Low Pressure Digital Sensor

SM5231, SM5331, SM5431
Gauge and Differential Pressure Sensor

FEATURES

- Pressure range from 0.8 to 2.49 psi; gauge, differential or asymmetric differential outputs
- Digital Accuracy: +/- 1 %FS
- 16-bit digital, pressure calibrated and temperature compensated output
- I^2C interface
- Compensated temperature range: -20 to 85°C
- Robust JEDEC SOIC-16 package for automated assembly
- Manufactured according to ISO9001 and ISO/TS 16949 standards

DESCRIPTION

The SM5X31 series are a low pressure MEMS sensor family offering state-of-the-art pressure transducer technology and CMOS mixed signal processing technology to produce a digital output, fully conditioned, multi-order pressure and temperature compensated output. This series provides JEDEC standard SOIC-16 package with dual vertical or horizontal ports options. It is available in gauge, differential, asymmetric differential configurations. With the dual porting, a reference measurement is possible to minimize errors due to changes in ambient pressure.

Combining the pressure sensor with a signal-conditioning ASIC in a single package simplifies the use of advanced silicon micro-machined pressure sensors. The pressure sensor can be mounted directly on a standard printed circuit board and a high level, calibrated pressure signal can be acquired from the digital interface. This eliminates the need for additional circuitry, such as a compensation network or microcontroller containing a custom correction algorithm.

Customer-specified pressure ranges and supply voltages are available.

The SM5231, SM5331 and SM5431 series shipped in sticks or tape & reel.

The AccuStable® quality label stands for <1% total accuracy error initially and <1% shift during operation over 10 year lifetime. Qualification is based on 1000 hours HTOL test at 85°C and 5V.

Medical	Industrial
Sleep Apnea	Air and Gas Flow Measurement
CPAP	Pneumatic Gauges
Ventilators	Pressure Switches
Gas Flow Instrumentation	Safety Cabinets
Air Flow Monitors	Life Sciences
Negative Pressure Wound Therapy	HVAC

1. Absolute Maximum Ratings

All parameters are specified at VDD = 3.3 V / 5.0 V supply voltage at 25°C, unless otherwise noted.

No.	Characteristic	Symbol	Minimum	Maximum	Units
1	Compensated Temperature	T_{COMP}	-20	85	°C
2	Operating Temperature[a]	T_{OP}	-40	105	°C
3	Storage Temperature[a]	T_{STG}	-40	125	°C
4	Proof Pressure[a, c]	P_{Proof}		12	psi
5	Burst Pressure[a, d]	P_{Burst}		15	psi
6	Supply voltage	$VDD_{MIN/MAX}$	-0.3	6	V
7	Media Compatibility[a, b]				

Notes:

a. Tested on a sample basis.

b. Clean, dry gas compatible with wetted materials. Wetted materials include silicon, epoxy, RTV, gold and aluminum.

c. Proof pressure is defined as the maximum pressure to which the device can be taken and still perform within specifications after returning to the operating pressure range

d. Burst pressure is the pressure at which the device suffers catastrophic failure resulting in pressure loss through the device.

2. ESD

All parameters are specified at VDD = 3.3 V / 5.0 V supply voltage at 25°C, unless otherwise noted.

No.	Description	Condition	Symbol	Min.	Typ.	Max.	Units
8	ESD HBM Protection at all Pins	AEC Q100-002 (HBM) chip level test	$V_{ESD(HBM)}$	-2		+2	kV

3. Electrical Characteristics

All parameters are specified at VDD = 5.0 V / 3.3 V DC supply voltage at 25°C, unless otherwise noted.

No.	Description	Symbol	Min.	Typ.	Max.	Units
9	Supply Voltage	V_{DD}	4.75	5.0	5.25	V
			3.0	3.3	3.6	
10	Low level input voltage at Digital I/O	$V_{IN,I2C,lo}$	-0.3		0.9	V
11	High level input voltage at Digital I/O	$V_{IN,I2C,hi}$	0.8*VDD		VDD + 0.3	V
12	Current Consumption			3.0		mA

4. External Components

No.	Description	Symbol	Min.	Typ.	Max.	Units
13	Supply bypass capacitor	C_{VDD}		100		nF

5. Operating Characteristics Table

All parameters are specified at VDD = 5.0 V / 3.3 V DC supply voltage at 25°C, unless otherwise noted.

