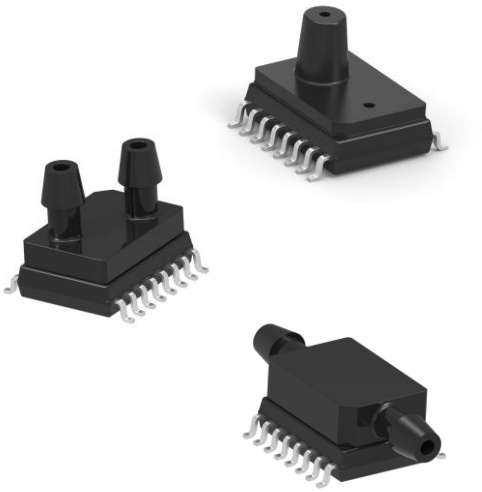


TPS LOW PRESSURE DIGITAL / ANALOG SENSOR

Gage & Differential Pressure Sensors

The TPS (TE Connectivity Pressure Sensors) are low pressure MEMS sensors offering state-of-the-art pressure transducer technology and CMOS mixed signal processing technology to produce either an analog and/or digital output fully conditioned, multi-order pressure and temperature compensated. This series provides JEDEC standard SOIC-16 package with dual vertical, dual horizontal or Manifold porting options. It is available in gage, differential and 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.

The TPS products are shipped in tape & reel.

Features

- Pressure ranges:
  from 25mbar to 100mbar
- Pressure type:
  - ✓ gage
  - ✓ differential
  - ✓ asymmetric differential
- 24 bits ADC
- I^2C/ I^3C digital and analog output interface available
- Pressure total error band : ± 1% FS (digital & analog)
- 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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CONNECT WITH A SPECIALIST

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1 PERFORMANCE SPECIFICATION

1.1 Available Part Number & Calibrated Pressure Ranges

Dual vertical port configuration :

Part number	Part Description[1]	P_{MIN} (mbar)	P_{MAX} (mbar)
20030258-00	TPS-070MG-CA1N-00-T	0	70
20032025-00	TPS-070MG-CA2N-00-T	0	70
20032023-00	TPS-025MG-CA1N-00-T	0	25

Dual horizontal port configuration :

Part number	Part Description[1]	P_{MIN} (mbar)	P_{MAX} (mbar)
20032512-00	TPS-040MD-BABN-00-T	-40	40

Note :

1. Part description is given on last datasheet page.

For specific part request, please contact TE representative for support.

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1.2 Absolute Maximum Ratings

All parameters are specified at VDD = 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
Media Compatibility[a]		Clean, dry air compatible with wetted materials [b]		

Burst pressure and proof pressure by pressure range

Part number	Proof Pressure[a, c] P_{Proof} (mbar)	Burst Pressure[a, d] P_{Burst} (mbar)
Up to P_{max} = 40mbar	310	415
Up to P_{max} = 100mbar	830	1035

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	JEDEC JESD47	$V_{ESD(HBM)}$	-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

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Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Conversion time for 1 conversion (P or T1) based on: fadc = 1 MHz fast start no CRC with calculation with transfer add 10 us from sleep mode	Tconv	OSR = 1 OSR = 2 OSR = 3 OSR = 4 OSR = 5 OSR = 6 OSR = 7 OSR = 8 OSR = 9	0.10 0.15 0.27 0.50 0.96 1.89 3.76 7.48 14.93	0.11 0.17 0.30 0.56 1.07 2.09 4.14 8.24 16.43	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
2. Default osr is 4

1.6 Operating Characteristics Table

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

Characteristic	Symbol	Min	Typ	Max	Units
Digital Pressure Output $^{@}P_{MIN}$	$DOUT_{MIN}$		10		%Full Scale
Digital Pressure Output $^{@}P_{MAX}$	$DOUT_{MAX}$		90		%Full Scale
Digital Full-Scale Span	DFS		80		%Full Scale
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	%Full Scale
Temperature accuracy	TACC		2		°C

