MS5525DSO (Digital Small Outline)

- **Integrated Digital Pressure Sensor (24-bit ΔΣ ADC)**
- **Fast Conversion Down to 1 ms**
- **Low Power, 1 µA (standby < 0.15 µA)**
- **Supply Voltage: 1.8 to 3.6V**
- **Pressure Range: 1 to 30 PSI**
- **I²C and SPI Interface**

RoHS Preliminary

DESCRIPTION

The MS5525DSO is a new generation of Digital Small Outline pressure sensors from MEAS with SPI and I²C bus interface designed for high volume OEM users. The sensor module includes a pressure sensor and an ultra low power 24-bit ΔΣ ADC with internal factory calibrated coefficients. It provides a 24-bit digital pressure and temperature value and different operation modes that allow the user to optimize for conversion speed and current consumption. The MS5525DSO can be interfaced to virtually any microcontroller. The communication protocol is simple, without the need of 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 modules, which have been widely used for over a decade.

The rugged engineered thermoplastic transducer is available in single and dual port configurations, and can measure absolute, gauge, compound, and differential pressure from 1 to 30psi.

FEATURES

- Small Outline IC Package
- Barbed Pressure Ports
- Low Power, High Resolution ADC
- Digital Pressure and Temperature Outputs

APPLICATIONS

- Factory Automation
- Altitude and Airspeed Measurements
- Medical Instruments
- Leak Detection

STANDARD RANGES (PSI)

FS Pressure	Absolute	Gauge	Differential	Compound
1		DB, SB, ST, DH	DB, SB,ST, DH	
2		DB, SB, ST, DH	DB, SB,ST, DH	
5		DB, SB, ST, DH	DB, SB,ST ,DH	
15	DB, DH	DB, SB, ST, DH	DB, DH	
30	DB, DH	DB, SB, ST, DH	DB, DH	SB, ST

See Package Configurations: DB= Dual Barb, DH= Dual Hole, SB, Single Barb, ST, Single Tube

MS5525DSO (High Resolution Digital)

ABSOLUTE MAXIMUM RATING

Parameter	Conditions	Min	Max	Unit	Symbol/Notes
Supply Voltage	T_A = 25°C	-0.3	3.6	V	V_{DD}
Storage Temperature		-40	125	°C	
Overpressure	T_A = 25 °C, both Ports		60	psi	
Burst Pressure	T_A = 25 °C, Port 1			psi	See Table 1
ESD	HBM	-4	+4	kV	EN 61000-4-2
Solder Temperature	250°C, 5 sec max.				

Table 1- BURST PRESSURE BY RANGE AND PORT DESIGNATION

Range	Port 1	Port 2	Unit
001	20	20	psi
002	20	20	psi
005	15	20	psi
015	45	90	psi
030	90	200	psi

ENVIRONMENTAL SPECIFICATIONS

Parameter	Conditions
Mechanical Shock	Mil Spec 202F, Method 213B, Condition C, 3 Drops
Mechanical Vibration	Mil Spec 202F, Method 214A, Condition 1E, 1Hr Each Axis
Thermal Shock	100 Cycles over Storage Temperature, 30 minute dwell
Life	1 Million FS Cycles
MTTF	>10Yrs, 70 ºC, 10 Million Pressure Cycles, 120%FS Pressure

MS5525DSO (Digital Small Outline)

PERFORMANCE SPECIFICATIONS

Supply Voltage[1] 3.0 Vdc
Reference Temperature: 25°C (unless otherwise specified)

PARAMETERS	MIN	TYP	MAX	UNITS	NOTES
Operating Voltage	1.8		3.6		
ADC			24	bits	
Pressure Accuracy	-0.25		0.25	%FS	2,5
Total Error Band (TEB)	-2.5		2.5	%FS	3
Temperature Accuracy (Reference Temperature)	-1.5		1.5	ºC	4,5
Temperature Accuracy	-2.5		2.5	ºC	4,5
Supply Current		See OSR Table Below		mA	
Compensated Temperature	0		85	ºC	
Operating Temperature	-40		+125	ºC	
Conversion Time		See OSR Table Below		mS	
Weight		3		grams	
Media	Non-Corrosive Dry Gases Compatible with Phosphor Bronze, Silicon, Pyrex, LCP, RTV, Gold, Aluminum and Epoxy. See "Wetted Material by Port Designation" chart below.				

Notes

1. Proper operation requires an external capacitor placed as shown in Application Circuit. Output is not ratiometric to supply voltage.
2. The maximum deviation from a best fit straight line(BFSL) fitted to the output measured over the pressure range at 25°C. Includes all errors due to pressure non linearity, hysteresis, and non repeatability.
3. The maximum deviation from ideal output with respect to input pressure and temperature over the compensated temperature range. Total error band (TEB) includes all accuracy errors, thermal errors over the compensated temperature range, span and offset calibration tolerances. TEB values are valid only at the calibrated supply voltage.
4. The deviation from a best fit straight line (BFSL) from 25°C. to 85°C.
5. Six coefficients must be read by microcontroller software and are used in a mathematical calculation for converting D1 and D2 into compensated pressure and temperature values.

OVERSAMPLNG RATIO (OSR) PERFORMANCE CHARACTERISTICS

SUPPLY CURRENT CHARACTERISTICS

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Supply current (1 sample per sec.)	I_{DD}	OSR	4096		12.5		µA
			2048		6.3		
			1024		3.2		
			512		1.7		
			256		0.9		
Peak supply current		during conversion			1.4		mA
Standby supply current		at 25℃			0.02	0.14	µA

ANALOG DIGITAL CONVERTER (ADC)

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
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	

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

Parameter	Conditions		Min.	Typ.	Max	Unit
Resolution RMS	OSR	4096		0.002		℃
		2048		0.003		
		1024		0.005		
		512		0.008		
		256		0.012		
Maximum error with supply voltage	V_{DD} = 1.8 V … 3.6 V		-0.5		+0.5	℃

INPUT/OUTPUT SPECIFICATIONS

DIGITAL INPUTS (CSB, I²C, DIN, SCLK)

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	$I_{leak25℃}$ $I_{leak85℃}$	at 25℃			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} = 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

