TPS ULTRA LOW PRESSURE DIGITAL SENSOR

Gage & Differential Pressure Sensors

The TPS (TE Connectivity Pressure Sensors) are digital, ultra-low-pressure sensors offering state-of-the-art MEMS pressure transducer technology and CMOS mixed signal processing technology to produce a digital, fully conditioned, multi-order pressure and temperature compensated sensor in JEDEC standard SOIC-16 package with a dual vertical porting option (dual horizontal porting available for selected configurations). It is available in a gage and a differential pressure configuration.

The total error band after board mount and system level autozero is less than 1%FS. The warmup behavior and long-term stability further confirms its expected performance over the life of the part.

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.

The TPS products are shipped in tape & reel.

Features

- Pressure ranges:
  - 125 and 250 Pa Differential
  - 250 up to 600 Pa Gage
- Pressure total error band after Autozero : ± 1% FS
- 24-bit I^2C digital output interface available
- Pressure calibrated and temperature compensated output
- Compensated temperature range: -20 to 85°C

Applications

- CPAP / Sleep Apnea
- Ventilators
- Gas Flow Instrumentation
- Air Flow Measurement
- HVAC / VAV

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1 PERFORMANCE SPECIFICATION

1.1 Part Number & Calibrated Pressure Ranges

Dual vertical port configuration :

Part number	Alias[1]	P_{MIN} (Pa)	P_{MAX} (Pa)
20032073-00	TPS-250PD-CA1N-00-T	-250	+250
20032001-00	TPS-150PD-CA1N-00-T	-150	+150
20032072-00	TPS-125PD-CA1N-00-T	-125	+125
20032074-00	TPS-250PG-CA1N-00-T	0	+250
20032075-00	TPS-300PG-CA1N-00-T	0	+300
20032002-00	TPS-500PG-CA1N-00-T	0	+500
20032022-00	TPS-500PG-CA2N-00-T	0	+500
20032076-00	TPS-600PG-CA1N-00-T	0	+600

Dual horizontal port configuration :

Part number	Alias[1]	P_{MIN} (Pa)	P_{MAX} (Pa)
20032213-00	TPS-250PD-BA1N-00-T	-250	+250
20032214-00	TPS-150PD-BA1N-00-T	-150	+150
20032215-00	TPS-125PD-BA1N-00-T	-125	+125
20032216-00	TPS-250PG-BA1N-00-T	0	+250
20032217-00	TPS-300PG-BA1N-00-T	0	+300
20032218-00	TPS-500PG-BA1N-00-T	0	+500
20032219-00	TPS-600PG-BA1N-00-T	0	+600

Note :

1. Alias description is given on last datasheet page.

1.2 Absolute Maximum Ratings

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

Characteristic	Symbol	Min	Max	Units
Compensated Temperature	T_{COMP}	-20	85	°C
Operating Temperature[a]	T_{OP}	-40	105	°C
Storage Temperature[a]	T_{STG}	-40	125	°C
Supply Voltage	V_{DD}	-0.3	6	V
Proof Pressure[c]	P_{Proof}	7		kPa
Burst Pressure[d]	P_{Burst}	20		kPa
Media Compatibility[a]		Clean, dry air compatible with wetted materials [b]		

Notes:

a) Tested on a sample basis.
b) Wetted materials include Silicon, glass, gold, aluminum, copper, silicone, epoxy, mold compound.
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.

1.3 ESD

Description	Condition	Symbol	Min	Max	Units
ESD HBM Protection at all Pins	AEC Q100-002 (HBM) chip level test	$V_{ESD(HBM)}$	-2	2	kV

1.4 External Components

Description	Symbol	Min	Typ	Max	Units
Supply bypass capacitor	C_{VDD}		100		nF

1.5 Operating Conditions

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage	VDD		3.0	5.0	5.5	V
Sleep supply Current	Islp_25oC	VDD = 5.0V, T = 25°C (no conversion, DAC off)		1.8	8	µA
Standby supply Current	Isty_25oC	VDD = 5.0V, T = 25°C (no conversion, DAC off, fast_start ="1")		156	200	µA
Supply current during analog output	Iaout	VDD = 5.0 V, T = 25°C, hvreg off, buffer on, ratiometric output		362		µA
Supply current during active conversion[1]	Iac_p Iac_Tr Iac_Tdsvdd	VDD = 5.0 V, T = 25°C, svdd = 1.8 V, fadc = 1 MHz excluding sensor current pressure resistive temperature diode temperature		2058 1857 1715		µA

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Conversion time for 1 conversion(P, T1 or T2) based on: fadc = 1 MHz fast start no CRC no reload with calculation with transfer add 10 us from sleep mode	Tconv	OSR = 0 OSR = 1 OSR = 2 OSR = 3 OSR = 4 OSR = 5 OSR = 6 OSR = 7 OSR = 8 OSR = 9	0.07 0.10 0.15 0.27 0.50 0.96 1.89 3.76 7.48 14.93	0.08 0.11 0.17 0.30 0.56 1.07 2.09 4.14 8.24 16.43	0.09 0.12 0.19 0.33 0.62 1.19 2.32 4.59 9.14 18.24	ms
Start up time	Tstart	Applying Power Supply to digital output ready		16.2		ms
Wake up time	Twaket	Wake up from sleep mode Wake up from standby		30 0		µs
Digital I/O leakage	Ileak	VDD = 5.0 V, T = 25°C	-1		1	µA