No.	Characteristic	Symbol	Minimum	Typical	Maximum	Units
15	Digital Pressure Output @ P_{MIN} (e)	$DOUT_{MIN}$		-26214		Counts
16	Digital Pressure Output @ P_{MAX} (e)	$DOUT_{MAX}$		26214		Counts
17	Digital Full Scale Span (e)	DFS		52428		Counts
18	Resolution				16	Bits
19	Digital Output Accuracy (f,g,h)	DACC	-1		+1	%FS

Calibrated Pressure Ranges				
No.	Device Type	P_{MIN} (psi)	P_{MAX} (psi)	Comment
24	SM5231– Gauge	0	+0.07 to +0.29	
25	SM5331 – Differential	-0.29 to -0.07	+0.07 to +0.29	Absolute value of P_{MIN} must match absolute value of P_{MAX}
26	SM5431 -- Asymmetric	-0.29 to 0	0 to +0.29	Delta between P_{MAX} and P_{MIN} must be at least 0.14 psi

Notes:

e. Only the typical values are shown here. However, the digital output values can be customized or changed upon request. Please refer to the tear sheet for the specific product to get updated information.

f. The accuracy specification applies across the compensated temp range. This specification includes the combination of linearity, repeatability, and hysteresis errors over pressure, temperature, and voltage.

g. Maximum 10-year zero pressure offset shift < ±1%FS based on 1000 hours of HTOL testing.

h. For less demanding applications, devices with relaxed accuracy specifications are available.

***Custom calibration pressures and voltages are available to meet specific customer demands.**

5. Sensor Transfer Function

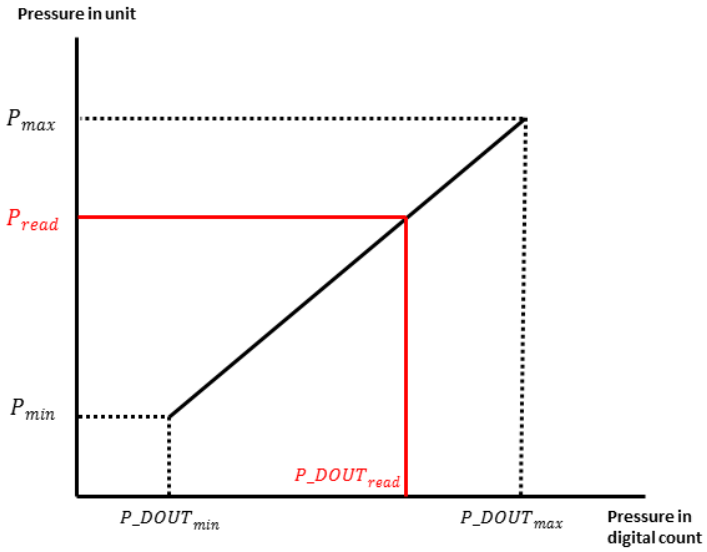
Digital Pressure Transfer Function

$$P_{read} = P_{min} + \frac{P\_DOUT_{read} - P\_DOUT_{min}}{P\_DOUT_{max} - P\_DOUT_{min}} (P_{max} - P_{min})$$

P_{min} and P_{max} are minimum and maximum rating pressure in specified pressure unit on the specification.

P_DOUT_{min} and P_DOUT_{max} are minimum and maximum digital counts on the specification.

P_DOUT_{read} is digital reading from the output and P_{read} is the converted pressure output based on P_DOUT_{read}.

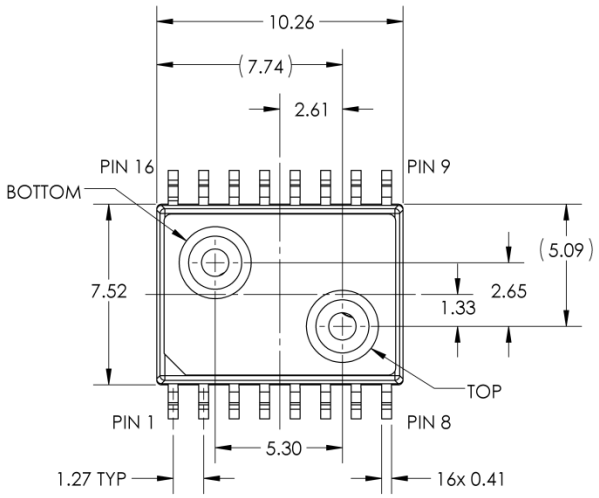


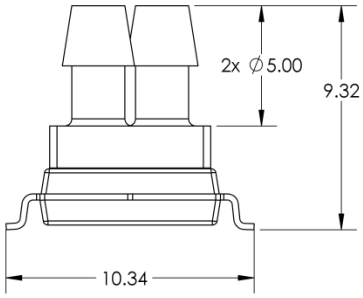
For example, the P_{min} and P_{max} for the sensor are specified as -0.1 and +0.1 psi. The $DOUT_{min}$ and $DOUT_{max}$ are -26214 and +26214. So,

