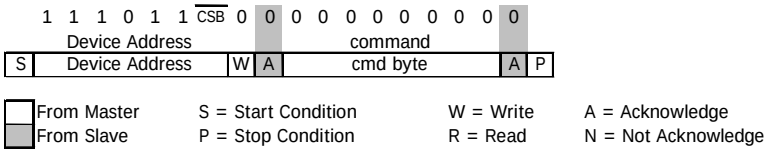


Figure 14: I²C ADC read sequence

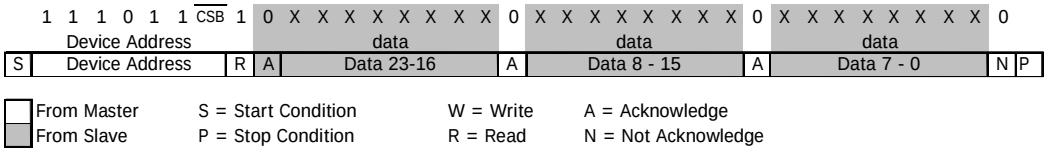


Figure 15: I²C answer from MS5701

APPLICATION CIRCUIT

The MS5701 is a circuit that can be used in conjunction with a microcontroller in mobile applications. It is designed for low-voltage systems with a supply voltage of 3 V.

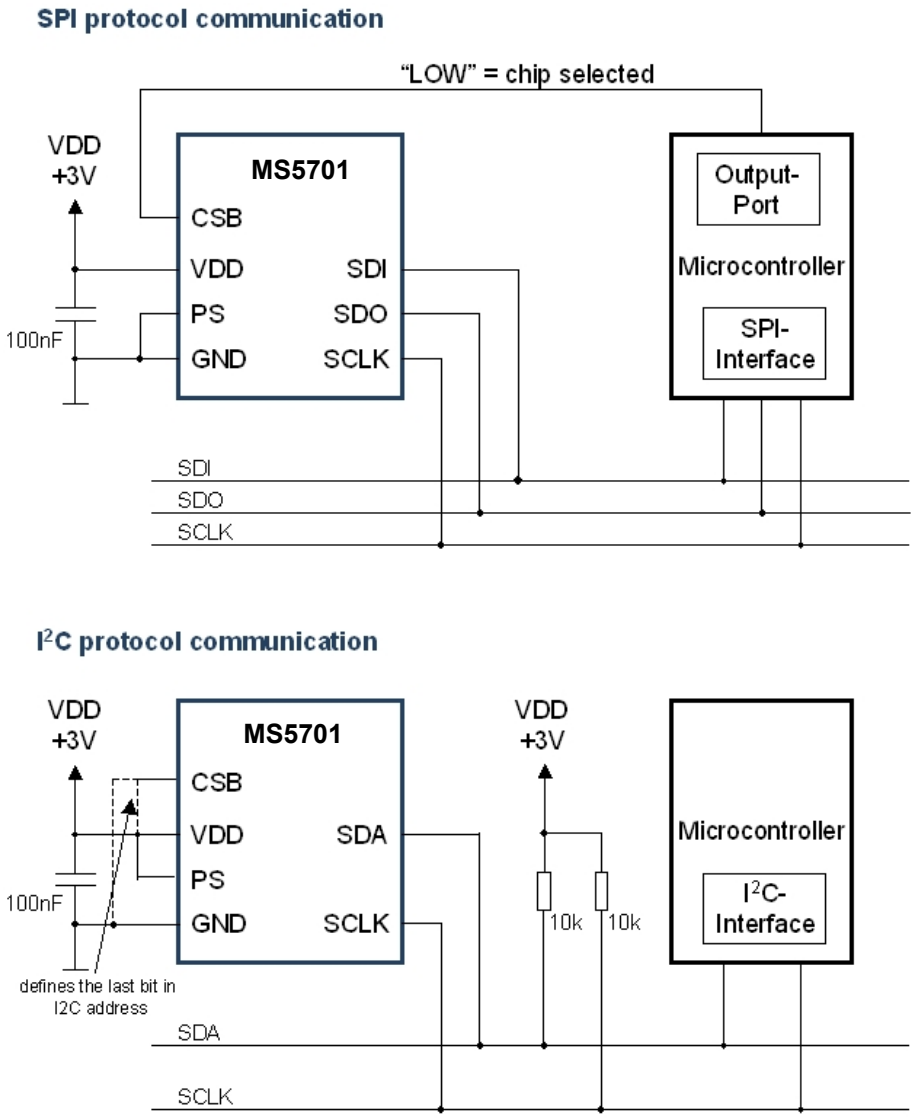
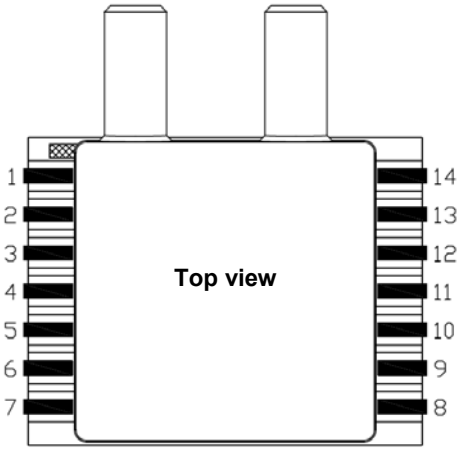