Note :
1. Analog output add 200µA

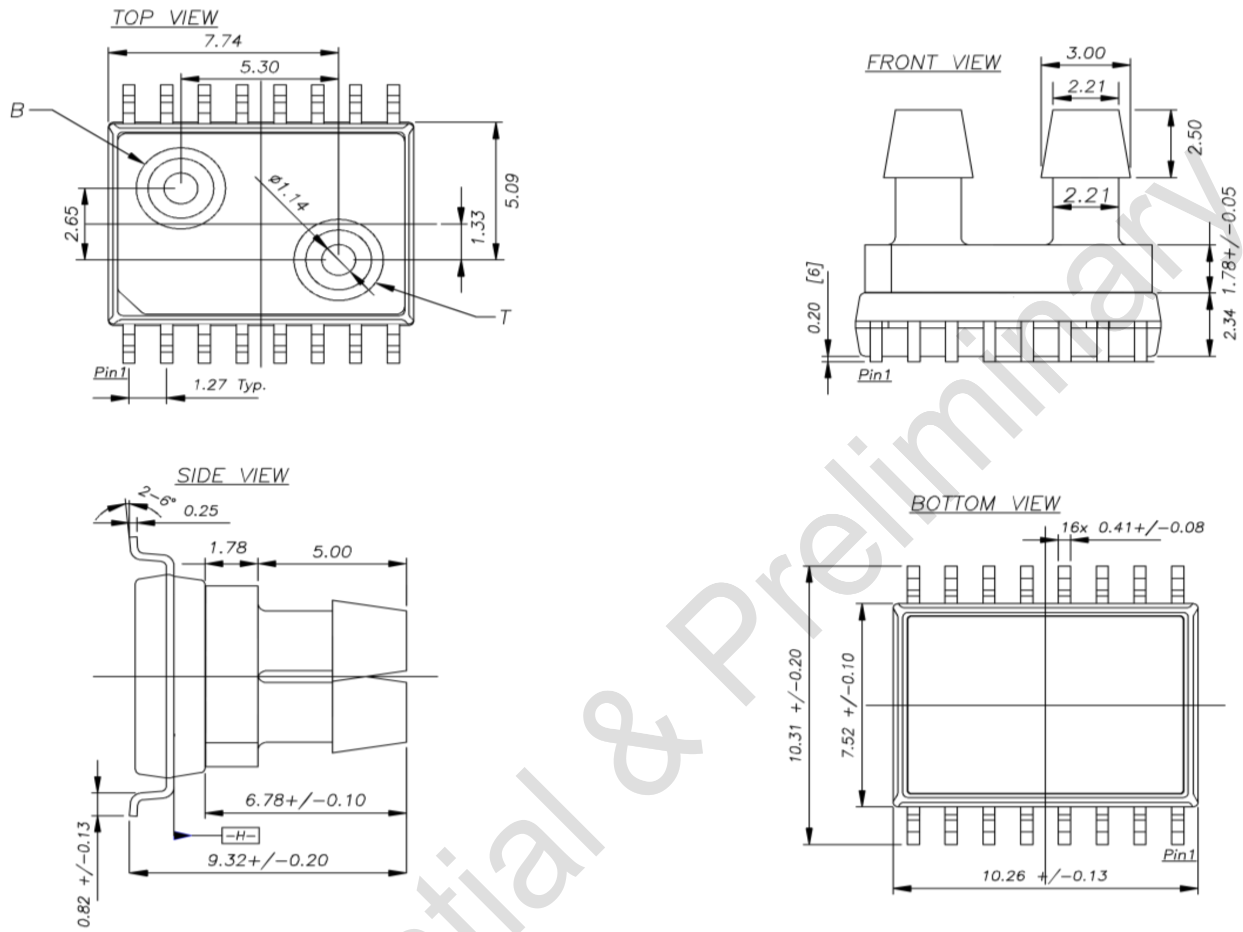
1.6 Operating Characteristics Table

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

Characteristic	Symbol	Min	Typ	Max	Units
Digital Pressure Output @ P_{MIN}	$DOUT_{MIN}$		1'677'721		Counts
Digital Pressure Output @ P_{MAX}	$DOUT_{MAX}$		15'099'485		Counts
Digital Full Scale Span	DFS		13'421'764		Counts
Resolution			24		Bits
Digital Output Total Error Band	DACC	-1		+1	%FS
Analog Pressure Output @ P_{MIN}	$AOUT_{MIN}$		10		%VDD
Analog Pressure Output @ P_{MAX}	$AOUT_{MAX}$		90		%VDD
Analog Full Scale Span	AFS		80		%VDD
Analog Output Total Error Band	AACC	-1		+1	%FS
Temperature accuracy	TACC		1		°C

2 PACKAGE DIMENSIONS

SOIC-16 Dual Vertical port (C) Package Dimensions

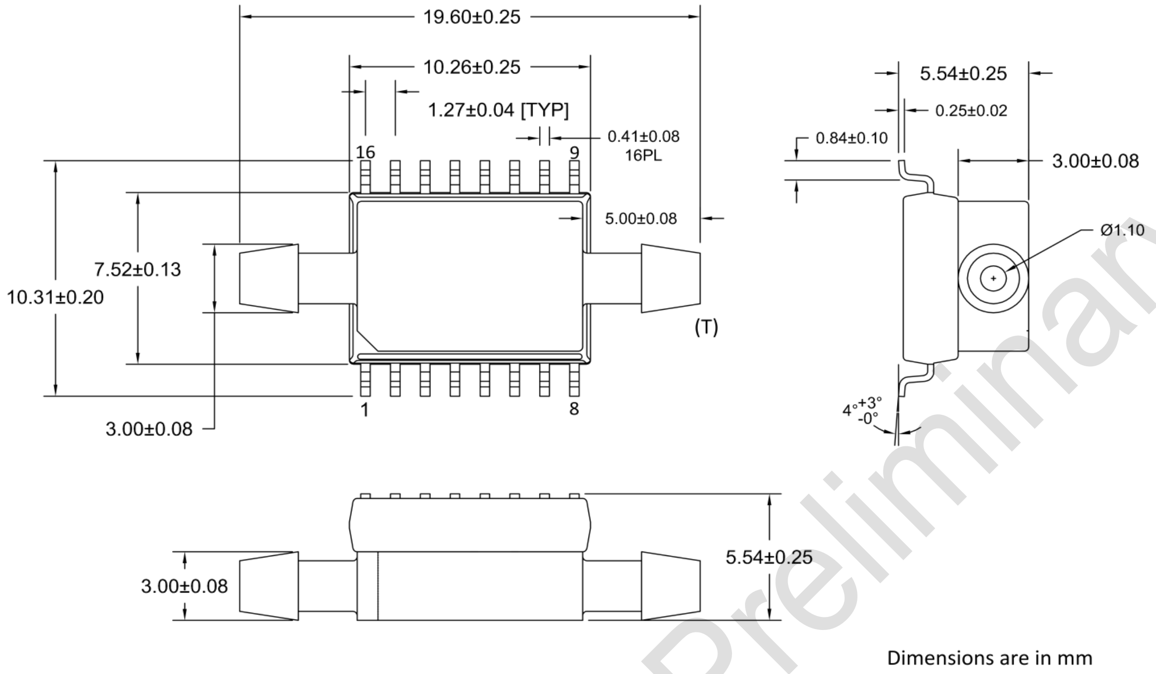


Lot number identification on top side

Notes:

- All dimensions in units of [mm]
- Moisture Sensitivity Level (MSL): Level 3
- Wetted materials: Silicon, glass, gold, aluminum, copper, silicone, 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.
- Bottom plate is anodized lid.
- Robust JEDEC SOIC-16 package for automated assembly
- Manufactured according to ISO9001, ISO14001 and ISO/TS 16949 standards

SOIC-16 Dual Horizontal port (B) Package Dimensions



Lot number identification on top side

Notes:

- All dimensions in units of [mm]
- Moisture Sensitivity Level (MSL): Level 3
- Wetted materials: Silicon, glass, gold, aluminum, copper, silicone, 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 a increase in sensor output.
- Bottom plate is stainless steel
- Robust JEDEC SOIC-16 package for automated assembly
- Electrically isolate the bottom metal cover, do not connect to the cover and keep the board underneath free from electrical circuits.
- Manufactured according to ISO9001, ISO14001 and ISO/TS 16949 standards

2.1 Pinout functions

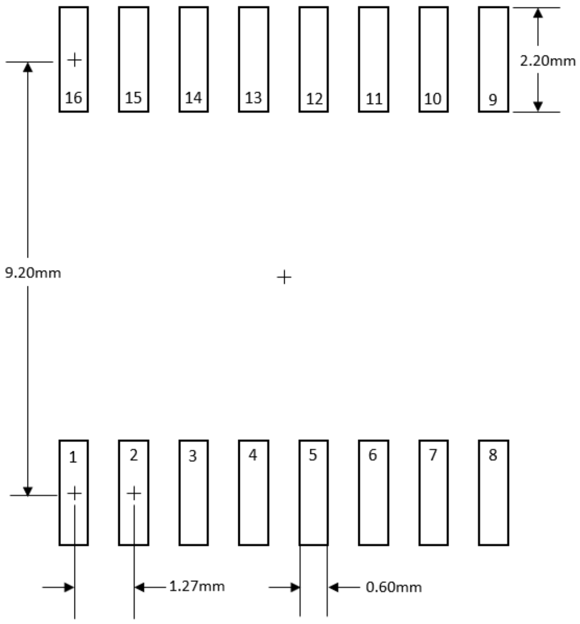
Dual port

	Dual port
Pin No	**Pin Function**
1	Aout
2	-
3	-
4	-
5	-
6	-
7	SDO
8	-
9	-
10	SDA
11	SCL
12	VSS
13	I.C. (VDD)
14	-
15	-
16	VDD

Notes:
- SDO : Refer to chapter **Error! Reference source not found.**.

2.2 PCB design guidelines

Below suggested PCB footprint is recommended to ensure high mount assembly yields.



Following PCB finishes are compatible with SO16 package :

- Hot Air Solder Leveled (HASL)
- Organic Solderability Protectant (OSP)
- Electroless Nickel Immersion Gold (ENIG)
- Immersion Sn and Immersion Ag.