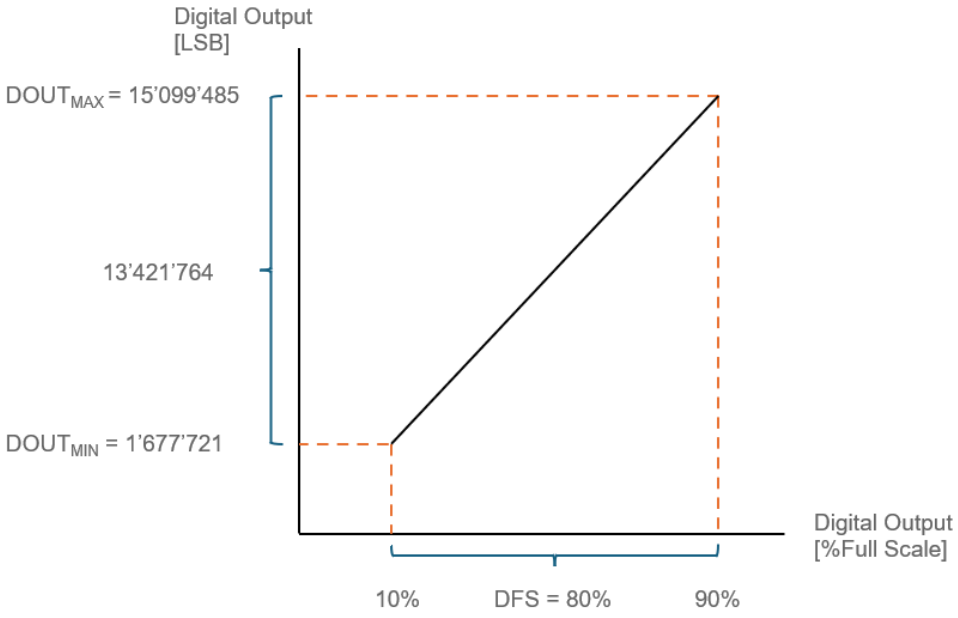


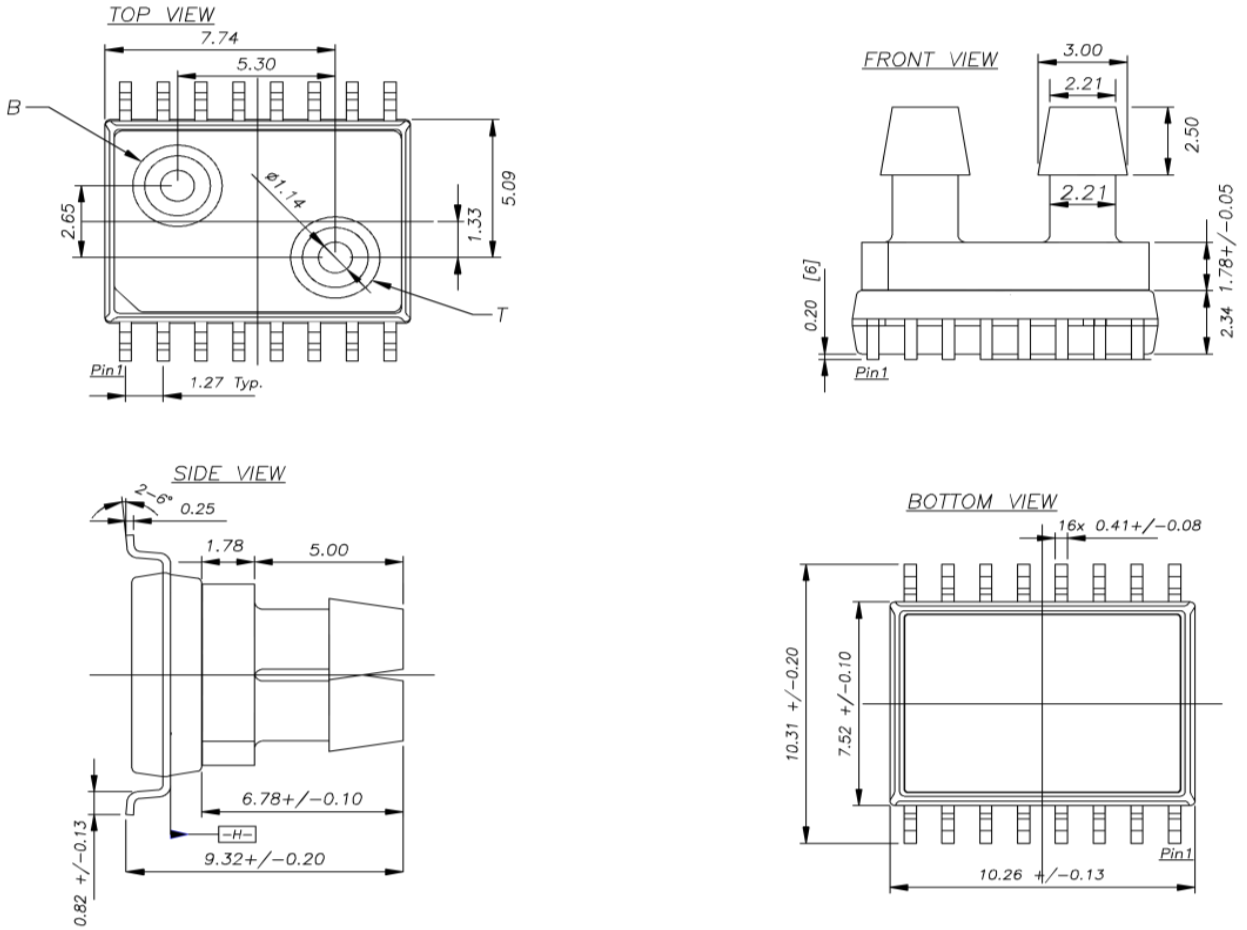
Figure 1: Digital Output / %FS Output

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2 PACKAGE DIMENSIONS

SOIC-16 Dual Vertical port (C) Package Dimensions



Lot number identification on top side

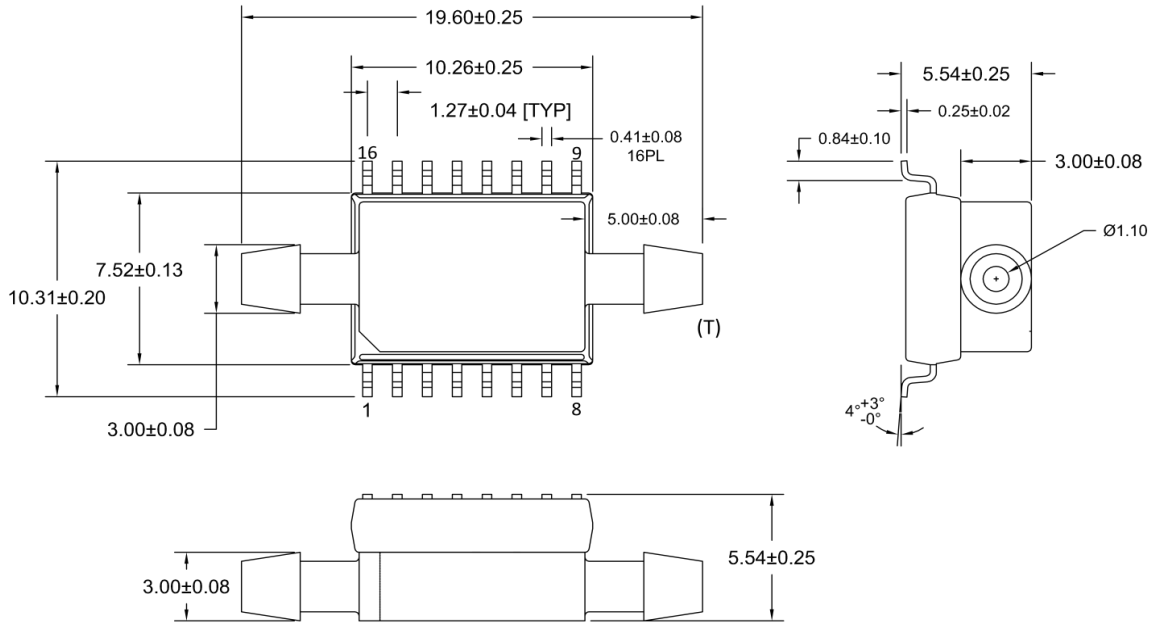
Notes:

- 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

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SOIC-16 Dual Horizontal port (B) Package Dimensions



Dimensions are in mm

Lot number identification on top side

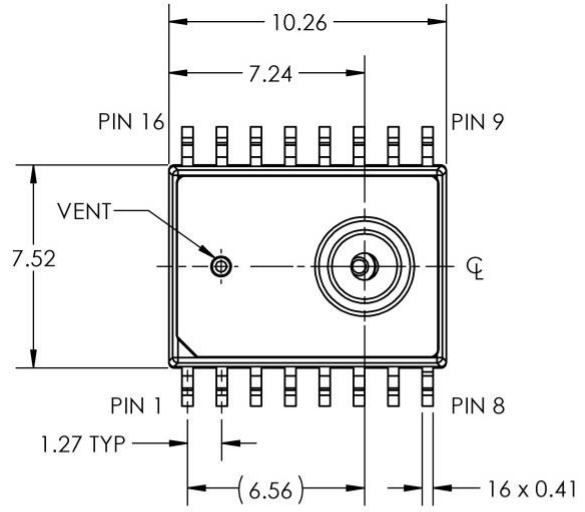
Notes:

- 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

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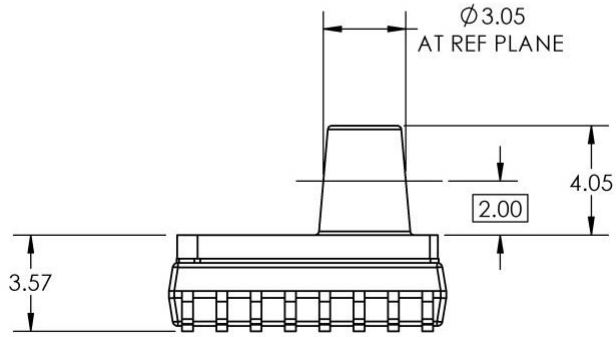
SOIC-16 Manifold port (K) Package Dimensions