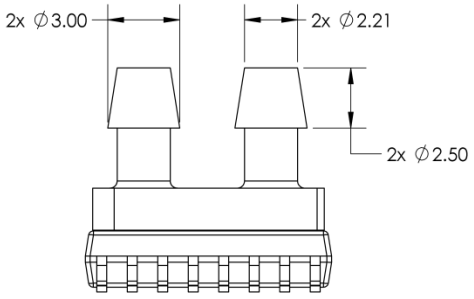
$$P_{read} = -0.1 + \frac{DOUT_{read} + 26214}{52428} \times 0.2 \text{ psi}$$

6. Package Dimensions

SOIC-16 (C) Vertical Package Dimensions



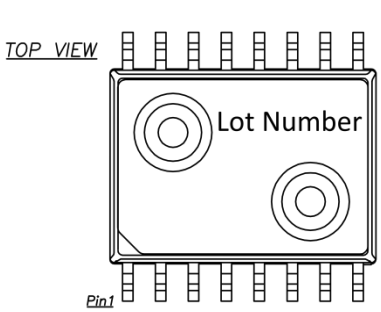


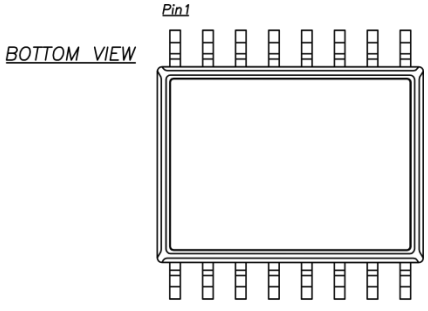


Notes:

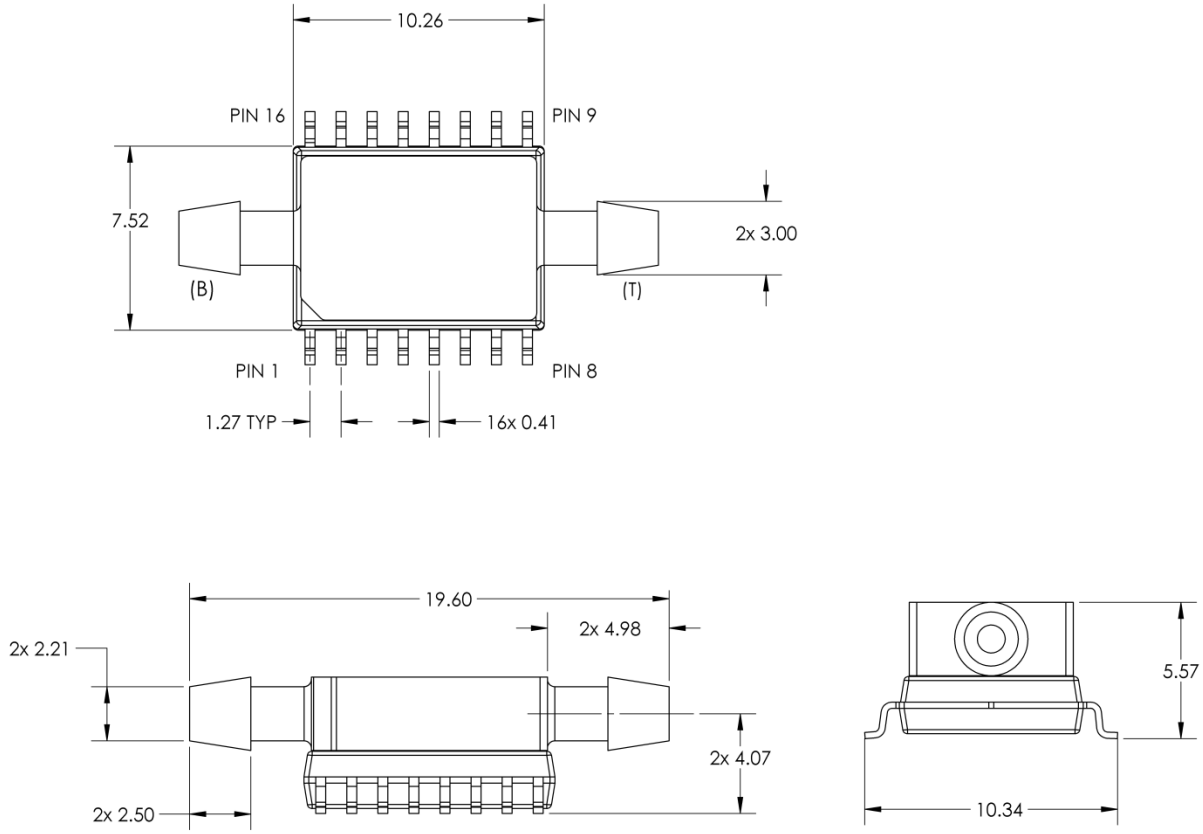
- All dimensions in units of [mm]
- Moisture Sensitivity Level (MSL): Level 3
- Wetted materials: Silicon, glass, gold, aluminum, copper, stainless, epoxy, mold compound.
- [B] is tube connected to bottom side of sensor die.
- [T] is tube connected to top side of sensor die. Topside pressure is positive pressure. An increase in topside pressure will result in an increase in sensor output unless otherwise noted on the tear sheet.