Figure 17: Typical application circuit with SPI / I^2C protocol communication

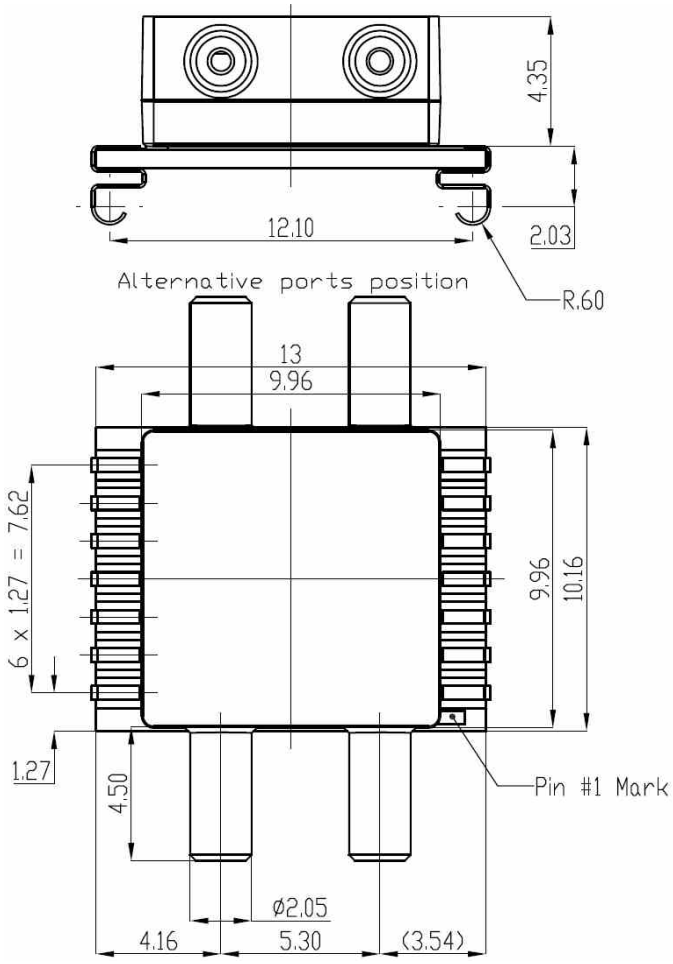
MS5701 Low Pressure Module

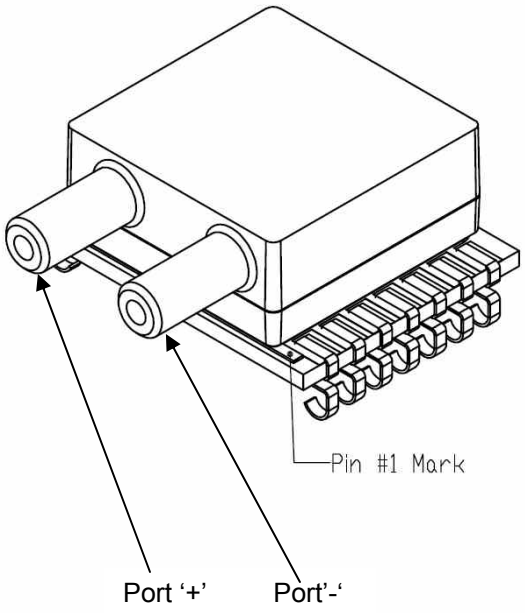
PIN CONFIGURATION

Pin	Name	Type	Function
1	CSB	I	Chip select (active low), internal connection with Pin 13
2	VDD	P	Positive supply voltage
3	PS	I	Protocol select: PS high (VDD) → I^2C PS low (GND) → SPI
4	SDI / SDA	I / IO	Serial data input / I^2C data IO
5	SDO	O	Serial data output
6	SCLK	I	Serial data clock
7	GND	G	Ground
8 to 12	N/C	-	Not connected
13	CSB	I	Chip select (active low), internal connection with Pin 1
14	N/C		Not connected



DEVICE PACKAGE OUTLINE





MOUNTING AND ASSEMBLY CONSIDERATIONS

SOLDERING

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

MOUNTING

The MS5701 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 PRESSURE PORT

The best connection to the pressure port is achieved with a flexible tube fitted to the full length of the nozzle. Care should be taken to keep the nozzle clean. The tube should be flexible enough to minimize the mechanical stress on the module.

CLEANING

The MS5701 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. 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 MS5701 is shipped in antistatic transport boxes. Any test adapters or production transport boxes used during the assembly of the sensor shall be of an equivalent antistatic material.