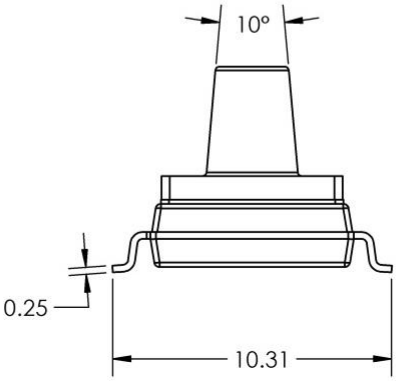


Lot number identification on top side

Notes:

- All dimensions in units of [mm]
- Moisture Sensitivity Level (MSL): Level 3
- Wetted materials: Silicon, RTV, Epoxy, Plastic
- Pressure to the port is applied to the die back side
- Stainless steel lid





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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	-
14	-
15	-
16	VDD

Notes:
- SDO : Refer to chapter 7.

Manifold port

	Manifold port
Pin No	Pin Function
1	-
2	SDA
3	SCL
4	CSB
5	-
6	VSS
7	-
8	VDD
9	-
10	-
11	-
12	-
13	-
14	Aout
15	SDO
16	-

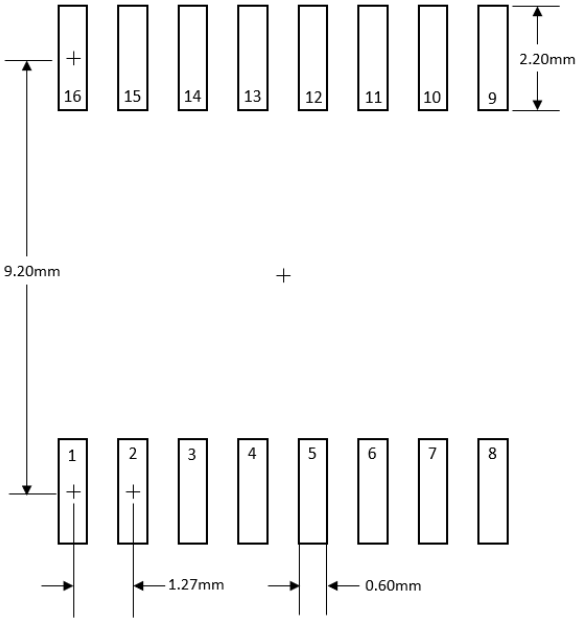
Notes:
- CSB : Refer to chapter 8.4.
- SDO : Refer to chapter 7.

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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.

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3 REFLOW PROFILE

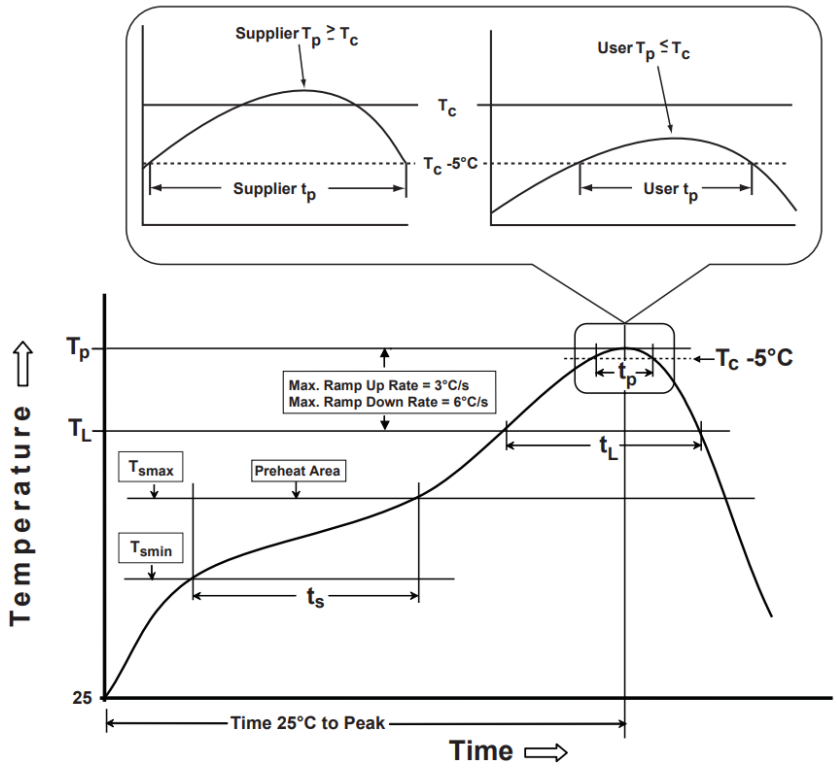
The actual profile parameters depend upon the solder paste used. The recommendations from paste manufacturers should be followed.

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

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4 FUNCTIONAL BLOCK

4.1 Memory

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

1. A few-time-programmable (FTP) non-volatile memory (NVM) of 32 words accessible in Read/Write.
2. Registers implemented as Flip-Flops.

At the start, the NVM will be copied into the register.

4.1.1 Non-Volatile 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 user can access the NVM address 0 to 31 as shown in the Table 1: User memory

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

4.1.2 Register

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

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.

If a CRC error is detected, the "crc_reg" flag in the "int_0" register will toggle to "1". However, this error does not halt the conversion processes.

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4.1.3 User Memory

User	Word name	Register Addr		Data [15:0]																
		Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
RW	PRES_4	97	61								p_ratio[2:0]			p_fil[2:0]				p_osr[3:0]	
RW	TEMP1_4	98	62								t1_ratio[2:0]			t1_fil[2:0]				t1_osr[3:0]	
RW	RESERVED	99	63																
RW	OPER	100	64	interrupt_mode	fast_start	int_cont_mode			fifo_interrupt_threshold[4:0]					fifo_mode[1:0]			delay[3:0]		
RW	DAC_2	101	65		dac_offset_comp_off	en_diag_ana		dac_clip_h[2:0]			dac_clip_l[2:0]		dac_t	drv_vdd_sel[1:0]		dac_buff_mode		dac_mode[2:0]	
RW	POST_GAIN_P	102	66								pgpp[15:0]								
RW	POST_GAIN_T1	103	67								t1gpp[15:0]								
RW	RESERVED	104	68																
RW	Post_OFF_P	105	69								popp[15:0]								
RW	Post_OFF_T1	106	6A								t1opp[15:0]								
RW	RESERVED	107	6B																
RW	COM	108	6C							i2c_daisy_on	en_spike_filter			I2C programmable address[6:1]					
RW	LIMIT_1	109	6D								p_thresh[15:00]								
RW	LIMIT_2	110	6E								p_thres[15:00]								
RW	LIMIT_3	111	6F								t1_thresh[15:00]								
RW	LIMIT_4	112	70								t1_thres[15:00]								
RW	RESERVED	113	71																
RW	RESERVED	114	72																
RW	INT_EN_0	115	73		general_int_en	en_crc_com	en_crc_reg		en_adc_error	en_calc_error	en_sensor_error	en_phigh	en_plow	en_thigh	en_tlow	en_fhigh	en_fempty	en_fthr	en_adc_done
RW	INT_EN_1	116	74						en_adc_udfl_t1	en_adc_udfl_p		en_adc_ovfl_t1	en_adc_ovfl_p		en_calc_udfl_t1	en_calc_udfl_p		en_calc_ovfl_t1	en_calc_ovfl_p
RW	INT_EN_2	117	75								en_sensor_chk[15:0]								
RW	RESERVED_1	118	76								space for customer data								
RW	RESERVED_2	119	77								space for customer data								
RW	RESERVED_3	120	78								space for customer data								
RW	RESERVED_4	121	79								space for customer data								
RW	RESERVED_5	122	7A								space for customer data								
RW	RESERVED_6	123	7B								space for customer data								
RW	RESERVED_7	124	7C								space for customer data								
RW	RESERVED_8	125	7D								space for customer data								
RW	EN_CRC_U_MEM	126	7E																en_crc_u_mem
RW	CRC_USER_MEM	127	7F	crc_user_mem															