FUNCTIONAL DESCRIPTION

BLOCK DIAGRAM

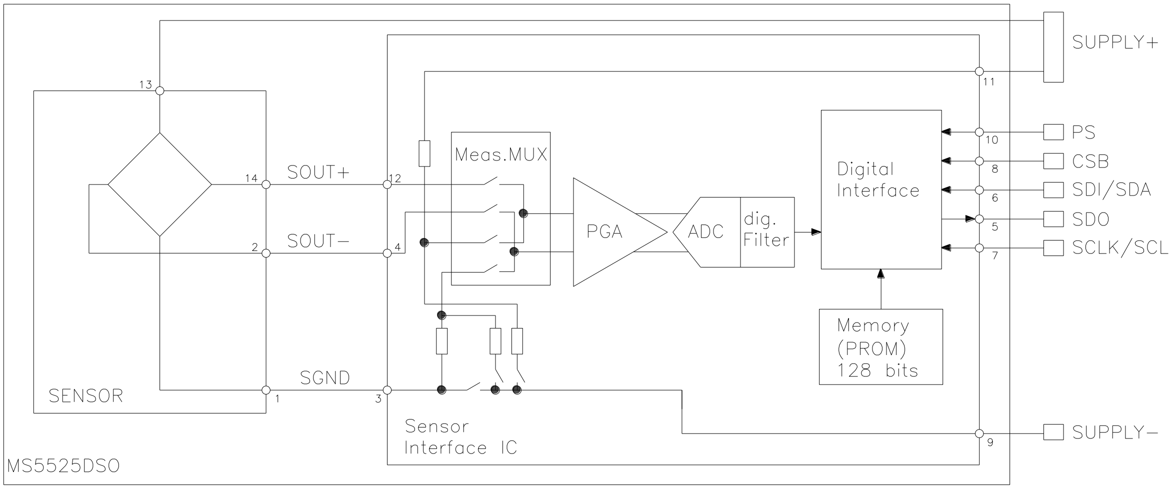


Figure 1: Block diagram of MS5525DSO

GENERAL

The MS5525DSO consists of a piezo-resistive sensor and a sensor interface IC. The main function of the MS5525DSO 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 three pressures. As a result, six 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 six coefficients, C1 through C6, must be read by the microcontroller software and used in the program converting D1 and D2 into compensated pressure and temperature values.
The coefficients C0 and C7 are for factory calibration and CRC.

SERIAL INTERFACE

The MS5525DSO has built in two types of serial interfaces: SPI and I^{2}C. Pulling the Protocol Select pin PS to low selects the SPI protocol, pulling PS to high activates the I^{2}C bus protocol.

Pin PS	Mode	Pins used
High	I^{2}C	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.

I^2C MODE & ADDRESSING

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. 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 I^2C -Mode the complement of the pin CSB (Chip Select) represents the LSB of the I^2C address. It is possible to use two sensors with two different addresses on the I^2C bus. The pin CSB must be connected to VDD or GND do not leave these pins unconnected.

Pin CSB	Address (7 bits)
High	0x76
Low	0x77

COMMANDS

The MS5525DSO 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 Ad2, Ad1 and Ad0 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 4: Command structure

MS5525DSO (Digital Small Outline)

Start
5525DSO-pp005GS Example
Tmin=-40°C , Tmax=125°C

↓

Read Calibration Data from PROM

Variable	Coefficient Description	Recommended Variable Type	Size [1] [Bit]	Value Min	Value Max	Example/ Typical
C1	Pressure Sensitivity, $SENS_{T1}$	unsigned int 16	16	0	65535	36402
C2	Pressure Offset, OFF_{T1}	unsigned int 16	16	0	65535	39473
C3	Temperature Coefficient, Pressure Sensitivity, TCS	unsigned int 16	16	0	65535	40393
C4	Temperature Coefficient, Pressure Offset, TCO	unsigned int 16	16	0	65535	29523
C5	Reference Temperature, T_{REF}	unsigned int 16	16	0	65535	29854
C6	Temperature Coefficient Temperature, TEMPSENS	unsigned int 16	16	0	65535	21917

↓

Read Digital Pressure and Temperature Data

D1	Digital Pressure Value	unsigned int 32	24	0	16777216	5990585
D2	Digital Temperature Value	unsigned int 32	24	0	16777216	3871665

↓

Calculate Temperature

dT	Difference between actual and reference temperature $dT = D2 - T_{REF} = D2 - C5 * 2^{Q5}$	signed int 32	25	-16776960	16777216	49112
TEMP	Measured temperature $TEMP=20°C+dT*TEMPSENS=2000+dT*C6/2^{Q6}$	signed int 32	41	-4000	12500	2513 =25.13 °C

↓

Calculate Temperature Compensated Pressure

OFF	Offset at actual temperature $OFF=OFF_{T1}+TCO * dT=C2*2^{Q2}+(C4*dT)/2^{Q4}$	signed int 64	41			2632212952
SENS	Sensitivity at actual temperature $SENS=SENS_{T1}+TCS*dT=C1*2^{Q1}+(C3*dT)/2^{Q3}$	signed int 64	41			1208319025
P	Temperature Compensated Pressure $P=D1*SENS-OFF=(D1*SENS/2^{21}-OFF)/2^{15}$	signed int 32	61			25005 =2.5005psi

↓

Display Pressure and Temperature Value

Figure 1: Flow chart for pressure and temperature reading and software compensation.

Qx Coefficients Matrix by Pressure Range

Part Number	Pmin	Pmax	Q1	Q2	Q3	Q4	Q5	Q6	T_{RES}	P_{RES}
5525DSO-pp001GS	0	1	14	16	8	5	7	21	0.01	0.0001
5525DSO-pp001DS	-1	1	15	17	7	5	7	21	0.01	0.0001
5525DSO-pp002GS	0	2	13	15	9	6	7	22	0.01	0.0001
5525DSO-pp002DS	-2	2	14	16	8	5	7	22	0.01	0.0001
5525DSO-pp005GS	0	5	15	16	7	5	7	21	0.01	0.0001
5525DSO-pp005DS	-5	5	16	18	7	4	7	22	0.01	0.0001
5525DSO-pp0015AS	0	15	16	16	7	5	7	22	0.01	0.0001
5525DSO-pp0015GS	0	15	16	16	7	5	7	22	0.01	0.0001
5525DSO-pp0015DS	-15	15	17	19	5	3	7	22	0.01	0.0001
5525DSO-pp0030AS	0	30	17	19	5	4	7	22	0.01	0.0001
5525DSO-pp0030GS	0	30	17	19	5	4	7	22	0.01	0.0001
5525DSO-pp0030DS	-30	30	17	19	5	3	7	22	0.01	0.0001

MEMORY MAPPING

Memory Mapping

<table>
<tr><th>Address</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>0</td><td colspan="16">Reserved for Manufacturer</td></tr>
<tr><td>1</td><td colspan="16">Coefficient 1 (C1)</td></tr>
<tr><td>2</td><td colspan="16">Coefficient 2 (C2)</td></tr>
<tr><td>3</td><td colspan="16">Coefficient 3 (C3)</td></tr>
<tr><td>4</td><td colspan="16">Coefficient 4 (C4)</td></tr>
<tr><td>5</td><td colspan="16">Coefficient 5 (C5)</td></tr>
<tr><td>6</td><td colspan="16">Coefficient 6 (C6)</td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">CRC</td></tr>
</table>

Figure 2: Memory PROM Mapping

Notes
[1] Maximal size of intermediate result during evaluation of variable.