3 REFLOW PROFILE

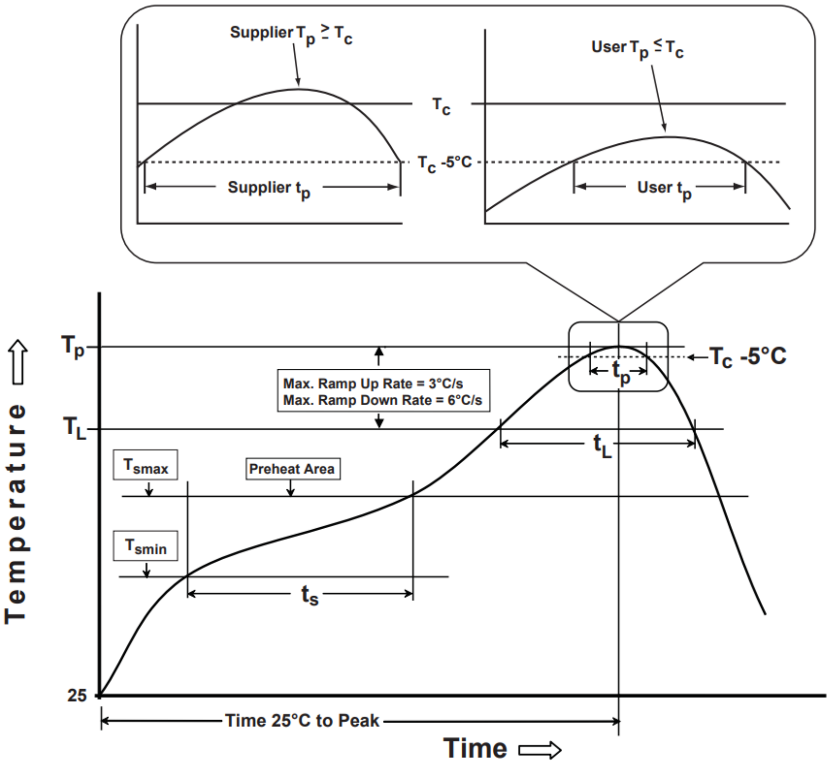
The actual profile parameters depend upon the solder paste used. The recommendations from paste manufacturers should be followed.

Below recommendations may be used as alternative solution.

Table 5-2 Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat/Soak Temperature Min (T_{smin}) Temperature Max (T_{smax}) Time (t_s) from (T_{smin} to T_{smax})	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-120 seconds
Ramp-up rate (T_L to T_p)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L) Time (t_L) maintained above T_L	183 °C 60-150 seconds	217 °C 60-150 seconds
Peak package body temperature (T_p)	For users T_p must not exceed the Classification temp in Table 4-1. For suppliers T_p must equal or exceed the Classification temp in Table 4-1.	For users T_p must not exceed the Classification temp in Table 4-2. For suppliers T_p must equal or exceed the Classification temp in Table 4-2.
Time (t_p)* within 5 °C of the specified classification temperature (T_c), see Figure 5-1.	20* seconds	30* seconds
Ramp-down rate (T_p to T_L)	6 °C/second max.	6 °C/second max.
Time 25 °C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile temperature (T_p) is defined as a supplier minimum and a user maximum.		

1.Classification reflow profile



2.Classification profile

4 FUNCTIONAL BLOCK

4.1 Memory mapping

The TPS Low Pressure sensor implements 2 major types of memory:

1. A few-time-programmable (FTP) non-volatile memory (NVM). The memory size is 2k-bit organized as 4 pages of 32 words.
2. Registers implemented as Flip-Flops. As used registers are 16-bit registers even some bits are not yet allocated.

NVM data are copied into register after power-up, reset/refresh commands and prior a conversion to allow faster data access during normal operations.

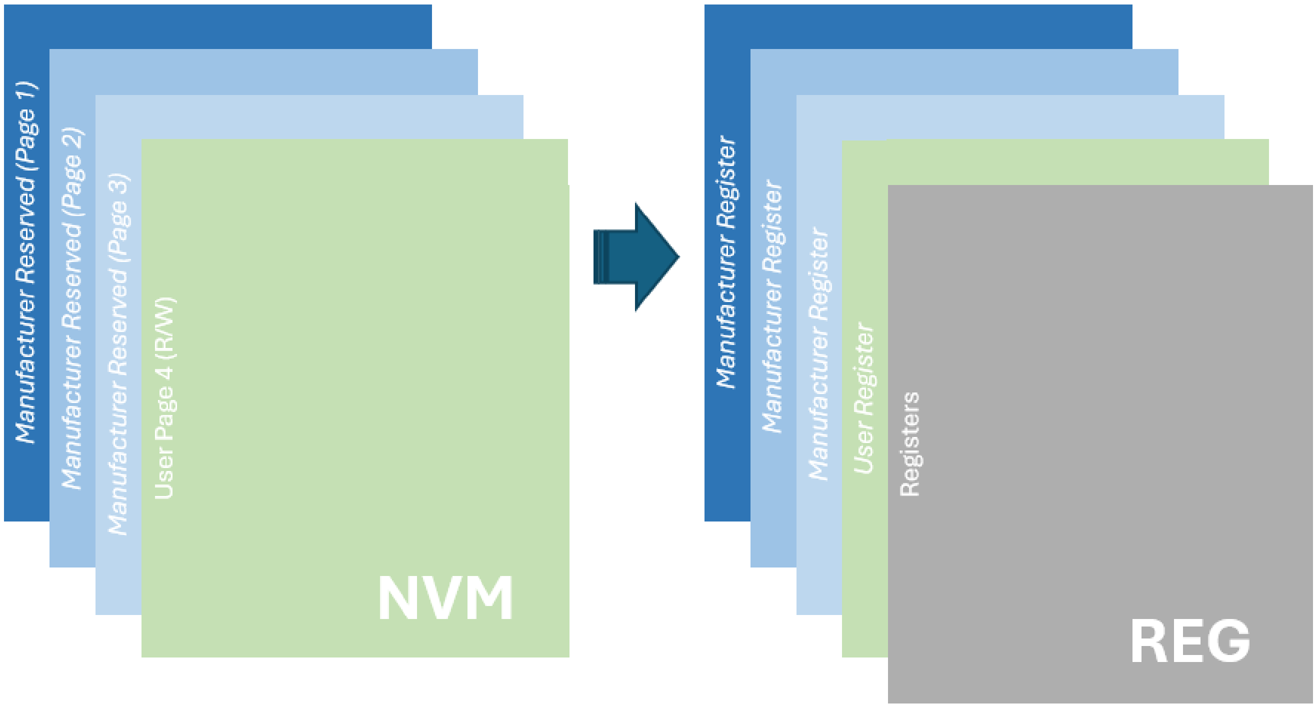


Figure 1: NVM / REG organization

4.1.1 Non-Valatile Memory Mapping (NVM)

The TPS Low Pressure uses a memory IP that is a few-time-programmable (FTP) nonvolatile memory (NVM). This NVM is used to keep configuration data while not powered.

The 2k-bit memory is divided into 4 pages of 32 words. Three pages are written protected, and the following assignment is used:

1. Page 1 => manufacturing settings
2. Page 2 => manufacturing settings
3. Page 3 => manufacturing settings
4. Page 4 => user accessible

NVM can be directly accessed via the interface commands *Erase/Write/Read NVM*.

4.1.2 Register

Registers memory (REG) includes:

1. a mirror of the NVM data (register address range from 0x00 to 0x7F)
2. additional functional registers

Typically, registers are physically instantiated as Flip-Flops. Access to registers is direct via the interface commands *Write/Read* register.

The following convention is used:

- RO : Read in normal mode. Write in Unlock mode
- RW : Read/Write in normal mode
- RW* : Read/Write special behavior
- R: Read only

During the initial 16ms timeframe following power-up and while safe mode is activated, the register retains the "default value during 16ms time window" as illustrated in the tables below.

During regular operation, registers hold the NVM content, which may consist of either the "default value after EWS" or newly programmed values.

The memory's integrity is verified directly on the register through a CRC check. This verification can be independently activated for each page using the "en_crc_px" flag. It occurs post-NVM to register mirroring and before each conversion process.

If a CRC error is detected, the "crc_reg" flag in the "int_0" register will toggle to "1". This error indication extends to the INT pin if both "general_int_en" and "en_crc_reg" are activated. However, this error does not halt the mirroring or conversion processes.

If "reload" is set to "1", one or two additional rounds of NVM to register mirroring will be executed, with the CRC recomputed. Those additional attempts are made before triggering the conversion process.