Table 1: User memory

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Word	Name	Description
PRES_4	p_ratio[2:0]	Enable chopper for pressure measurment
PRES_4	p_filt[2:0]	Pressure filtering in autonomous mode
PRES_4	p_osr[3:0]	Pressure oversampling
TEMP1_4	t1_ratio[2:0]	Enable chopper for temperature 1 measurment
TEMP1_4	t1_filt[2:0]	Temperature 1 filtering in autonomous mode
TEMP1_4	t1_osr[3:0]	Temperature 1 oversampling
OPER	interrupt_mode	interrupt mode behavior, interrupt_mode = 0 collecting by OR function, interrupt_mode = 1 update mode
OPER	fast_start	Fast startup mode (keep biasing on & keep the oscillator powered). 0:Bias OFF; 1: Bias ON
OPER	int_cont_mode	Define the behavior of the interrupt pin while using thresholds detections. 0: Interrupt mode; 1: Continious mode
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
OPER	fifo_mode[1:0]	FIFO operation 0: off; 1: stop at FIFO full; 2,3: overwrite at FIFO full
OPER	delay[3:0]	Delay between measurements used for the autonomous mode. 0:OFF (digital mode); Programmable between 0 to 60s
DAC_2	dac_offset_comp_off	Offset compensation of the output buffer
DAC_2	dac_clip_h[2:0]	DAC upper voltage limit = 0.65 vdd + dac(2:0) x 0.05 vdd
DAC_2	dac_clip_l[2:0]	DAC lower voltage limit = dac(2:0) 0.05 x vdd
DAC_2	dac_t	Switching between temperature and pressure output to the DAC; 0 = pressure, 1 = temperature
DAC_2	drv_vdd_sel[1:0]	Program regulated vdd in case of high voltage supply
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
DAC_2	dac_mode[2:0]	Define the output behavior of the dac (ratiometric, 0-5V absolute, current loop)
POST_GAIN_P	pgpp[15:0]	Post calibration gain for pressure (value added after the digital filter)
POST_GAIN_T1	t1gpp[15:0]	Post calibration gain for Temperature 1 (value added after the digital filter)
Post_OFF_P	popp[15:0]	Post calibration offset for pressure (value added after the digital filter)
Post_OFF_T1	t1opp[15:0]	Post calibration offset for Temperature 1 (value added after the digital filter)
COM	i2c_daisy_on	Enable i2c daisy chain mode
COM	en_spike_filter	Enable I2C internal 50ns spike filter
COM	I2C programmable address[6:1]	Optional I2C address bits 6:1; bit 0, the LSB is determined by the CSB pin (CSB=0 -> LSB=1; CSB=1 -> LSB=0)
INT_EN	general_int_en	If general_int_en is set to "0", all interrupt will be masked
INT_EN	en_crc_com	Enable CRC check during communication
INT_EN	en_crc_reg	Enable CRC check on the memory
INT_EN	en_adc_error	Global enable of ADC errors.
INT_EN	en_calc_error	Global enable of calculation errors.
INT_EN	en_sensor_error	Global enable of sensor errors.
INT_EN	en_phigh	Enable detection of pressure higher than the higher threshold
INT_EN	en_plow	Enable detection of pressure lower than the lower threshold
INT_EN	en_thigh	Enable detection of temperature higher than the higher threshold
INT_EN	en_tlow	Enable detection of temperature lower than the lower Threshold
INT_EN	en_ffull	Enable detection of FIFO containing 32 unread values
INT_EN	en_fempty	Enable detection of FIFO when all values are read back
INT_EN	en_fthr	Enable detection of FIFO containing n unread values
INT_EN	en_adc_done	Enable detection of a finished conversion
INT_EN	en_adc_udfl_t1	Enable ADC underflow check for temperature 1
INT_EN	en_adc_udfl_p	Enable ADC underflow check for pressure
INT_EN	en_adc_ovfl_t1	Enable ADC overflow check for temperature 1
INT_EN	en_adc_ovfl_p	Enable ADC overflow check for pressure
INT_EN	en_calc_udfl_t1	Enable calculation underflow check for temperature 1
INT_EN	en_calc_udfl_p	Enable calculation underflow check for pressure
INT_EN	en_calc_ovfl_t1	Enable calculation overflow check for temperature 1
INT_EN	en_calc_ovfl_p	Enable calculation overflow check for pressure
INT_EN	en_sensor_chk[15:0]	Enable sensor check mask
CUST	space for customer data	Customer memory space
CRC	en_crc_u_mem	Enable CRC on user memory
CRC	crc_user_mem	CRC user memory

Table 2: Memory content

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

The 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 sets various operating modes like the FIFO and the delay between the automatic measurements.

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

Table 3: OPER register

Word	Name	Description
OPER	interrupt_mode	interrupt mode behavior, interrupt_mode = 0 collecting by OR function, interrupt_mode = 1 update mode
OPER	fast_start	Fast startup mode (keep biasing on & keep the oscillator powered). 0:Bias OFF; 1: Bias ON
OPER	int_cont_mode	Define the behavior of the interrupt pin while using thresholds detections. 0: Interrupt mode; 1: Continious mode
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
OPER	fifo_mode[1:0]	FIFO operation 0: off; 1: stop at FIFO full; 2,3: overwrite at FIFO full
OPER	delay[3:0]	Delay between measurements used for the autonomous mode. 0:OFF (digital mode); Programmable between 0 to 60s

Table 4: Operating register definition

4.1.4.1 Delay

When the delay register is set (not off), the user needs to enter the command start automatic mode to enable the automatic measurement according to the setup in the configuration register. The delay means the delay between one measurement finished and the next measurement starting.

During the automatic measurement, all user commands are accepted, except the ‘conversion’, all write commands and all NVM actions.