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

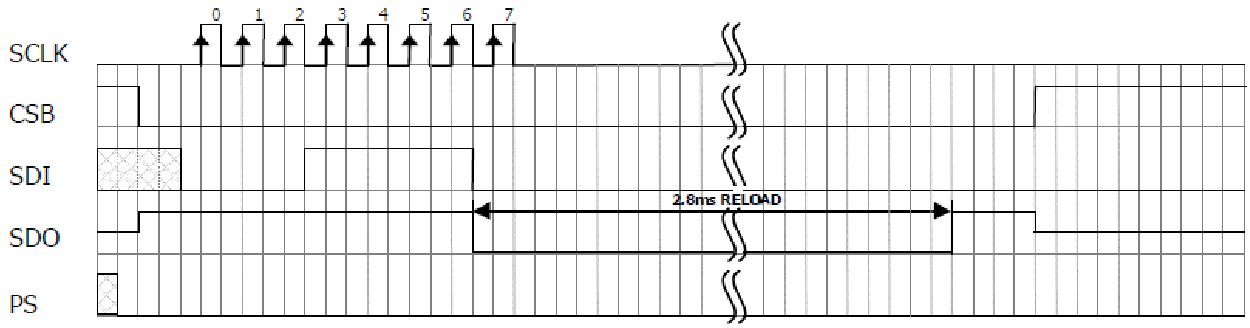


Figure 5: Reset command sequence SPI mode 0

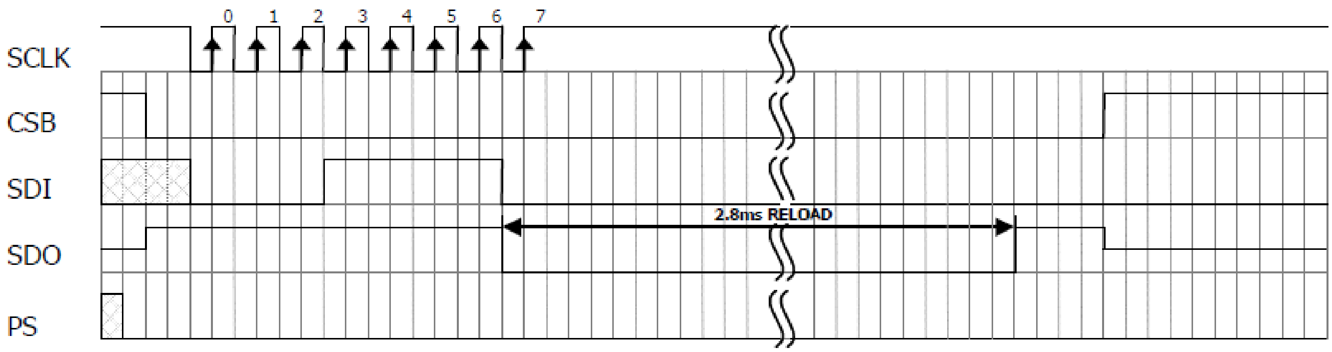


Figure 6: Reset command sequence SPI mode 3

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.

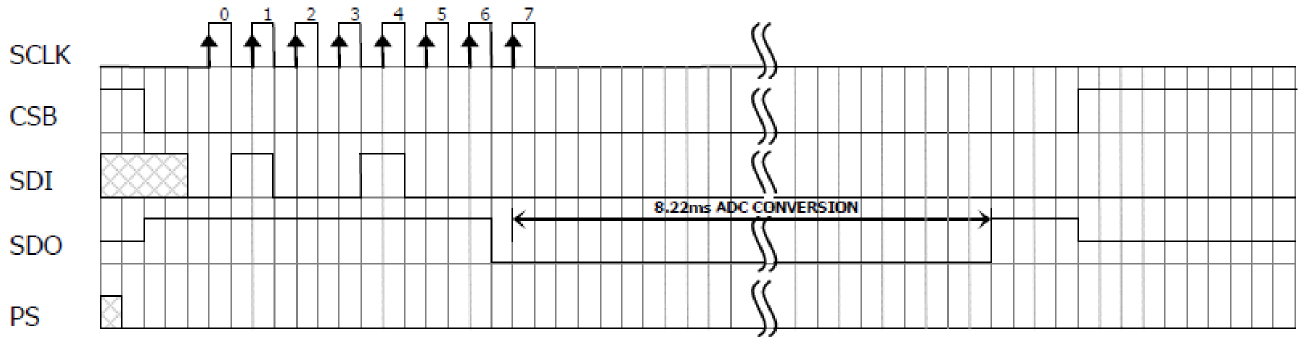


Figure 7: Conversion out sequence, Typ=d1, OSR = 4096

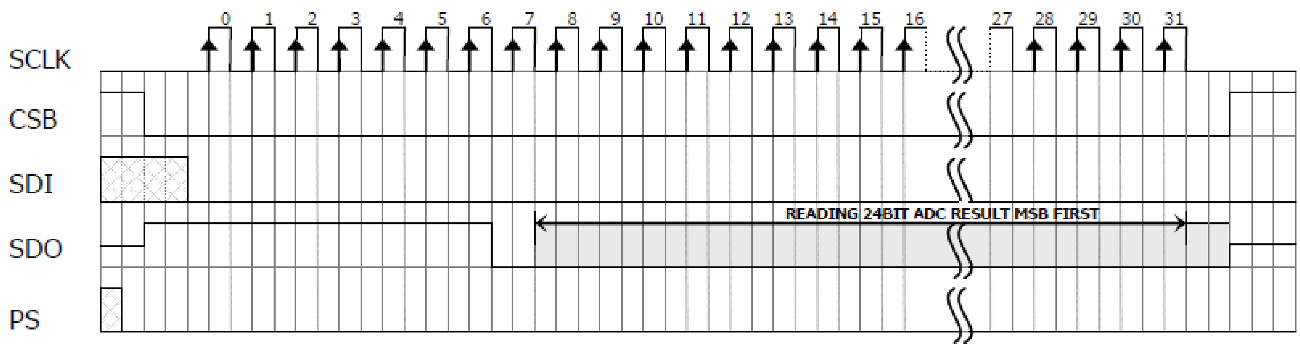


Figure 8: ADC Read sequence

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.