Part & Lot Number Identification





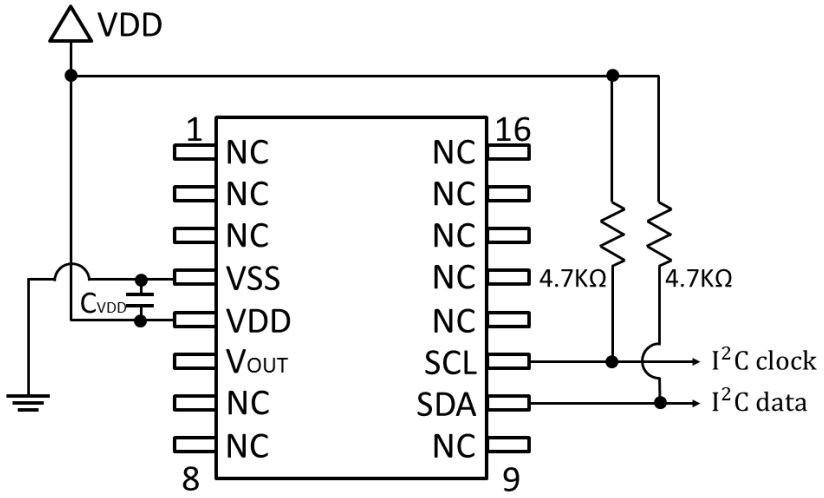
SOIC-16 Horizontal (B) Package Dimensions



Qualification Standards

REACH Compliant
RoHS Compliant
PFOS/PFOA Compliant
For qualification specifications, please contact Sales at sales@si-micro.com