The automatic mode can be stopped by a stop automatic mode command. In case there’s an ongoing conversion running at the same time, the automatic triggering of new conversions is stopped but the already-started conversions will finish regularly, and the ratio counter will be reset. This always means a complete set of requested measurements (P, T1) will be done.

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

The default value of delay[3:0] is 0b0000.

4.1.4.2 FIFO mode & FIFO interrupt threshold

As soon as the FIFO mode is ‘ON’ the FIFO starts the operation according to the mode set. To reset the FIFO, it must 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.

For further information about the FIFO operation, please refer to §4.2.

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4.1.5 Configuration Register

In the NVM, there are 2 distinct registers respectively for Pressure, Temperature 1. 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.

The default value of P/T1 configuration register is 0x0004.

User	Word name	Register Addr		Data (15:0)															
		Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
RW	PRES_4	97	61							p_ratio[2:0]			p_filt[2:0]			p_osr[3:0]			
RW	TEMP1_4	98	62							t1_ratio[2:0]			t1_filt[2:0]			t1_osr[3:0]			

Table 6: Configuration register

Word	Name	Description
PRES_4	p_ratio[2:0]	Enable chopper for pressure measurment
PRES_4	p_filt[2:0]	Pressure filtering in autonomous mode
PRES_4	p_osr[3:0]	Pressure oversampling
TEMP1_4	t1_ratio[2:0]	Enable chopper for temperature 1 measurment
TEMP1_4	t1_filt[2:0]	Temperature 1 filtering in autonomous mode
TEMP1_4	t1_osr[3:0]	Temperature 1 oversampling

Table 7: Configuration register definition

4.1.5.1 Ratio

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**
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 the ratio between pressure and temperature in automatic mode.

The default value of ratio[2:0] is 0b000.

In the 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, no conversion is scheduled due to all ratios ≥2.

One full measurement cycle corresponds to the acquisition (in this order) of T1 and P.

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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.

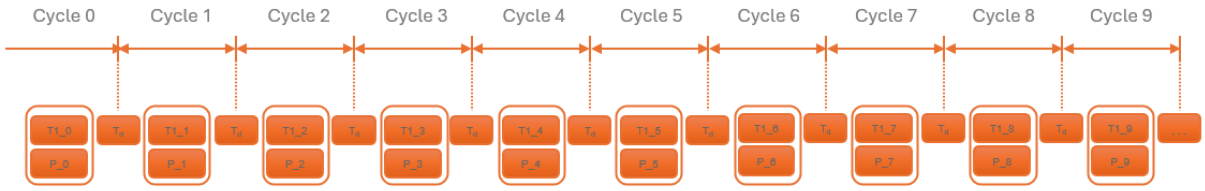


Figure 2 Measurement cycles

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

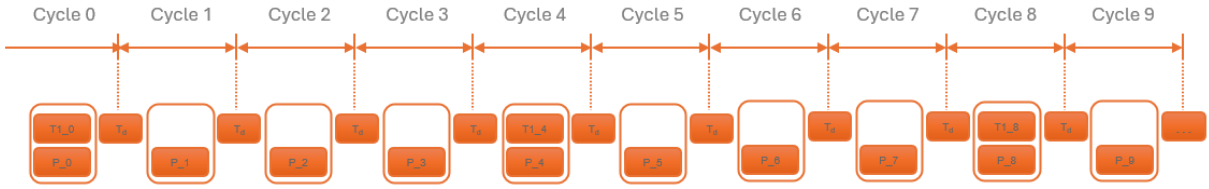


Figure 3 Measurement cycles

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

4.1.5.2 Filter

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 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.

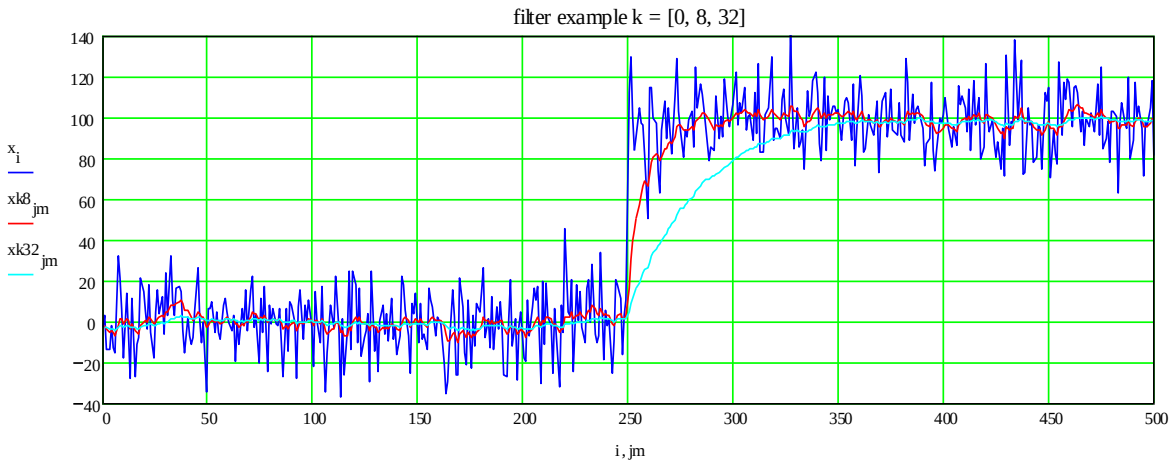


Figure 4: Filter behavior of a noise signal jumping from 0 to 100 using k=0.8 and 32

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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.

The default value of filt[2:0] is 0b000.

4.1.5.3 Over-Sampling Ratio (OSR)

The OSR defines the speed and noise of the ADC. Please check chapter 1.5 for conversion time.

OSR[3:0]				Over sampling
bit[3]	bit[2]	bit[1]	bit[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 10: Over sampling ratio (accuracy of the conversion)

The default value of osr[3:0] is 0b0100.

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

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4.1.6 COM Register

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

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

Table 11: COM register

Word	Name	Description
COM	i2c_daisy_on	Enable i2c daisy chain mode
COM	en_spike_filter	Enable I2C internal 50ns spike filter
COM	I2C programmable address[6:1]	Optional I2C address bits 6:1; bit 0, the LSB is determined by the CSB pin (CSB=0 -> LSB=1; CSB=1 -> LSB=0)

Table 12: COM register definition

4.2 FIFO Operation

The FIFO can be enabled by setting “FIFO mode” in “OPER” register:

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

Table 13: OPER register

fifo_mode[1:0]		**Mode**
bit[1]	bit[0]	
0	0	off
0	1	full mode
1	0	update mode
1	1	update mode

Table 14: FIFO mode

The default value of fifo_mode[1:0] is 0b00.

Once activated, FIFO registers have the capacity to hold a maximum of 32 sets of temperature and pressure data.

The FIFO operates on a first-in, first-out (FIFO) basis, meaning the first data entered is the first to be outputted, as illustrated in the figure below. The configuration of the operation is based on the relevant bit settings in the "OPER" register.