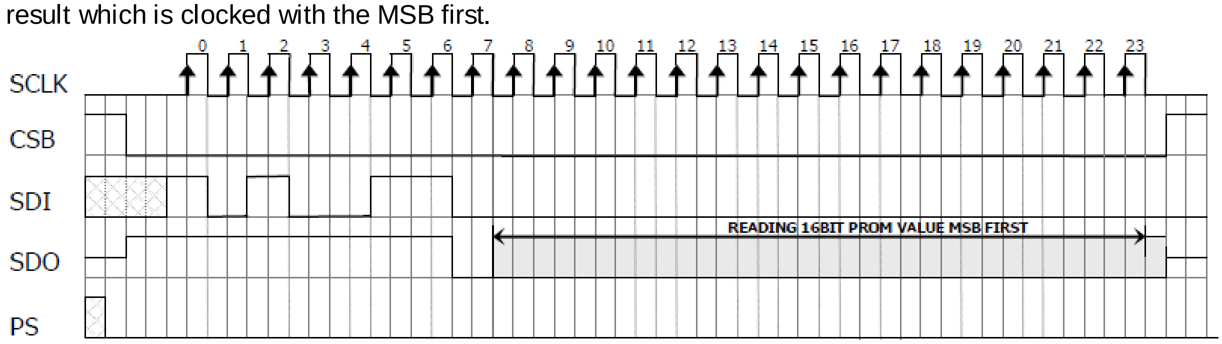


Figure 9: PROM Read sequence, address = 011 (Coefficient 3).

I²C INTERFACE

COMMANDS

Each I²C communication message starts with the start condition and it is ended with the stop condition. The MS5525DSO 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 MS5525DSO to function is to send several SCLKs followed by a reset sequence or to repeat power on reset.

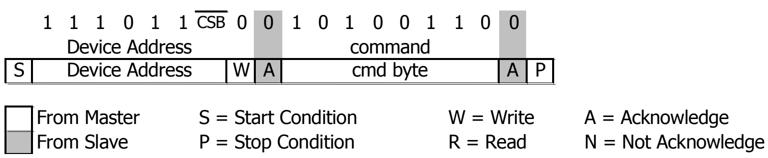


Figure 10: I²C Reset Command

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.

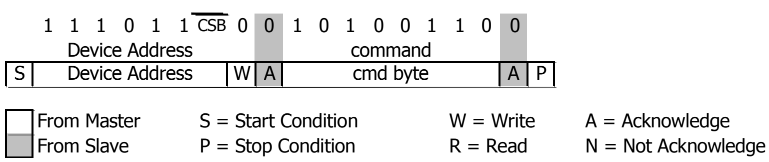


Figure 11: I2C Command to read memory address= 011 (Coefficient 3)

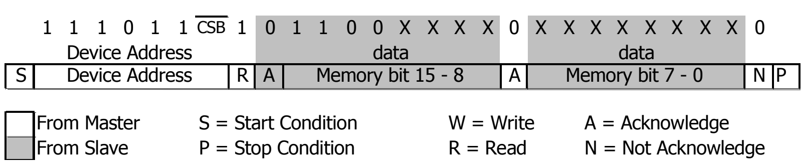


Figure 12: I2C response from MS5525DSO

CONVERSION SEQUENCE

A conversion can be started by sending the command to MS5525DSO. 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 MS5525DSO, 24 SCLK cycles may be sent to receive all result bits. Every 8-bit the system waits for an acknowledge signal.

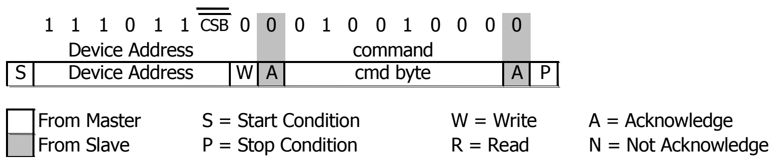


Figure 13: I²C Command to initiate a pressure conversion (OSR=4096, typ=D1)

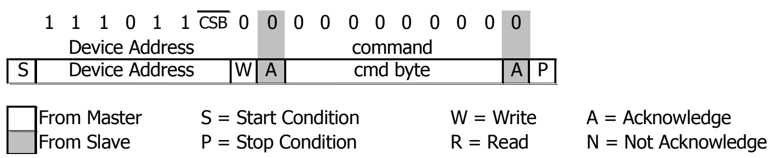


Figure 14: I²C ADC read sequence

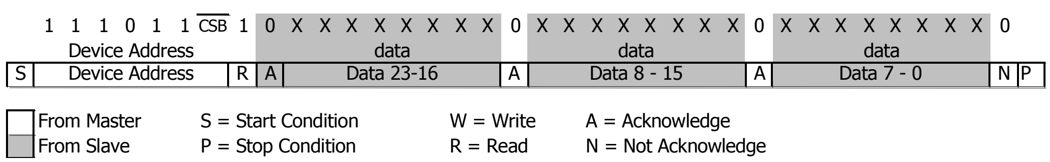


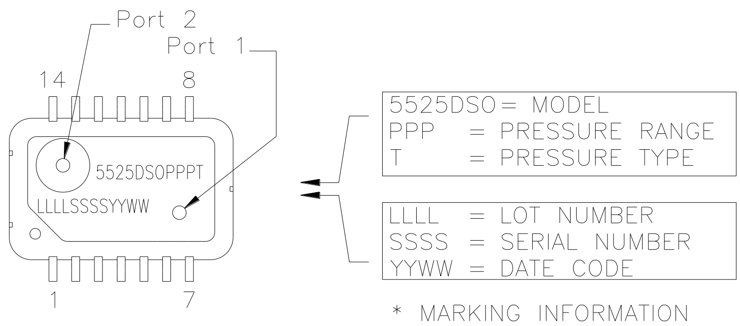
Figure 15: I²C response from MS5525DSO

CYCLIC REDUNDANCY CHECK (CRC)

MS5525DSO 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.