DECOUPLING CAPACITOR

Particular care must be taken when connecting the device to the power supply. A 100 nF ceramic capacitor must be placed as close as possible to the MS5701 VDD pin. This capacitor will stabilize the power supply during data conversion and thus, provide the highest possible accuracy.

MS5701 Low Pressure Module

ORDERING INFORMATION

Product Code	Product	Art. No
MS5701-03MG	Differential Pressure Module – 3.75 mbar / 1.5 inH_2O Gauge	MS570103MG01-00
MS5701-05MG	Differential Pressure Module – 5 mbar / 2 inH_2O Gauge	MS570105MG01-00
MS5701-07MG	Differential Pressure Module – 7.5 mbar / 3 inH_2O Gauge	MS570107MG01-00
MS5701-10MG	Differential Pressure Module – 10 mbar / 4 inH_2O Gauge	MS570110MG01-00
MS5701-20MG	Differential Pressure Module – 20 mbar / 8 inH_2O Gauge	MS570120MG01-00
MS5701-50MG	Differential Pressure Module – 50 mbar / 20 inH_2O Gauge	MS570150MG01-00
MS5701-05MD	Differential Pressure Module – ± 2.5 mbar / ± 1 inH_2O Differential	MS570105MD01-00
MS5701-07MD	Differential Pressure Module – ± 3.75 mbar / ± 1.5 inH_2O Differential	MS570107MD01-00
MS5701-10MD	Differential Pressure Module – ± 5 mbar / ± 2 inH_2O Differential	MS570110MD01-00
MS5701-20MD	Differential Pressure Module – ±10 mbar / ± 4 inH_2O Differential	MS570120MD01-00
MS5701-50MD	Differential Pressure Module – ±25 mbar / ±10 inH_2O Differential	MS570150MD01-00

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