4.1.3 User Memory

NVM Page	NVM Addr dec	User	Word name	Register Addr Dec	Register Addr Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
4	0	RW	DIG	96	60	Reserved_0															reload
4	1	RW	PRES_4	97	61	Reserved_0				p_resol[1:0]		p_ratio[2:0]			p_filt[2:0]			p_osr[3:0]			
4	2	RW	TEMP1_4	98	62	Reserved_0				t1_resol[1:0]		t1_ratio[2:0]			t1_filt[2:0]			t1_osr[3:0]			
4	3	RW	TEMP2_4	99	63	Reserved_0				t2_resol[1:0]		t2_ratio[2:0]			t2_filt[2:0]			t2_osr[3:0]			
4	4	RW	OPER	100	64	interrupt_mode	fast_start	int_cont_mode	en_switch	sel_t	fifo_interrupt_threshold[4:0]					fifo_mode[1:0]		delay[3:0]			
4	5	RW	DAC_2	101	65	Reserved_0	dac_offset_com	Reserved_0	dac_clip_h[2:0]			dac_clip_l[2:0]			dac_t	drv_vdd_sel[1:0]		dac_buff_mode	dac_mode[2:0]		
4	6	RW	POST_GAIN_P	102	66	Reserved_0															
4	7	RW	POST_GAIN_T1	103	67	Reserved_0															
4	8	RW	POST_GAIN_T2	104	68	Reserved_0															
4	9	RW	Post_OFF_P	105	69	Reserved_0															
4	10	RW	Post_OFF_T1	106	6A	Reserved_0															
4	11	RW	Post_OFF_T2	107	6B	Reserved_0															
4	12	RW	COM	108	6C	Reserved_0							i2c_daisy_on	en_spike_filter	Reserved_0	I2C programmable address[6:1]					
4	13	RW	LIMIT_1	109	6D	Reserved_0															
4	14	RW	LIMIT_2	110	6E	Reserved_0															
4	15	RW	LIMIT_3	111	6F	Reserved_0															
4	16	RW	LIMIT_4	112	70	Reserved_0															
4	17	RW	LIMIT_5	113	71	Reserved_0															
4	18	RW	LIMIT_6	114	72	Reserved_0															
4	19	RW	INT_EN_0	115	73	Reserved_0	general_int_en	en_crc_com	en_crc_reg	Reserved_0	en_adc_error	en_calc_error	en_sensor_error	en_phigh	en_plow	en_thigh	en_tlow	en_ffull	en_fempty	en_fthr	en_adc_done
4	20	RW	INT_EN_1	116	74	Reserved_0				en_adc_udfl_t2	en_adc_udfl_t1	en_adc_udfl_p	en_adc_ovfl_t2	en_adc_ovfl_t1	en_adc_ovfl_p	en_calc_udfl_t2	en_calc_udfl_t1	en_calc_udfl_p	en_calc_ovfl_t2	en_calc_ovfl_t1	en_calc_ovfl_p
4	21	RW	INT_EN_2	117	75	en_sensor_chk[15:0]															
4	22	RW	RESERVED_1	118	76	space for customer data															
4	23	RW	RESERVED_2	119	77	space for customer data															
4	24	RW	RESERVED_3	120	78	space for customer data															
4	25	RW	RESERVED_4	121	79	space for customer data															
4	26	RW	RESERVED_5	122	7A	space for customer data															
4	27	RW	RESERVED_6	123	7B	space for customer data															
4	28	RW	RESERVED_7	124	7C	space for customer data															
4	29	RW	RESERVED_8	125	7D	space for customer data															
4	30	RW	EN_CRC_4	126	7E	Reserved_0															en_crc_p4
4	31	RW	CRC_4	127	7F	Reserved_0								crc_page_4							

Table 1: User memory

Page	Word	Name	Description	Default value during 16ms time window
4	DIG	reload	Enables the reload of the memory to the register if CRC fails before a conversion	0x0
4	PRES_4	p_resol[1:0]	Number of bit sent during ADC read command for pressure	0x0
4	PRES_4	p_ratio[2:0]	Enable chopper for pressure measurment	0x0
4	PRES_4	p_filt[2:0]	Pressure filtering in autonomous mode	0x0
4	PRES_4	p_osr[3:0]	Pressure oversampling	0x0
4	TEMP1_4	t1_resol[1:0]	Number of bit sent during ADC read command for T1	0x0
4	TEMP1_4	t1_ratio[2:0]	Enable chopper for temperature 1 measurment	0x0
4	TEMP1_4	t1_filt[2:0]	Temperature 1 filtering in autonomous mode	0x0
4	TEMP1_4	t1_osr[3:0]	Temperature 1 oversampling	0x0
4	TEMP2_4	t2_resol[1:0]	Number of bit sent during ADC read command for T2	0x0
4	TEMP2_4	t2_ratio[2:0]	Enable chopper for temperature 2 measurment	0x0
4	TEMP2_4	t2_filt[2:0]	Temperature 2 filtering in autonomous mode	0x0
4	TEMP2_4	t2_osr[3:0]	Temperature 2 oversampling	0x0
4	OPER	interrupt_mode	interrupt mode behavior, interrupt_mode = 0 collecting by OR function, interrupt_mode = 1 update mode	0x0
4	OPER	fast_start	Fast startup mode (keep biasing on & keep the oscillator powered). 0:Bias OFF; 1: Bias ON	0x0
4	OPER	int_cont_mode	Define the behavior of the interrupt pin while using thresholds detections. 0: Interrupt mode; 1: Continious mode	0x0
4	OPER	en_switch	Enable switch operation (switch with hysteresis). 0: Switch OFF; 1: Switch ON	0x0
4	OPER	sel_t	Selected output temperature (T1 or T2). 0: T1 selected; 1: T2 selected	0x0
4	OPER	fifo_interrupt_threshold[4:0]	Triggers the interrupt if n measurements are ready in the FIFO. 0: OFF; 1:threshold=1…31: Theshold=31	0x00
4	OPER	fifo_mode[1:0]	FIFO operation 0: off; 1: stop at FIFO full; 2,3: overwrite at FIFO full	0x0
4	OPER	delay[3:0]	Delay between measurements used for the autonomous mode. 0:OFF (digital mode); Programmable between 0 to 60s	0x0
4	DAC_2	dac_offset_comp_off	Offset compensation of the output buffer	0x0
4	DAC_2	dac_clip_h[2:0]	DAC upper voltage limit = 0.65 vdd + dac(2:0) x 0.05 vdd	0x0
4	DAC_2	dac_clip_l[2:0]	DAC lower voltage limit = dac(2:0) 0.05 x vdd	0x0
4	DAC_2	dac_t	Switching between temperature and pressure output to the DAC; 0 = pressure, 1 = temperature	0x0
4	DAC_2	drv_vdd_sel[1:0]	Program regulated vdd in case of high voltage supply	0x0
4	DAC_2	dac_buff_mode	Switch between analog buffer and current buffer. 0: dac buffer for analog modes, 1: dac buffer for current loop application	0x0
4	DAC_2	dac_mode[2:0]	Define the output behavior of the dac (ratiometric, 0-5V absolute, current loop)	0x0
4	COM	i2c_daisy_on	Enable i2c daisy chain mode	0x0
4	COM	en_spike_filter	Enable I2C internal 50ns spike filter	0x1
4	COM	I2C programmable address[6:1]	Optional I2C address bits 6:1; bit 0, the LSB, is determined by the CSB pin for Manifold configuration (CSB=0 -> LSB=1; CSB=1 -> LSB=0)	0x3A
4	INT_EN	general_int_en	If general_int_en is set to "0", all interrupt will be masked on INT pin or on I3C interface.	0x0
4	INT_EN	en_crc_com	Enable CRC check during communication	0x0
4	INT_EN	en_crc_reg	Enable CRC check on the memory	0x0
4	INT_EN	en_adc_error	Global enable of ADC errors.	0x0
4	INT_EN	en_calc_error	Global enable of calculation errors.	0x0
4	INT_EN	en_sensor_error	Global enable of sensor errors.	0x0
4	INT_EN	en_phigh	Enable detection of pressure higher than the higher threshold	0x0
4	INT_EN	en_plow	Enable detection of pressure lower than the lower threshold	0x0
4	INT_EN	en_thigh	Enable detection of temperature higher than the higher threshold	0x0
4	INT_EN	en_tlow	Enable detection of temperature lower than the lower Threshold	0x0
4	INT_EN	en_ffull	Enable detection of FIFO containing 32 unread values	0x0
4	INT_EN	en_fempty	Enable detection of FIFO when all values are read back	0x0
4	INT_EN	en_fthr	Enable detection of FIFO containing n unread values	0x0
4	INT_EN	en_adc_done	Enable detection of a finished conversion	0x0
4	INT_EN	en_adc_udfl_t2	Enable ADC underflow check for temperature 2	0x0
4	INT_EN	en_adc_udfl_t1	Enable ADC underflow check for temperature 1	0x0
4	INT_EN	en_adc_udfl_p	Enable ADC underflow check for pressure	0x0
4	INT_EN	en_adc_ovfl_t2	Enable ADC overflow check for temperature 2	0x0
4	INT_EN	en_adc_ovfl_t1	Enable ADC overflow check for temperature 1	0x0
4	INT_EN	en_adc_ovfl_p	Enable ADC overflow check for pressure	0x0
4	INT_EN	en_calc_udfl_t2	Enable calculation underflow check for temperature 2	0x0
4	INT_EN	en_calc_udfl_t1	Enable calculation underflow check for temperature 1	0x0
4	INT_EN	en_calc_udfl_p	Enable calculation underflow check for pressure	0x0
4	INT_EN	en_calc_ovfl_t2	Enable calculation overflow check for temperature 2	0x0
4	INT_EN	en_calc_ovfl_t1	Enable calculation overflow check for temperature 1	0x0
4	INT_EN	en_calc_ovfl_p	Enable calculation overflow check for pressure	0x0
4	INT_EN	en_sensor_chk[15:0]	Enable sensor check mask	0x0000
4	CUST	space for customer data	Customer memory space	0x0000
4	CRC	en_crc_p4	Enable CRC on page 4	0x0
4	CRC	crc_page_4	CRC of memory page 4	0x67