MS5525DSO (Digital Small Outline)

PINOUT, MARKING, AND PRESSURE TYPE CONFIGURATION



Pressure Type	Pmin	Pmax	Description
Absolute	0psiA	+Prange	Output is proportional to the difference between 0psiA (Pmin) and pressure applied to Port 1.
Differential/ Bidirectional	-Prange	+Prange	Output is proportional to the difference between Port 1 and Port 2. Output swings positive when Port 2> Port 1. Output is 50% of total counts when Port 1=Port 2.
Gauge	0psiG	+Prange	Output is proportional to the difference between 0psiG (Pmin) and Port 1. Output swings positive when Port 2> Port 1.
Compound	-15psiG	+Prange	Output is proportional to the difference between -15psiG pressure (Pmin) and pressure applied to Port 2.

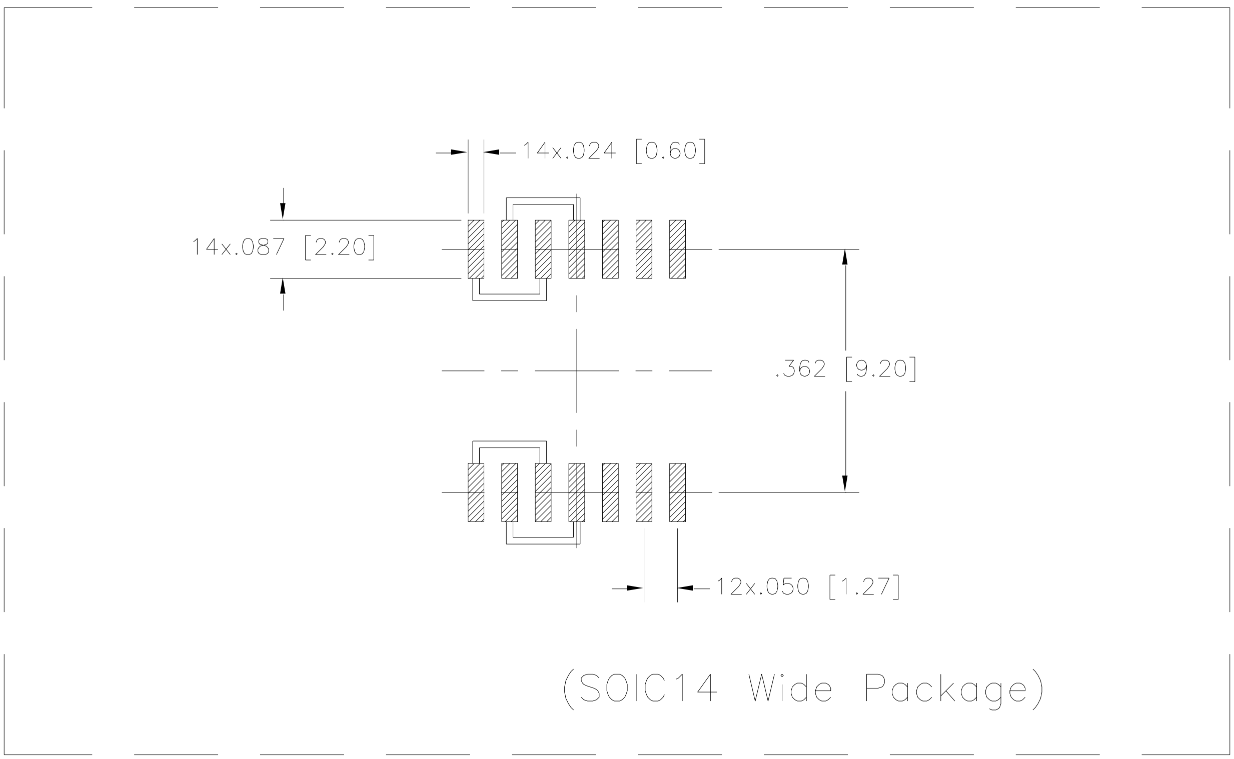
Pin Name	Pin	Function I2C	SPI
SGND	1,3	Sensor Ground	
SOUT-	2,4	Sensor Outputs, Negative	
SDO	5		Serial Data Output
SDA/SDI	6	I^2C Data Input and Output	SPI Serial Data Input
SCL/SCLK	7	I^2C Clock	SPI Clock
CSB	8	Defines I^2C Address	Chip Select (Active Low)
GND	9	Ground	
PS	10	Protocol Select PS = (VDD) I^2C Protocol Selected CSB= (VDD) I^2C Address =1110110X (0xEC, 0xED) CSB= (GND) I^2C Address=1110111X (0xEE, 0xEF)	 PS = (GND) SPI Protocol Selected
Supply+	11,13	Positive Supply Voltage	
SOUT+	12,14	Sensor Outputs, Positive	

WETTED MATERIAL BY PORT DESIGNATION

		Material								
Style	Port	LCP	Phosphor Bronze	Silicon	Pyrex	RTV	Gold	Aluminum	Silicone Gel	Epoxy
DB, DH	Port 2	X		X	X	X				X
	Port 1	X	X	X	X	X		X		X
ST,SB	Port 2	X		X	X	X				X

"X" Indicates Wetted Materials

RECOMMEND PCB LAYOUT

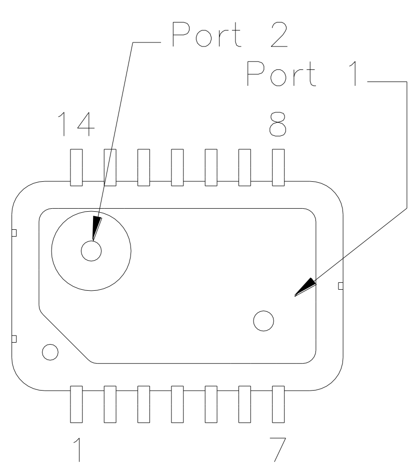


The recommend PCB layout details the required interconnections between the piezo-resistive sensor and internal sensor interface IC that is in accordance to the table below. Additional connections for the CSB and PS pins must be made to define the digital protocol; these are detailed in the application circuit on the following page.