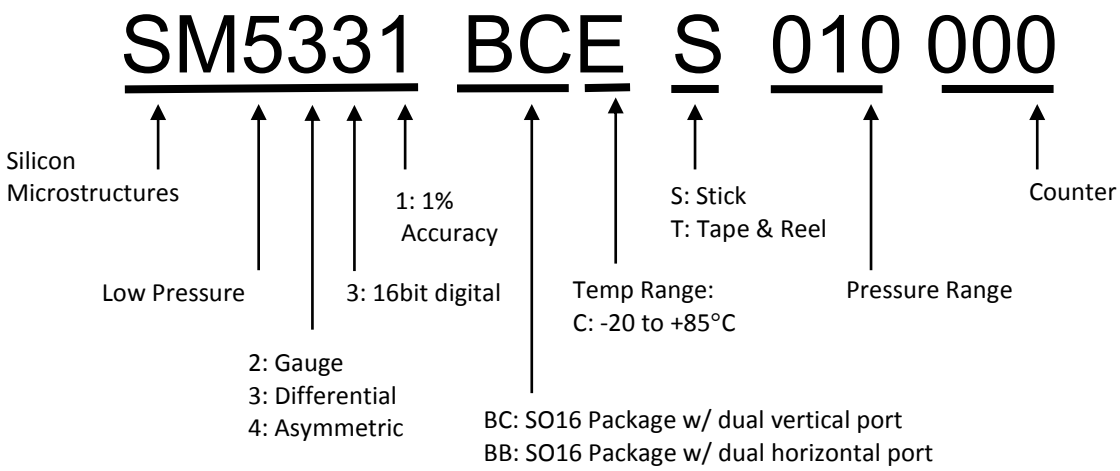
SM5X31+ Family Applications Circuit



Pin No.	Pin function	Pin No.	Pin function
1	NC	9	NC
2	NC	10	SDA
3	NC	11	SCL
4	VSS	12	NC
5	VDD	13	NC
6	NC	14	NC
7	NC	15	NC
8	NC	16	NC

Ordering Information: Specific part number information is provided on a separate tear sheet for each product. The general part number ordering information is provided below:

7. Part Number Legend



8.1 I²C Electrical Table

No.	Description	Condition	Symbol	Min.	Typ.	Max.	Units
1	SDA output low voltage	I_{SDA} = 3 mA	$V_{SDA,OL}$	0		0.4	V
2	Low-to-High transition threshold	pins SA0, SCL	$V_{SDA,LH}$	0.5	0.6	0.7	*VDD
3	High-to-Low transition threshold	pins SA0, SCL	$V_{SDA,HL}$	0.3	0.4	0.5	*VDD
4	I²C clock frequency		f_{SCL}	0		400	kHz
5	Bus free time between a START and STOP condition *)		t_{BUSF}	1300			ns
6	Clock low time *)		t_{LO}	1300			ns
7	Clock high time *)		t_{HI}	600			ns
8	START condition hold time *)		t_{SH}	100			ns
9	Data setup time *)		t_{SU}	100			ns
10	Data hold time *)		t_{H}	0			ns
11	Setup time for repeated START condition *)		t_{RSH}	600			ns
12	Setup time for STOP condition *)		t_{PSU}	600			ns
13	Rise time of SDA and SCL signals *)		t_{R}			300	ns
14	Fall time of SDA and SCL signals *)		t_{F}			300	ns

*) Not tested in production

8.2 I²C Interface

The SMI pressure sensor features an I²C slave interface. This interface provides direct access to registers of the memory of the pressure sensor. An external I²C master (e.g. a microcontroller) can read from and write to memory addresses (registers) of the device using the following commands:

- **Random write:** Sets a memory address and writes data to consecutive memory addresses of the device starting at the set memory address.
- **Random read:** Sets a memory address and reads data from consecutive memory addresses of the device starting at the set memory address.
- **Read last:** Reads data from the device starting at the last memory address set by the master. This facilitates repeated reading of the same memory addresses without transmitting a memory address first.

All reads/writes must start at word aligned addresses (i.e. LSB of memory address equals 0) and read/write an even number of bytes.

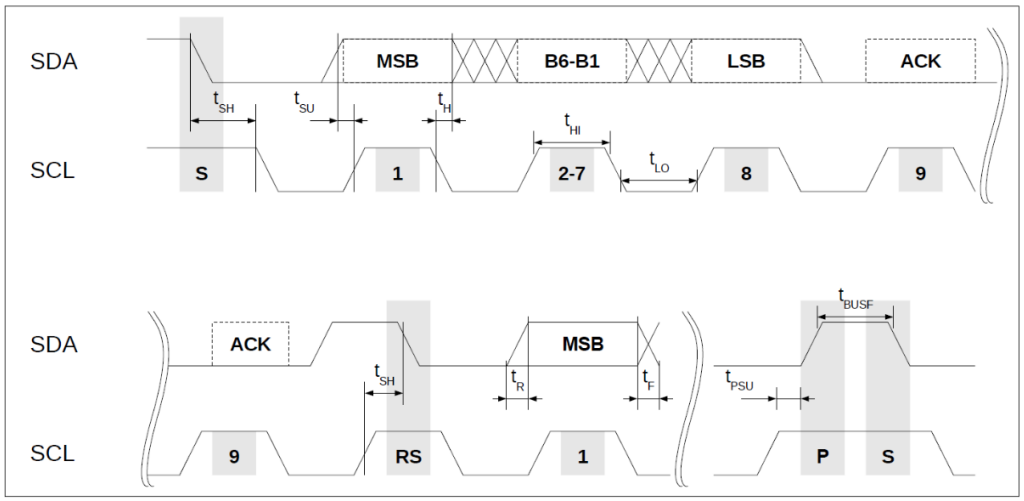


Figure 1: I²C Interface Timing Diagram

8.3 I²C Command Format

The SMI pressure sensor uses a standard 7-bit I²C slave address field. The LSB of the slave address specifies the frame type used to perform read and write operations.