Table 2: User memory content and default values

4.1.4 Operating Register (ALL BIT SET IN NVM BY USER)

Operating register can be accessed through the Read/Write REG commands, as well as with Read/Write-Operating commands. In the NVM via the Read/Write NVM commands.

The operating register does set various operating modes like the FIFO and the delay between the automatic measurements. As soon as the delay register is set (not off), the automatic measurement starts according to the setup in the configuration register. The delay means the delay between one measurement finished and the next measurement starting.

Page	User	Word name	Addr		Data [15:0]															
			Dec	Hex	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	RW	OPER	100	64	interrupt_mode	fast_start	int_cont_mode	en_switch	sel_t	fifo_interrupt_threshold[4:0]					fifo_mode[1:0]		delay[3:0]			

Table 3: OPER register

Page	Word	Name	Description	Default value during 16ms time window
4	OPER	interrupt_mode	interrupt mode behavior, interrupt_mode = 0 collecting by OR function, interrupt_mode = 1 update mode	0x0
4	OPER	fast_start	Fast startup mode (keep biasing on & keep the oscillator powered). 0:Bias OFF; 1: Bias ON	0x0
4	OPER	int_cont_mode	Define the behavior of the interrupt pin while using thresholds detections. 0: Interrupt mode; 1: Continious mode	0x0
4	OPER	en_switch	Enable switch operation (switch with hysteresis). 0: Switch OFF; 1: Switch ON	0x0
4	OPER	sel_t	Selected output temperature (T1 or T2). 0: T1 selected; 1: T2 selected	0x0
4	OPER	fifo_interrupt_threshold[4:0]	Triggers the interrupt if n measurements are ready in the FIFO. 0: OFF; 1:threshold=1…31: Theshold=31	0x00
4	OPER	fifo_mode[1:0]	FIFO operation 0: off; 1: stop at FIFO full; 2,3: overwrite at FIFO full	0x0
4	OPER	delay[3:0]	Delay between measurements used for the autonomous mode. 0:OFF (digital mode); Programmable between 0 to 60s	0x0

Table 4: Operating register definition

"sel_t" is needed to select which temperature we output on the communication interface and which temperature will be used to populate the FIFO. The main reason is to reduce the size of the FIFO. Even if temperature 2 is selected to populate the FIFO, T1 is always used to compensate the pressure.

delay[3:0]				**Delay**
bit[3]	bit[2]	bit[1]	bit[0]	
0	0	0	0	off
0	0	0	1	0 ms
0	0	1	0	1 ms
0	0	1	1	5 ms
0	1	0	0	10 ms
0	1	0	1	20 ms
0	1	1	0	50 ms
0	1	1	1	0.1 sec
1	0	0	0	0.2 sec
1	0	0	1	0.5 sec
1	0	1	0	1 sec
1	0	1	1	2 sec
1	1	0	0	5 sec
1	1	0	1	10 sec
1	1	1	0	20 sec
1	1	1	1	60 sec

Table 5: Delay

As soon as the FIFO mode is 'ON' the FIFO starts the operation according to the mode set. To reset the FIFO, it has to be switched off.

The FIFO interrupt threshold can be chosen between 1.31 and initiates an interrupt as soon as the threshold number of samples is reached. If the threshold is off the interrupt is not activated.

4.1.5 Configuration Register

In the NVM, there are 3 distinct registers respectively for Pressure, Temperature 1 and Temperature 2. These registers can be accessed with Read/Write REG commands, as well as Read/Write Config commands. Value in the NVM is accessed through Read/Write NVM commands.

NVM		User	Word name	Register Addr		Data [15:0]															
Page	Addr																				
	dec			Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
4	1	RW	PRES_4	97	61	Reserved_0				p_resol[1:0]		p_ratio[2:0]			p_filt[2:0]			p_osr[3:0]			
4	2	RW	TEMP1_4	98	62	Reserved_0				t1_resol[1:0]		t1_ratio[2:0]			t1_filt[2:0]			t1_osr[3:0]			
4	3	RW	TEMP2_4	99	63	Reserved_0				t2_resol[1:0]		t2_ratio[2:0]			t2_filt[2:0]			t2_osr[3:0]			

Table 6: Configuration register

Page	Word	Name	Description	Default value during 16ms time window
4	PRES_4	p_resol[1:0]	Number of bit sent during ADC read command for pressure	0x0
4	PRES_4	p_ratio[2:0]	Enable chopper for pressure measurment	0x0
4	PRES_4	p_filt[2:0]	Pressure filtering in autonomous mode	0x0
4	PRES_4	p_osr[3:0]	Pressure oversampling	0x0
4	TEMP1_4	t1_resol[1:0]	Number of bit sent during ADC read command for T1	0x0
4	TEMP1_4	t1_ratio[2:0]	Enable chopper for temperature 1 measurment	0x0
4	TEMP1_4	t1_filt[2:0]	Temperature 1 filtering in autonomous mode	0x0
4	TEMP1_4	t1_osr[3:0]	Temperature 1 oversampling	0x0
4	TEMP2_4	t2_resol[1:0]	Number of bit sent during ADC read command for T2	0x0
4	TEMP2_4	t2_ratio[2:0]	Enable chopper for temperature 2 measurment	0x0
4	TEMP2_4	t2_filt[2:0]	Temperature 2 filtering in autonomous mode	0x0
4	TEMP2_4	t2_osr[3:0]	Temperature 2 oversampling	0x0

Table 7: Configuration register definition

The **ratio** is used to select different conversion ratios of temperature and pressure. The delay for automatic conversion is set in the operating register.

ratio[2:0]			**Ratio P/T1/T2**
bit[2]	bit[1]	bit[0]	
0	0	0	1
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	64

Table 8 ratio between pressure and temperatures in automatic mode.

In case of FIFO update or FIFO full mode, the latest temperature is always copied to always have a pair of measurements in the FIFO.

In the phase where the timer triggers an event, but no conversion is scheduled due to all ratios ≥2.

One full measurement cycle corresponds to the acquisition of T2, T1 and P.

A ratio of “1” indicates that you perform 1 measurement over 1 cycle. A ratio of “2”, indicates that you perform 1 measurement over 2 cycles.