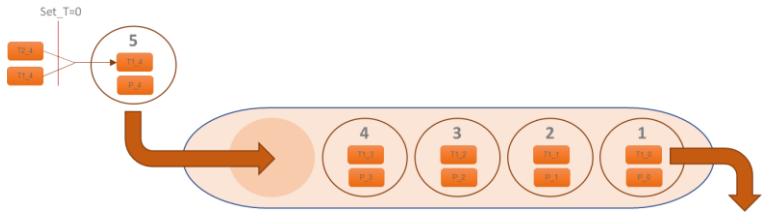


Figure 5: FIFO principle

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The data stored in the FIFO depends on the configuration of the IIR filter.

The compensated data are stored in the FIFO. Compensated data uses a 22-bit format. Hence, if the IIR filter is turned off, two LSBs equal to "00" will be appended to the 22-bit MSB. With filtering enabled, we aim for better resolution. Consequently, the compensated and filtered value will be stored in 24 bits. The compensated data can also be replaced by diagnostics if they are enabled in the diagnostics mask register.

In FIFO mode "OFF", both pointers (FPTRRD & FPTRWR) are aligned and set to "0", ", and error coding insertion on Read ADC data is disabled

1. In **FIFO mode 1**, also known as **FIFO full mode**, when the FIFO reaches its capacity, any incoming values from the ADC are discarded, meaning they are not written into any FIFO register.

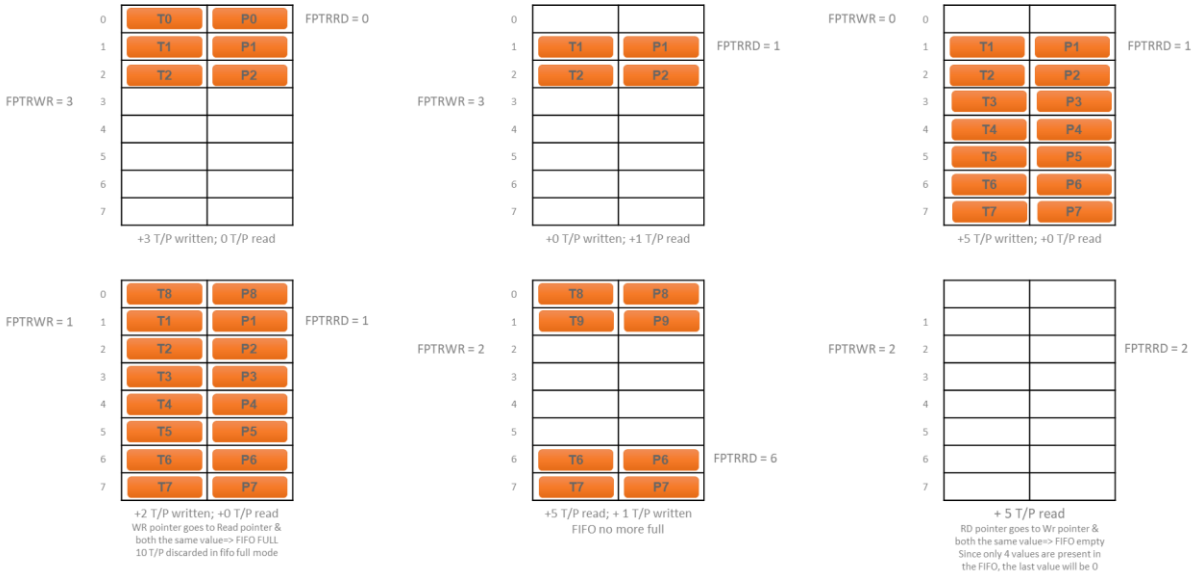
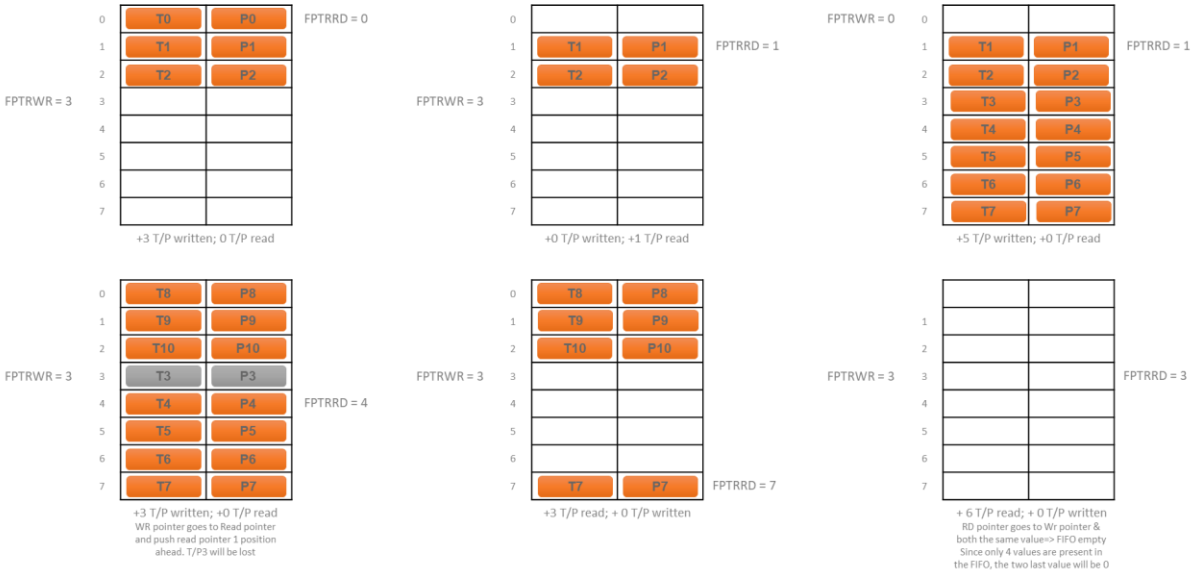


Figure 6. FIFO full mode operation

2. In **FIFO mode 2**, referred to as **FIFO update mode**, when the FIFO reaches its capacity, not only does the write cursor progress forward, but the read cursor also advances to ensure it remains at least one position ahead of the write cursor.



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The depth of the FIFO can be configured using FIFO threshold. The FIFO threshold can be configured within the operating register (see Chapter: Interrupt & Interrupt mask register). It allows for setting a FIFO threshold ranging from 1 to 31. An interrupt triggered by the FIFO threshold occurs immediately after the FIFO has stored the designated number of data samples.