PAD NO.	FUNCTION	PAD NO.	FUNCTION
1	SGND	8	CSB
2	SOUT−	9	SUPPLY−
3	SGND	10	PS
4	SOUT−	11	SUPPLY+
5	SDO	12	SOUT+
6	SDI/SDA	13	SUPPLY+
7	SCLK/SCL	14	SOUT+

FUNCTION PINS THAT SHARE THE SAME NAME (SGND, SOUT+, SOUT−, SUPPLY+) MUST BE CONNECTED TOGETHER ON PCB FOR PROPER OPERATION.

NEED TO PLACE 0.1uF DECOUPING CAPACITOR BETWEEN SUPPLY+ AND SUPPLY− ON PCB AND AS CLOSE AS POSSIBLE TO SENSOR



APPLICATION CIRCUIT

The MS5525DSO is a circuit that can be used in conjunction with a microcontroller. It is designed for low-voltage systems with a supply voltage of 3 V.

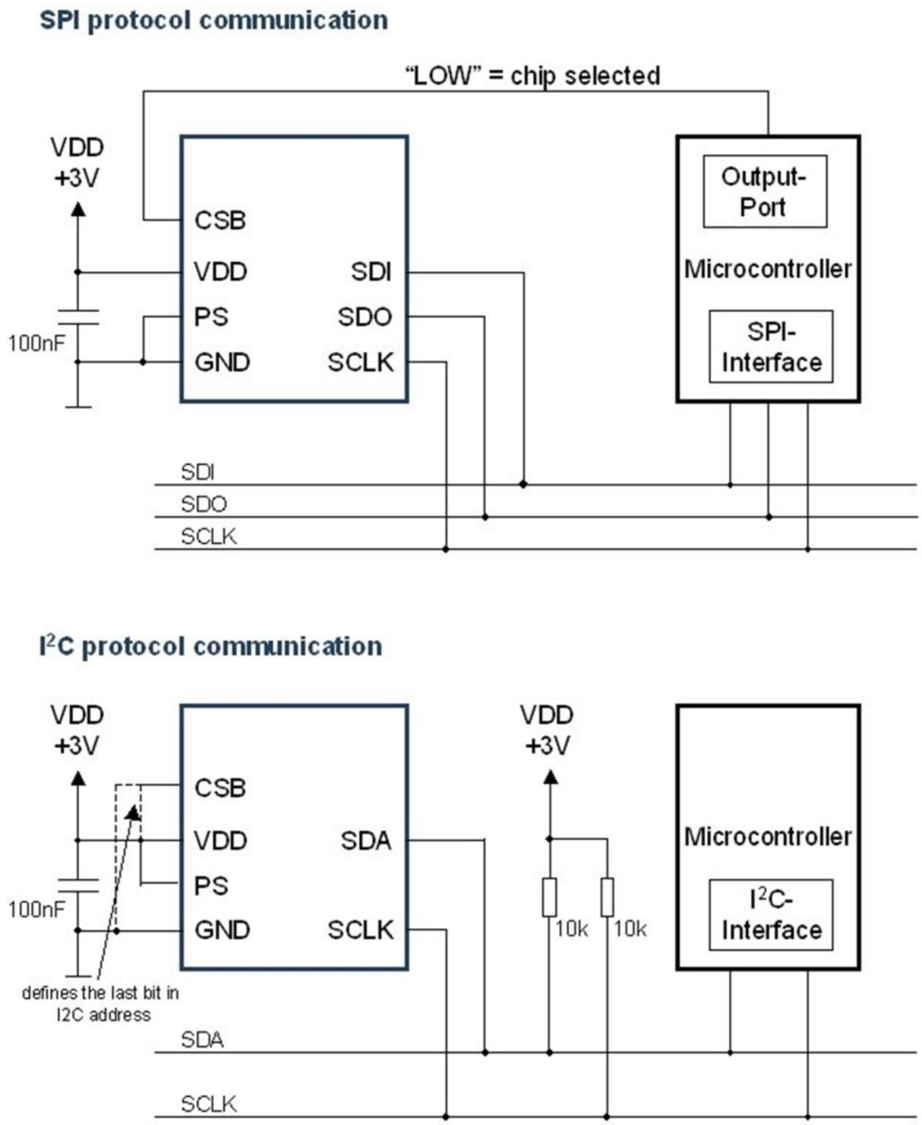


Figure 17: Typical application circuit with SPI / I^2C protocol communication

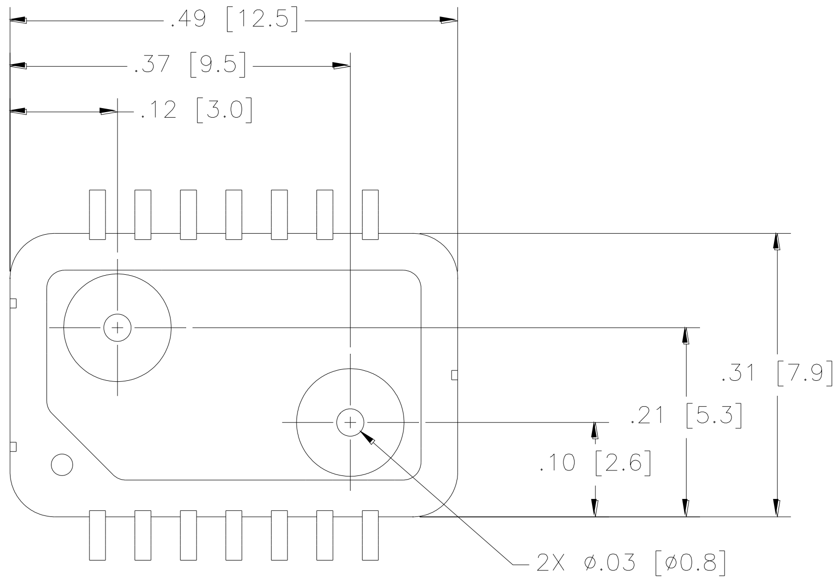
Note

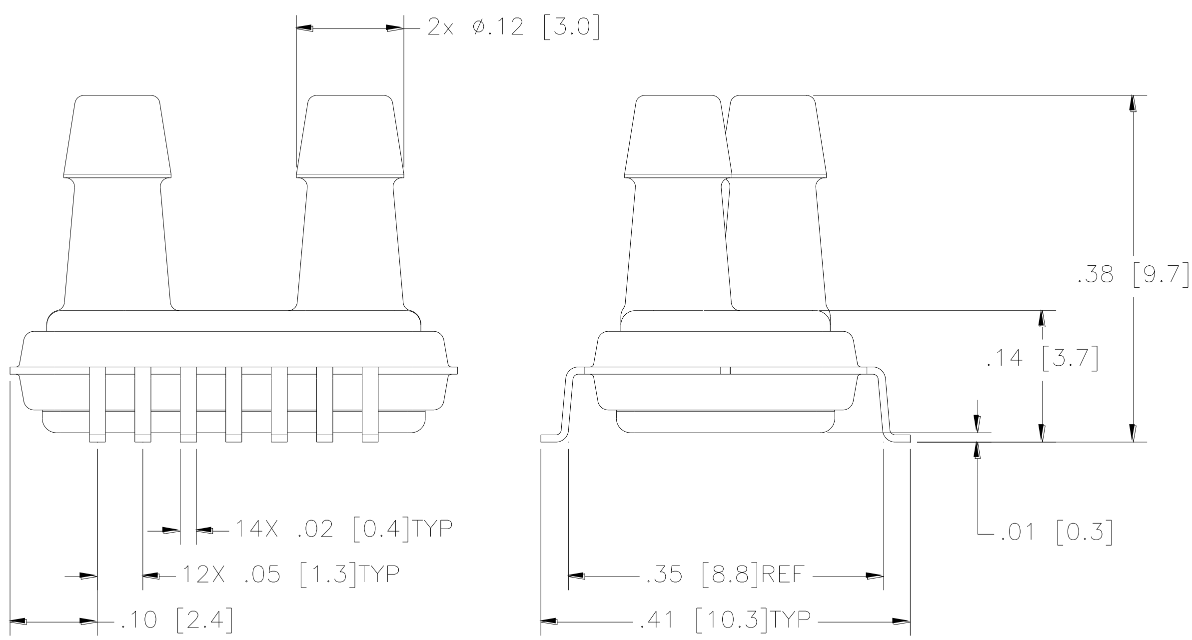
1. Place 100nF capacitor between Supply and GND to within 2 cm of sensor.

MS5525DSO (Digital Small Outline)

DIMENSIONS

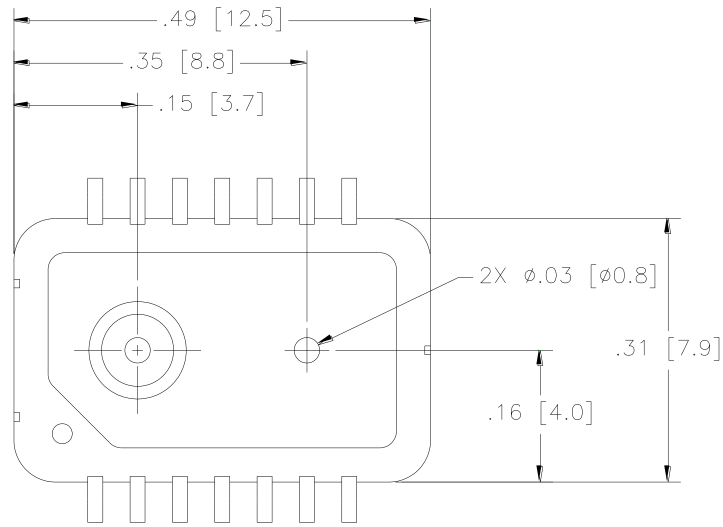
MS5525DSO-DBxxxyS

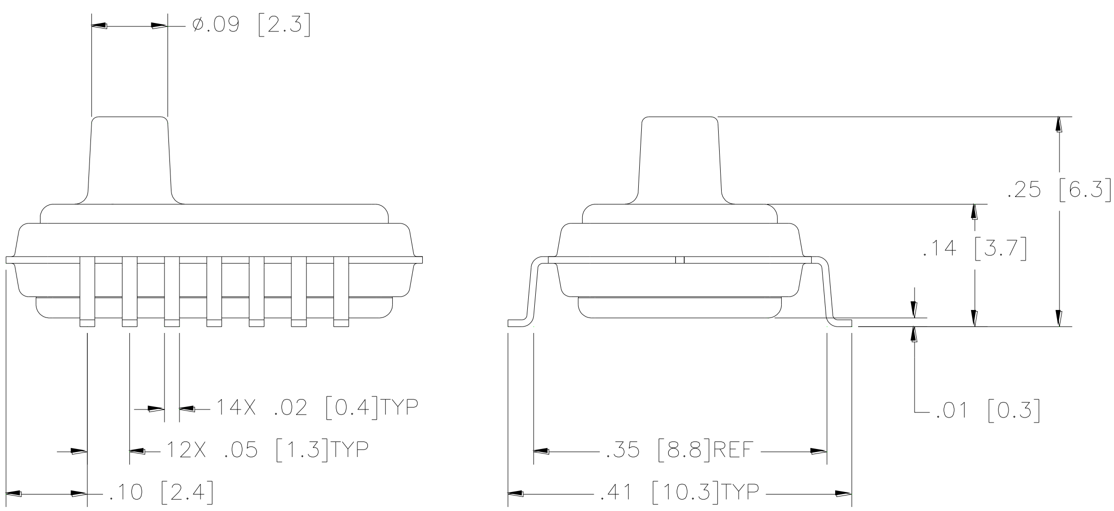




MS5525DSO (Digital Small Outline)