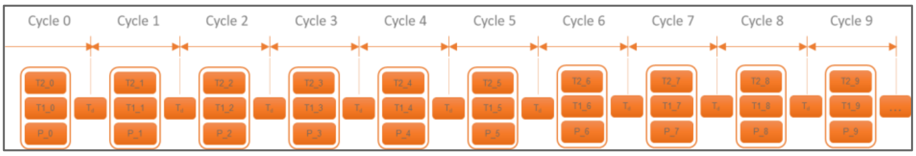


Figure 2 Measurement cycles

Figure 2 shows the full measurement cycles (ADC acquisitions) when p_ratio=1, t1_ratio=1 & t2_ratio=1. The time between two measurement cycles (T_d) is defined by delay[3:0].

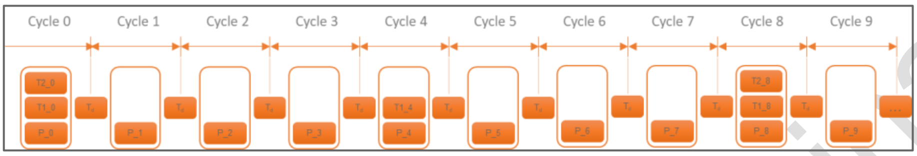


Figure 3 Measurement cycles

Figure 3 shows the full measurement cycles (ADC acquisitions) when p_ratio=1, t1_ratio=4 & t2_ratio=8.

The **filter** calculates an IIR average with the programmable coefficient k :

$$adc_{mean(n)} = adc_{mean(n-1)} - \frac{adc_{mean(n-1)}}{k} + \frac{adc}{k}$$

Which yields in a transfer function of:

$$H(z) = \frac{1}{k} * \frac{1}{1 - z^{-1} * \frac{k-1}{k}}$$

The delay between the samples is defined by the update rate.

If the filter is switched on, the already available ADC value is used as the start value adc_mean. This can be either the previous adc_mean before the filter was turned off, or the value of the last ADC conversion done.

To restart the filter, switch it off, do a new conversion and switch it on again.

The settling time for a big jump to reach 90% of the final value is 2.2 x k samples.

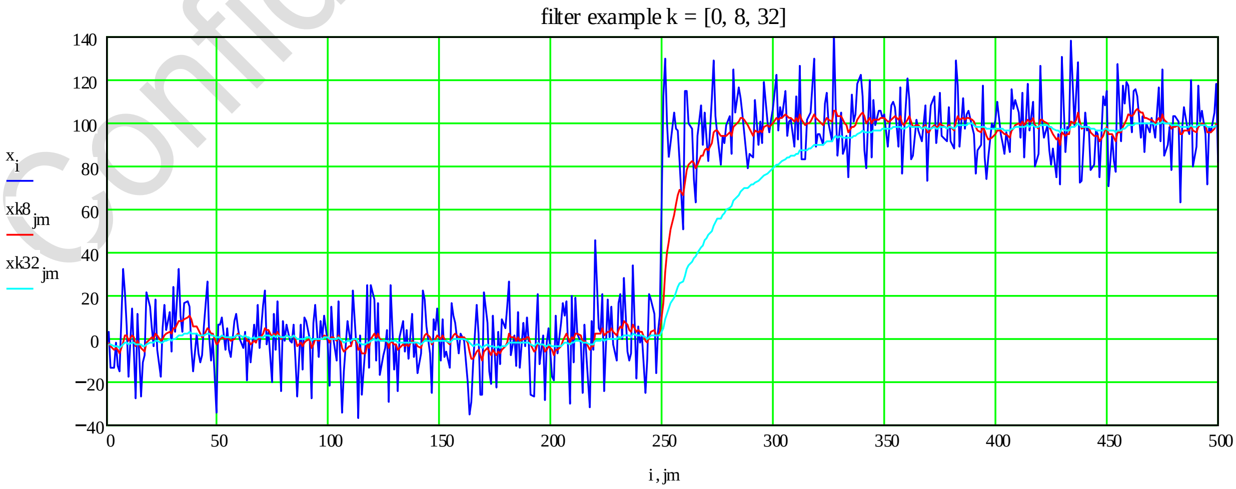


Figure 4: Filter behavior of a noise signal jumping from 0 to 100 using k=0.8 and 32

The table here below shows the reduction factor on the rms noise:

filt[2:0]			IIR Filter	noise_reduction factor
bit[2]	bit[1]	bit[0]		
0	0	0	off	1.00 +/- 0.00
0	0	1	2	1.73 +/- 0.07
0	1	0	4	2.65 +/- 0.21
0	1	1	8	3.87 +/- 0.50
1	0	0	16	5.54 +/- 1.00
1	0	1	32	8.20 +/- 1.20
1	1	0	64	11.95 +/- 2.00
1	1	1	128	15.82 +/- 2.70

Table 9 IIR filter.

Resol[1:0] defines how many bits are sent to the controller when a Read ADC command is sent. This means if p_resol is 24-bit and t1_resol is 16-bit, Read ADC T1 P would read first 16 bits of temperature followed by 24 bits of pressure. A Read ADC P with the same setup would read 24 bits of pressure.

resol[1:0]		Data length on I/F
bit[1]	bit[0]	
0	0	24 bit
0	1	16 bit
1	0	8 bit
1	1	8 bit

Table 10 resol: data length for communication.

The **OSR** defines the speed and noise of the ADC.

OSR[3:0]				Over sampling
bit[3]	bit[2]	bit[1]	bit[0]	
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	9
1	0	1	1	9
1	1	0	0	9
1	1	0	1	9
1	1	1	0	9
1	1	1	1	9

Table 11: Over sampling ration (accuracy of the conversion)

During a conversion running or in the automatic mode, the ‘write config’ command is not accepted.

4.1.6 COM Register

The COM register, only contain the parameters for communication. The register is accessible with Read/Write REG commands. Value in the NVM is accessed through Read/Write REG commands.

NVM		User	Word name	Register		Data [15:0]															
Page	Addr			Addr																	
	dec			Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
4	12	RW	COM	108	6C	Reserved_0							i2c_daisy_on	en_spike_filter	Reserved_0	I2C programmable address[6:1]					

Table 12: COM register

Page	Word	Name	Description	Default value during 16ms time window
4	COM	i2c_daisy_on	Enable i2c daisy chain mode	0x0
4	COM	en_spike_filter	Enable I2C internal 50ns spike filter	0x1
4	COM	I2C programmable address[6:1]	Optional I2C address bits 6:1; bit 0, the LSB, is determined by the CSB pin for Manifold configuration (CSB=0 -> LSB=1; CSB=1 -> LSB=0)	0x3A

Table 13: COM register definition

4.2 Calculation

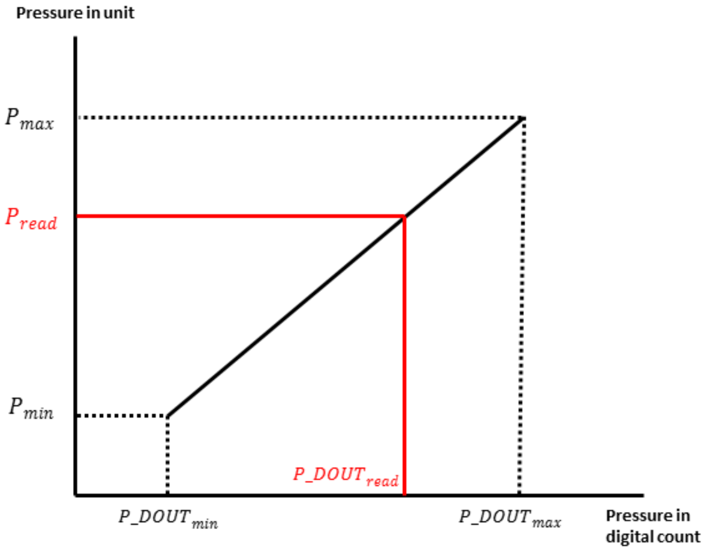
4.2.1 Pressure Calculation:

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

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}.