FIFO_interrupt_threshold[4:0]					Threshold
bit[4]	bit[3]	bit[2]	bit[1]	bit[0]	
0	0	0	0	0	OFF
0	0	0	0	1	1
0	0	0	1	0	2
0	0	0	1	1	3
0	0	1	0	0	4
0	0	1	0	1	5
0	0	1	1	0	6
0	0	1	1	1	7
0	1	0	0	0	8
0	1	0	0	1	9
0	1	0	1	0	10
0	1	0	1	1	11
0	1	1	0	0	12
0	1	1	0	1	13
0	1	1	1	0	14
0	1	1	1	1	15
1	0	0	0	0	16
1	0	0	0	1	17
1	0	0	1	0	18
1	0	0	1	1	19
1	0	1	0	0	20
1	0	1	0	1	21
1	0	1	1	0	22
1	0	1	1	1	23
1	1	0	0	0	24
1	1	0	0	1	25
1	1	0	1	0	26
1	1	0	1	1	27
1	1	1	0	0	28
1	1	1	0	1	29
1	1	1	1	0	30
1	1	1	1	1	31

Table 15: FIFO Interrupt threshold

For example, if FIFO threshold is equal to 5, the interrupt will occur if the write cursor is 5 data samples ahead of the read cursor and 5 data samples can be read. The FIFO interrupts will be set only at the end of a conversion. The FIFO will not stop at the threshold and fills in the 32 positions until the FIFO is full.

Please refer to the Interrupt Register for other FIFO interrupts behaviors.

4.2.1 Read values from FIFO registers

To extract data from the FIFO, utilize the "read ADC" command. Upon receiving this command, the data at the designated position indicated by the read cursor is accessed and at the same time, the read pointer is incremented. If the reading is incomplete, the data is lost.

The maximum number of readings attainable varies between FIFO full mode and FIFO update mode. In FIFO full mode, waiting until the FIFO registers are filled enables the retrieval of the 32 most recent values. Conversely, in FIFO update mode under identical conditions, only 31 values can be retrieved. This intentional design choice in update mode prevents the write cursor and read cursor from addressing the same FIFO register.

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4.2.2 A common application: FIFO combined with automatic mode

Once the automatic mode is activated, access to configuration registers is no longer permitted. Hence, it is crucial to verify that the P and T1 configurations are correctly configured before enabling automatic mode.

Example 1:

In automatic mode (delay[3:0] higher than 0), and with the following configuration,

	p	t1
p/t1_ratio	1	4

Table 16: FIFO example 1 configuration

A pressure conversion is done every cycle and a temperature conversion every 4th cycle. In this case, the latest available temperature is copied to the actual position, to always have a pair of measurements in the FIFO.

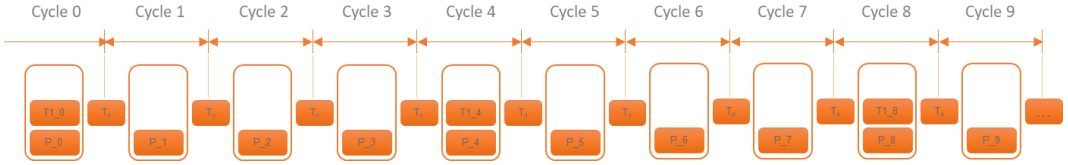


Figure 7: Measurement cycles for example 1

Each cycle time is different depending on the number of action(s) it must perform. The computation engine must be turned on at the end of each cycle where at least one conversion was performed.

Inside the FIFO:



Figure 8: FIFO content for example 1

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Example 2:

In automatic mode (delay[3:0] higher than 0), and with the following configuration,

	p	t1
p/t1_ratio	2	4

Table 17: FIFO example 2 configuration

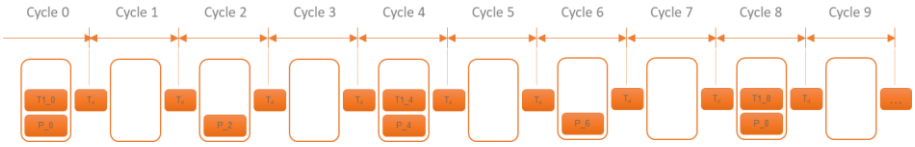


Figure 9: Measurement cycle for example 2

Remark

- For example, cycle 1 is a real short cycle since no conversion is triggered and no DSP compensation is required. The timing will be mostly defined by the two delays.

Inside the FIFO:



Figure 10: FIFO content for example 2

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4.3 DAC

An on-chip 14-bit DAC is provided by the ASIC to generate analog voltage output. The 14-bit resolution spans from 0% to 100% of the DAC reference voltage, while the linear range is assured within the 5% to 95% range.

The reference voltage can be configured in two ways:

1. It can be directly linked to the supply VDD when operating in ratiometric mode.
2. It can be connected to the output of an internal regulator, which may provide either 3V or 5V. In both scenarios, VDD must exceed the targeted regulated voltage by at least 200mV.

The choice between these two options is made automatically during the configuration of dac_mode[2:0]:

dac_mode[2:0]			DAC Mode
bit[2]	bit[1]	bit[0]	
0	0	0	DAC OFF
1	0	0	Ratiometric analog output
1	0	1	Absolute 3V output
1	1	0	Absolute 5V output
1	1	1	-

Table 18: dac_mode[2:0]

The output voltage is expressed as:

$$DAC_VOUT = DAC_CODE \cdot \frac{DAC_VREF}{2^{14} - 1}$$

Where:

1. DAC_VREF can be either VDD, 3V or 5V depending on dac_mode[2:0]
2. DAC_CODE[13:0] represents either the pressure value when dac_t="0" or the temperature value when dac_t="1". DAC_CODE[13:0] corresponds to the MSB of the compensated data (p_comp[24:10] or t1_comp[24:10] without any diagnostic or error flag insertion. In case of interrupt, diagnostic or error flag, AOUT will be forced either to 0V or DAC_VREF
3. DAC_CODE is clipped according to dac_clip_h[2:0] & dac_clip_l[2:0] stored into the memory (see here below)

The user can limit the output voltage. The lower limit can be adjusted from 0% to 35% in 5% increments, while the upper limit can be adjusted from 65% to 100% in 5% increments.

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dac_clip_h[2:0]			Output voltage clippping high	DAC clipping Value in hex
bit[2]	bit[1]	bit[0]		
0	0	0	1.00×Vref	3FFF
0	0	1	0.95×Vref	3CCC
0	1	0	0.90×Vref	3999
0	1	1	0.85×Vref	3666
1	0	0	0.80×Vref	3332
1	0	1	0.75×Vref	2FFF
1	1	0	0.70×Vref	2CCC
1	1	1	0.65×Vref	2999

Table 19: dac_clip_h[2:0]

dac_clip_l[2:0]			Output voltage clippping low	DAC clipping Value in hex
bit[2]	bit[1]	bit[0]		
0	0	0	0.0×Vref	0000
0	0	1	0.5×Vref	0333
0	1	0	0.10×Vref	0666
0	1	1	0.15×Vref	0999
1	0	0	0.20×Vref	0CCD
1	0	1	0.25×Vref	1000
1	1	0	0.30×Vref	1333
1	1	1	0.35×Vref	1666

Table 20: dac_clip_l[2:0]