For LSB = 0 the protocol is compatible to standard I²C EEPROMs, for LSB = 1 the protocol is extended by a CRC protection. Thus, each device occupies two I²C addresses: even addresses are for standard EEPROM compatible protocols and odd addresses are for CRC protected protocols. Unprotected and CRC protected frames can be interleaved.

The two different frame types - standard EEPROM (without CRC) or CRC protected - are shown in the next two figures.

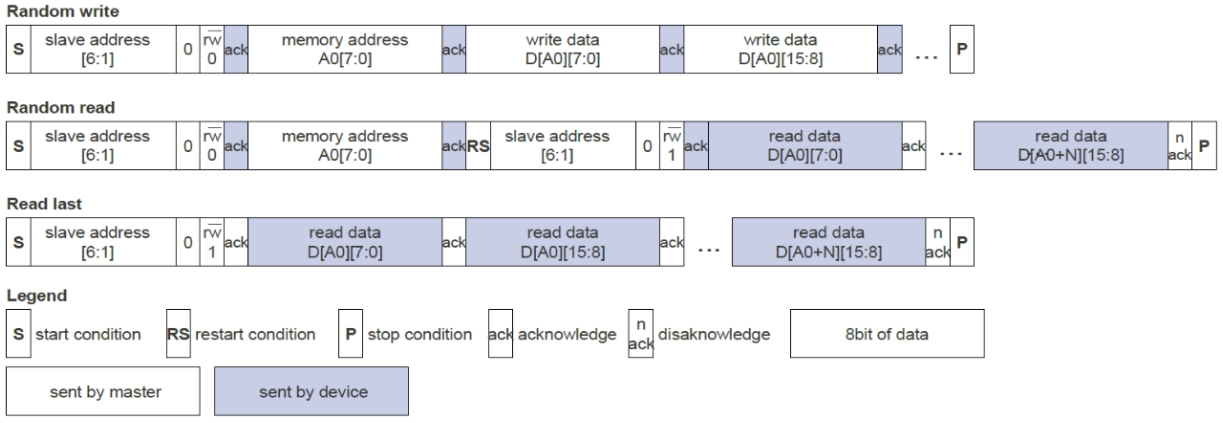


Figure 2: I²C Read / Write Commands - Standard EEPROM compatible protocol

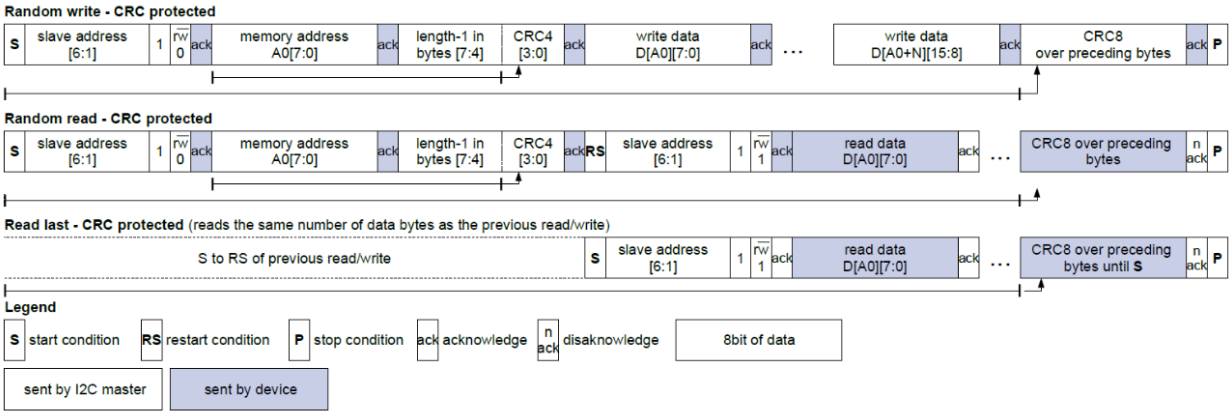


Figure 3: I²C Read / Write Commands - CRC protected protocol

The memory address field sets the byte address of the first memory location to be read from or written to. Only 16-bit-word aligned reads/writes are supported, i.e. the LSB of memory address has to be always zero. The read/write data is transferred MSB first, low byte before high byte.