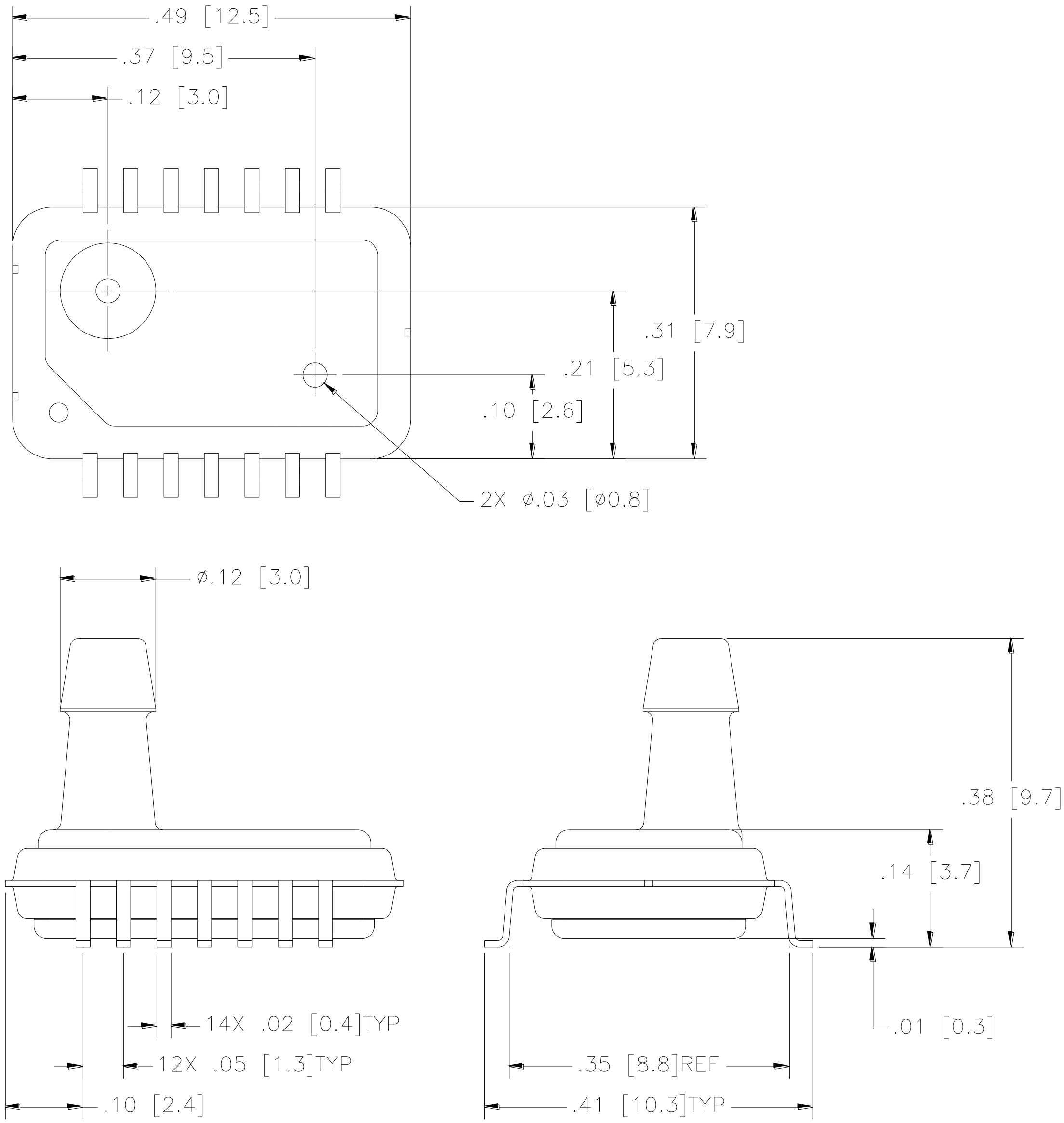
MS5525DSO-STxxxyS





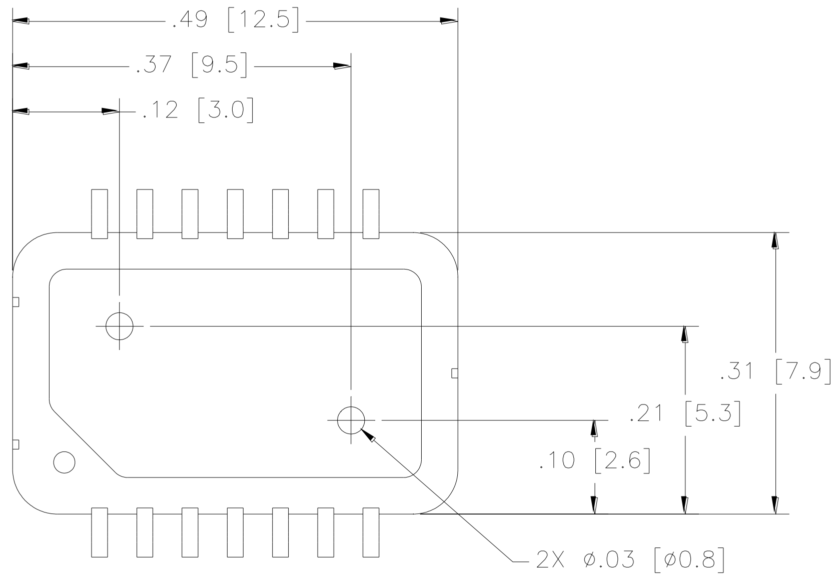
MS5525DSO (Digital Small Outline)

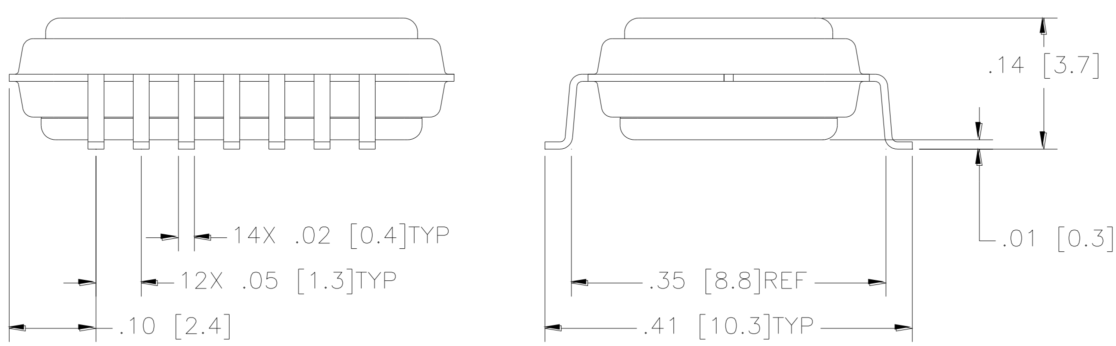
MS5525DSO-SBxxxyS



MS5525DSO (Digital Small Outline)

MS5525DSO-DHxxxyS





MS5525DSO (Digital Small Outline)

ORDERING INFORMATION

5525DSO	-	DB	005	G	S
Model	**-**	**Package Style**	**Pressure Range**	**Pressure Type**	**Pin Style**
MS5525DSO	-	**DB** = Dual Barb **SB** = Single Barb **ST** = Single Tube **DH** = Dual Hole	**001** **002** **005** **015** **030**	**A** = Absolute **D** = Differential **G** = Gage **C** = Compound	**S** = Gull Wing