4.2.2 Temperature Calculation:

$$T_{read} = -20°C + \frac{T1\_DOUT_{read} - T\_DOUT_{min}}{T\_DOUT_{max} - T\_DOUT_{min}}(105)$$

5 APPLICATION CIRCUIT

5.1 Dual-port I2C

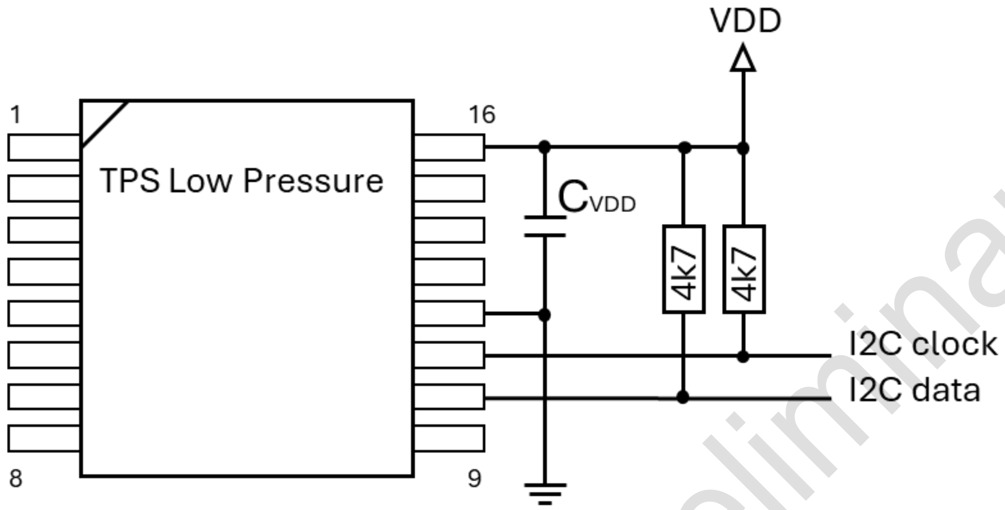


Figure 5: Application circuit Dual-port I2C

6 SERIAL DIGITAL INTERFACE

TPS Low Pressure sensor has built the serial interface I2C.

There are commands, which trigger an internal action which may take more time than the command itself. This is mainly the case at PON, Reset, Refresh Register or if a Conversion is started. To keep a predictable behavior of the chip during a running conversion or in the automatic mode the configuration cannot be changed (Write Config is not accepted by the digital part). A new conversion cannot be started during a conversion running (Conversion command is not accepted by the digital part during this time).

The internal behavior can any time be monitored on SDO. The serial data output (SDO) is used to monitor the status of TPS Low Pressure Sensor digital core and to send the results requested by a command. The SDO can indicate various situations, depending on the state of the TPS Low Pressure Sensor digital core. Here are possible conditions and corresponding states of SDO:

- SDO = “1” – when device is reset and is ready.
- SDO = “0” – whenever a valid command is detected, SDO goes low for one clock cycle.
- SDO = “0” – when device is busy, erase/write NVM, conversion, reset, refresh, POR.
- SDO during power-on-reset: Refer to dedicated chapter on Power on (PON).
- SDO has a different behavior in daisy chain mode application
- SDO output indicates only busy state and command recognition.

6.1 Command Structure

Size of each command is 1 byte (8 bits) as described in Table 14 below.
ADC read command will return 24 bits result of the above requested finished conversion (P, T1, T2).
All commands are the same and are explained in the next table.

User Commands										
Commands	bit [7]	bit [6]	bit [5]	bit [4]	bit [3]	bit [2]	bit [1]	bit [0]	Data MOSI	Data MISO
Read Sensor ID	0	0	0	0	1	0	0	CRC	no data	+ 8 data bytes
Reset	0	0	0	1	0	0	0	CRC	no data	no data
Refresh	0	0	0	1	0	0	1	CRC	no data	no data
Write Operating Mode	0	0	0	1	0	1	0	CRC	+2 data bytes	no data
Read Operating Mode	0	0	0	1	0	1	1	CRC	no data	+2 data bytes
Start automatic mode	0	0	0	1	1	0	0	CRC	no data	no data
Stop automatic mode	0	0	0	1	1	0	1	CRC	no data	no data
Write Config	0	0	1	0	0	A1	A0	CRC	+2 data bytes	no data
Read Config	0	0	1	0	1	A1	A0	CRC	no data	+2 data bytes
Conversion **	0	1	0	0	1	1	1	CRC	no data	no data
Read ADC **	0	1	0	1	T2	T1	P	CRC	no data	Depends config
Write Interrupt Mask	0	1	1	0	0	A1	A0	CRC	+2 data bytes	no data
Read Interrupt Mask	0	1	1	0	1	A1	A0	CRC	no data	+2 data bytes
Write Interrupt Reg	0	1	1	1	0	A1	A0	CRC	+2 data bytes	no data
Read Interrupt Reg	0	1	1	1	1	A1	A0	CRC	no data	+2 data bytes
Write NVM	1	0	0	0	0	1	1	CRC	+1 addr byte + 2 data bytes	no data
Erase NVM	1	0	0	1	0	1	1	CRC	+1 addr byte	no data
Read NVM	1	0	1	0	0	1	1	CRC	+1 addr byte	+2 data bytes
Write Limits	1	1	0	0	A2	A1	A0	CRC	+2 data bytes	no data
Read Limits	1	1	0	1	A2	A1	A0	CRC	no data	+2 data bytes
Write REG***	1	1	1	0	0	0	0	CRC	+1 addr byte + 2 data bytes	no data
Read REG	1	1	1	0	0	0	1	CRC	+1 addr byte	+2 data bytes

Table 14: User commands

** Read ADC with all T2, T1 and P = 0 are invalid commands and will not be accepted by the controller. The command will not be acknowledged in the I2C mode

*** only page 4 can be accessed by the user.

6.2 I2C Interface

TPS Low Pressure sensor acts as an ordinary I2C Slave Device without Master capability. Supports both SDR Mode and HDR Mode.

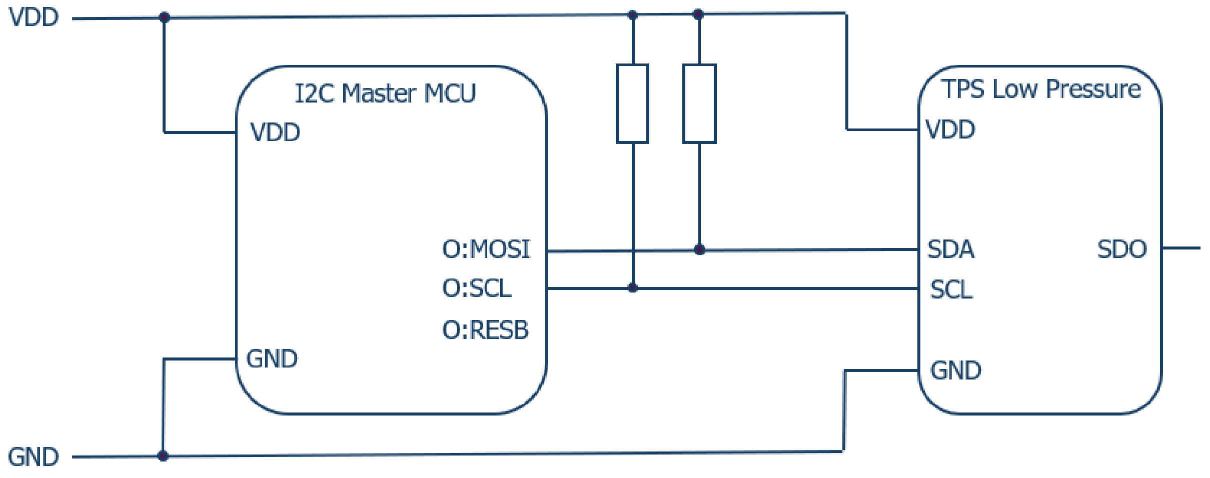


Figure 6: TPS Low Pressure sensor I2C application circuit

TPS Low Pressure sensor has a hard coded I2C address following the **Error! Reference source not found.**.

The $\bar{c}$ in the address is defined with the complement of the value at the input of CSB pin. If CSB=1 then the address will be 1110'100x, while if the CSB=0 then the address will be 1110'101x.

Dual-Port	Base2	Base10	Base16
Standard I2C address	1110'100x	116	x74
Alternative I2C address	0100'010x	34	x22

Table 155: Dual-Port I2C address

In I2C mode, I2C command write(R/W=0) with a valid address will always be acknowledged (ACK). However, invalid command won't be accepted, as described in Table 14. The command acceptance result will be reflected on SDO output.