The length field (bits[7:4]) required for CRC protected frames specifies the number of data bytes to be transferred decremented by one, i.e. a value of 0001b corresponds to two bytes. All frames must transfer an even number of bytes. The maximum length for CRC protected read/write frames is 16/4 bytes. For unprotected frames the length is unlimited.

The CRC4 and CRC8 for redundancy check are computed in the same bit and byte order as the transmission over the bus. The polynomials employed are:

CRC4: polynomial 0x03; initialization value: 0x0F

CRC8: polynomial 0xD5; initialization value: 0xFF

If a CRC error occurs, then the event bit “com_crc_error” in the STATUS register will be set.

8.4 I²C Command Examples

For all examples below the 7-bit device slave address used is 0x6C for unprotected commands, and 0x6D for CRC protected commands, respectively. These addresses are the default addresses and are used unless otherwise stated in the part number specific data sheet.

The command sequence following describes an unprotected Read command (without CRC) of 3 subsequent 16-bit words starting at memory address 0x2E to read the corrected IC temperature, corrected pressure signal, and (synchronized) status bits of the sensor.

Byte #	0	1	2	3	4	5	6	7	8
SBM (sent by master)	0xD8	0x2E	0xD9						
SBM comment	slave address 6C + LSB = 0 for *Write*	memory address	slave address 6C + LSB = 1 for *Read*						
SBS (sent by sensor)				0xF2	0x7D	0xEA	0x82	0x1E	0x00
SBS comment				DSP_T (Lo-Byte) ad. 0x2E	DSP_T (Hi-Byte)	DSP_S (Lo-Byte) ad. 0x30	DSP_S (Hi-Byte)	sync‘ed Status (b7 - b0) ad. 0x32	sync‘ed Status (b15 - b8)

Random Read:

The following sequence describes the CRC protected version of reading 3 subsequent 16-bit words starting at memory address 0x2E to read the corrected IC temperature, corrected pressure signal, and (synchronized) status bits of the sensor.

Random Read - protected by CRC:

Byte #	0	1	2	3	4	5	6	7	8	9	10
SBM (sent by master)	0xDA	0x2E	0x5B	0xDB							
SBM comment	slave address 6D + LSB = 0 for *Write*	memory address	3: length = 4Byte B: CRC4	slave address 6D + LSB = 1 for *Read*							
SBS (sent by sensor)					0xF2	0x7D	0xEA	0x82	0x1E	0x00	0x65
SBS comment					DSP_T (Lo-Byte) ad. 0x2E	DSP_T (Hi-Byte)	DSP_S (Lo-Byte) ad. 0x30	DSP_S (Hi-Byte)	sync'ed Status (b7 - b0) ad. 0x32	sync'ed Status (b15 - b8)	CRC8 (calc'd)

The following sequence writes one 16-bit word to address 0x22 (without CRC protection). This will copy 0x6C32 into the command register CMD to move the component to Sleep Mode.

Random Write:

Byte #	0	1	2	3
SBM (sent by master)	0xD8	0x22	0x32	0x6C
SBM comment	slave address 6C + LSB = 0 for *Write*	memory address	Lo-Byte written to CMD[7:0]	Hi-Byte written to CMD[15:8]
SBS (sent by sensor)				
SBS comment				

8.5 Register Descriptions

Register Read or Write are performed via the digital communication interface. After power-up of the IC all registers except STATUS and CMD are write protected.

Command register:

0x22	CMD			
bits	**name**	**default**	**rw**	**description**
15:0	cmd	0	w	Writing to this register controls the state of the BAP device. 0x6C32: SLEEP Mode Initiate the power state SLEEP, powering down the ASIC 0xB169: RESET Performs a reset. After reset the power-up sequence will be executed, i.e. the registers are loaded with data from the configuration memory, also a CRC check is performed.

Temperature register:

0x2E	DSP_T			
bits	**name**	**default**	**rw**	**description**
15:0	dsp_t		r	Corrected temperature measurement value of the sensor. Whenever this register is updated with a new measurement the STATUS.dsp_t_up event bit is set.

Pressure register:

0x30	DSP_S			
bits	**name**	**default**	**rw**	**description**
15:0	dsp_s		r	corrected pressure measurement value of the sensor. Whenever this register is updated with a new measurement the STATUS.dsp_s_up event bit is set.

The registers DSP_T and DSP_S contain invalid data after power-up until the first temperature and pressure values have been measured by the device and transferred to these registers. In case a NVM CRC error occurred, the DSP_T and DSP_S registers would never be updated. ***Thus, after power up it is necessary to wait until the STATUS.dsp_s_up and dsp_t_up bits have been set at least once before using the temperature or pressure data. It is not sufficient to wait just for a fixed time delay.***

Status register - synchronized:

0x32	STATUS_SYNC				
bits	**name**	**default**	**rw**	**type**	**description**
0	idle	0	rw	status	STATUS.idle
1	- reserved -	0	rw	event	reserved
2	- reserved -	0	rw	event	reserved
3	dsp_s_up	0	rw	event	when DSP_S is read STATUS.dsp_s_up is copied here
4	dsp_t_up	0	rw	event	when DSP_T is read STATUS.dsp_t_up is copied here
5	- reserved -	0	rw	status	reserved
6	- reserved -	0	rw	status	reserved
7	bs_fail	0	rw	event	STATUS.bs_fail
8	bc_fail	0	rw	event	STATUS.bc_fail
9	- reserved -	0	rw	event	reserved
10	dsp_sat	0	rw	status	STATUS.dsp_sat
11	com_crc_error	0	rw	event	STATUS.com_crc_error
12	- reserved -	0	rw	status	reserved
13	- reserved -	0	rw	status	reserved
14	dsp_s_missed	0	rw	event	STATUS.dsp_s_missed
15	dsp_t_missed	0	rw	event	STATUS.dsp_t_missed

The bits STATUS_SYNC[15:5,0] are identical to the bits STATUS[15:5,0].

The bits STATUS_SYNC[4:3] are copied from the STATUS register when the corresponding DSP registers are read. First reading the DSP registers and then STATUS_SYNC ensures that both values are consistent to each other.

The synchronized status STATUS_SYNC register can be used to continuously poll the pressure, temperature and status of the device with a single read command by reading three 16 bit words starting at address 0x2E. By evaluating STATUS_SYNC.dsp_t_up and STATUS_SYNC.dsp_s_up it can be determined if the values in DSP_T and DSP_S acquired during the same read contain recently updated temperature or pressure values.

Status register:

0x36	STATUS				
bits	**name**	**default**	**rw**	**type**[1]	**description**
0	idle	0	rw	status	0: chip in busy state 1: chip in idle state
1	- reserved -	0	rw	event	reserved
2	- reserved -	0	rw	event	reserved
3	dsp_s_up	0	rw	event	1: DSP_S register has been updated. Cleared when DSP_S is read
4	dsp_t_up	0	rw	event	1: DSP_T register has been updated. Cleared when DSP_T is read.
5	- reserved -	0	rw	status	reserved
6	- reserved -	0	rw	status	reserved
7	bs_fail	0	rw	event	1: bridge supply failure occurred
8	bc_fail	0	rw	event	1: sensor bridge check failure occurred
9	- reserved -	0	rw	event	reserved
10	dsp_sat	0	rw	status	1: a DSP computation leading to the current DSP_T or DSP_S values was saturated to prevent overflow
11	com_crc_error	0	rw	event	1: communication CRC error
12	- reserved -	0	rw	status	reserved
13	- reserved -	0	rw	status	reserved
14	dsp_s_missed	0	rw	event	1: dsp_s_up was 1 when DSP_S updated
15	dsp_t_missed	0	rw	event	1: dsp_t_up was 1 when DSP_T updated

1) "Event" type flags remain set until cleared by writing '1' to the respective bit position in STATUS register (not STATUS_SYNC). Writing 0xFFFF to the STATUS register will clear all event bits. "Status" type flag represents a condition of a hardware module of the IC and persists until the condition has disappeared.

Serial Number register 0:

0x50	SER0			
bits	**name**	**default**	**rw**	**description**
15:0	ser0		r	Serial number of the IC, Lo-Word

Serial Number register 1:

0x50	SER1			
bits	**name**	**default**	**rw**	**description**
15:0	ser1		r	Serial number of the IC, Hi-Word

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