6.3 Detailled Commands

6.3.1 Reset

Using a reset command during an ongoing NVM erase or write operation is not allowed!

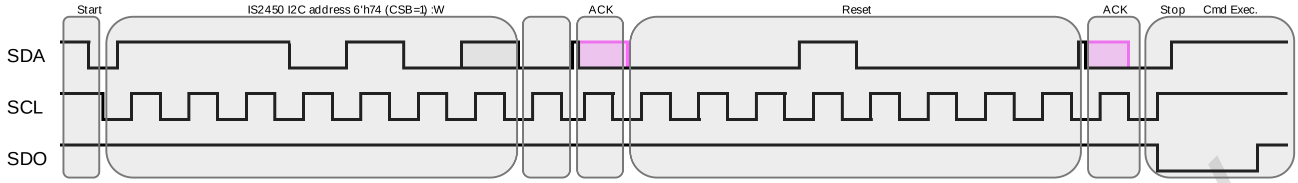


Figure 7: I2C Reset command

6.3.2 Write Config

Write config allows to configure raw/comp data, read resolution, ratio, filter and OSR of each measurement type separately.

This command is not accepted during an ongoing conversion.

Command		Register				
Wr config		Page	User	Word name	addr	
A1	A0				dec	hex
0	0	4	RW	PRES_4	97	61
0	1	4	RW	TEMP1_4	98	62
1	0	4	RW	TEMP2_4	99	63
1	1	-	-	-	-	-

Table 16: Write config command address vs register address

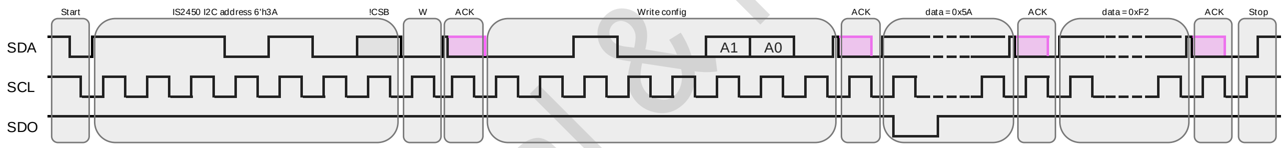


Figure 8: I2C write configuration register command

6.3.3 Read Config

Read config allows to verify the written configuration.

Command		Register				
Rd config		Page	User	Word name	addr	
A1	A0				dec	hex
0	0	4	RW	PRES_4	97	61
0	1	4	RW	TEMP1_4	98	62
1	0	4	RW	TEMP2_4	99	63
1	1	-	-	-	-	-

Table 17: read config command address vs register address

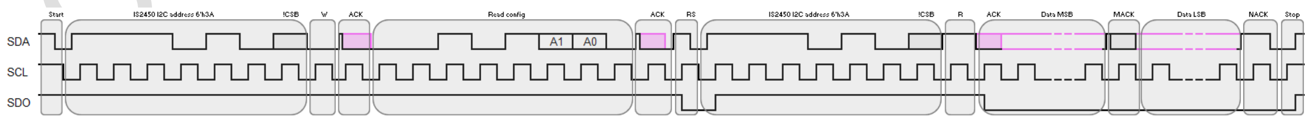


Figure 9: I2C read configuration register command

6.3.4 Write REG

This command allow writing into the register map.

The address range for this command is from 96 to 127.

Burst mode is implemented for this command.

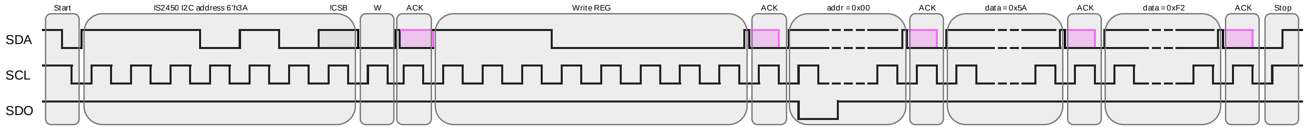


Figure 10: I2C write REG command

In case CRC and burst mode is used, the CRC is sent after every 2 data bytes.

6.3.5 Read REG

This command allows reading the register map.

The address range for this command is from 96 to 127.

Burst mode is implemented for this command.

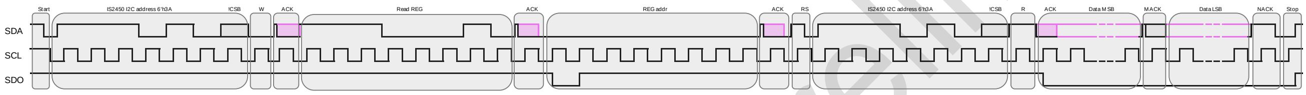


Figure 11: I2C read REG command

With CRC, the data packet will be sent in the following order and still operates in a burst mode.

- Read-out data MSB, Read-out data LSB, CRC, Read-out data MSB, Read-out data LSB, CRC …

6.3.6 Conversion

An ADC conversion is started using a conversion command. After the command is recognized by the chip SDO goes low. SDO goes high again when conversion is completed. The conversions time is depending on the OSR.

The result of the conversion is transferred to the data register after the conversion. It is possible to trigger on the rising edge of SDO to get the time when the operation is finished. This command is not accepted during an ongoing conversion.

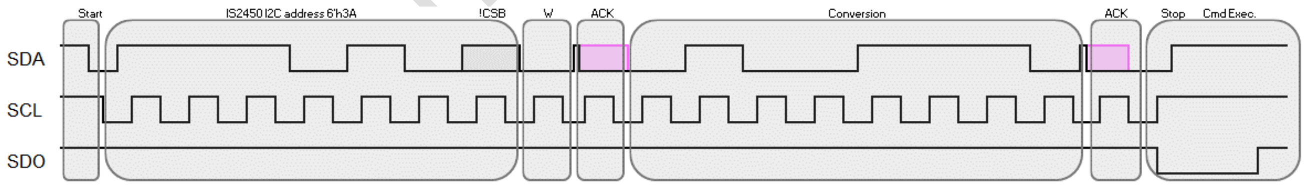


Figure 12: I2C conversion command

6.3.7 Read ADC

The ADC read command retrieves the result of a conversion command, and its behavior is influenced by several configuration bits:

1. The settings of the T2, T1, and P flags within the command itself.
2. The data read length can be configured in the operating register using t2_resol, t1_resol, and p_resol.

After power up and in FIFO "off" mode, attempting to read the ADC without any prior conversion will yield all zeros. However, after a conversion is completed, the last conversion result will be read.

When FIFO is empty, reading will yield all zeros regardless of whether FIFO update mode or FIFO full mode is activated,

The temperature conversions will be executed first, followed by the pressure conversion. As soon as the three conversions are done, the computation engine is triggered. All data are then available and can be read out by a read ADC command.

Reading data while the commanded conversion session is still ongoing will return previous values for all requested data. This precaution is taken to prevent the possibility of returning corrupt data resulting from concurrent write and read operations. The host should only read data after the conversion process has fully completed.

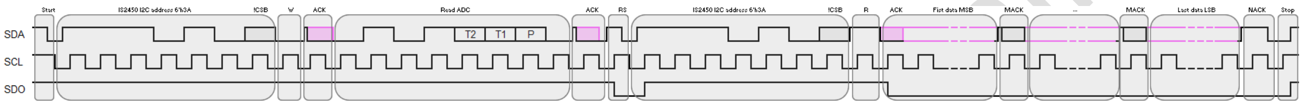


Figure 13: I2C read ADC

. Alias description

Alias Description

TPS-xxxPx-xAxN-00-T

Product family

TPS	TE Pressure Sensor

Maximum pressure

125	125
150	150
250	250
300	300
500	500
600	600

Pressure unit

P	Pascal

Pressure Type

D	Symmetric Differential[1]
G	Gage[2]

Package Type and Porting

C	SOIC-16 w/ dual vertical porting
B	SOIC-16 w/ dual horizontal porting

Supply voltage

A	3-5V

Output

1	Standard I^2C address
2	Alternative I^2C address

Special protection

N	None

Counter for custom options

00	Standard

Shipment

T	Tape & Reel

Notes :

1. Minimum pressure is negative value of maximum pressure
2. Minimum pressure is 0 mbar.

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