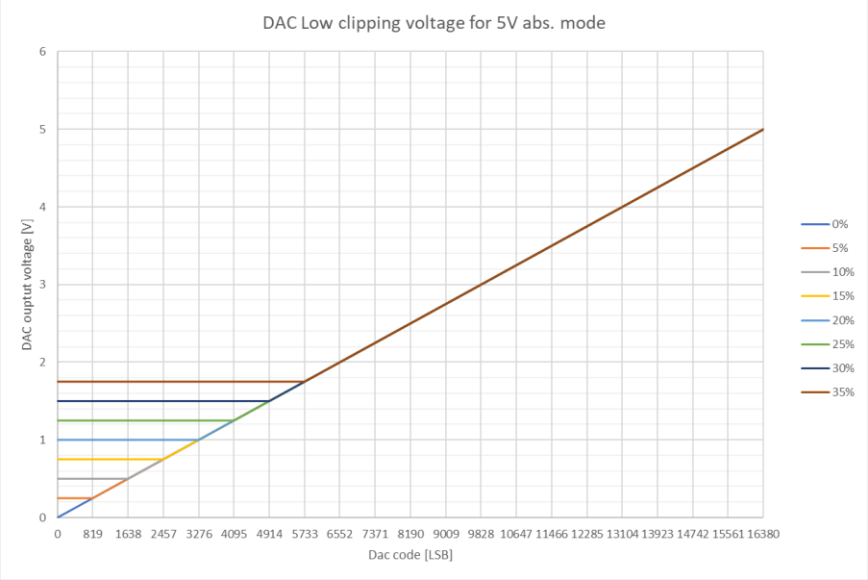


Figure 11: DAC clipping voltage on the low side

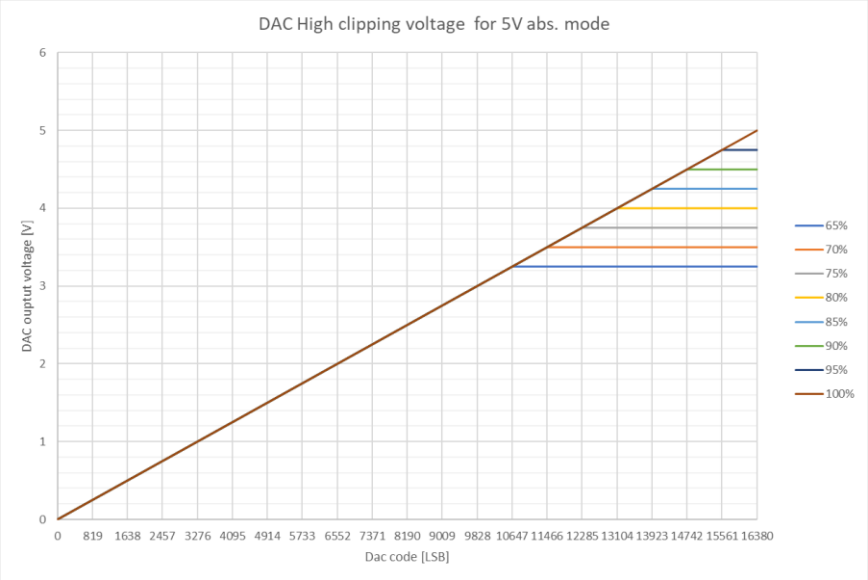


Figure 12: DAC clipping voltage on the high side

en_diag_ana signal (from the memory) can globally disable the error & interrupt signaling on AOUT. By default, en_diag_ana is “0”. If en_diag_ana is set to “1”, the value of the interrupt register can be propagated to AOUT according to the table here below.

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Diagnostic or interrupt description	Flag	dac_out [15] signaling high error	dac_out [14] signaling low error
Sensor diagnostic error	sensor_error	0	1
Sensor ADC saturation	adc_error	0	1
Memory CRC	crc_reg	0	1
Sensor computation error	calc_error	1	0
Low threshold detection	plow / tlow	0	1
High threshold detection	thigh / thigh	1	0

Table 21: Error & Interrupt signaling

Sensor diagnostic error has the highest priority, and it decreases until threshold detection that has the lowest priority.

4.3.1 Ratiometric analog output mode

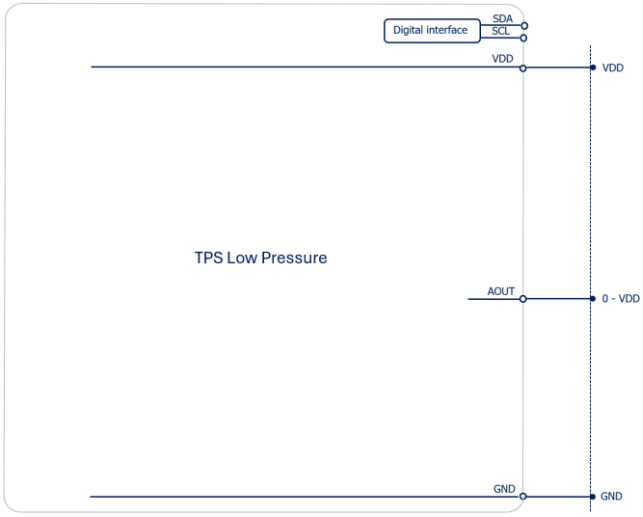


Figure 13: Ratiometric analog output

In ratiometric analog output mode, communication can occur in several ways:

1. Following the standard communication for a three-pin module, AOUT is connected to the SDA pin, as depicted in the image above (Figure 13).
2. Employing all other interfaces.

TPS Low Pressure can be switched to “analog out” mode under the following conditions:

1. After a restart (Power down – Power up cycle), provided correct configuration in the NVM
2. Upon receiving a reset command, given correct configuration in the NVM.

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4.3.2 Absolute 3V analog output mode

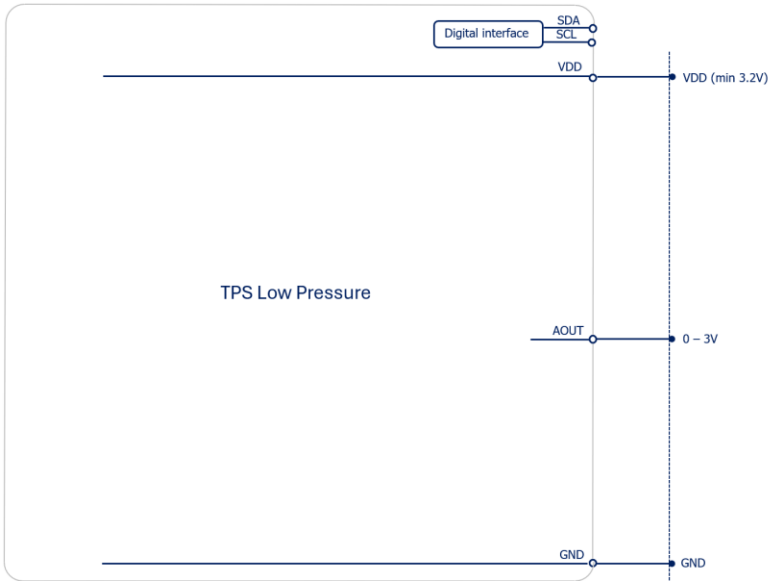


Figure 14: Absolute 3V analog output

The communication interface is set the same way as for Ratiometric analog output.

4.3.3 Absolut 5V analog output mode

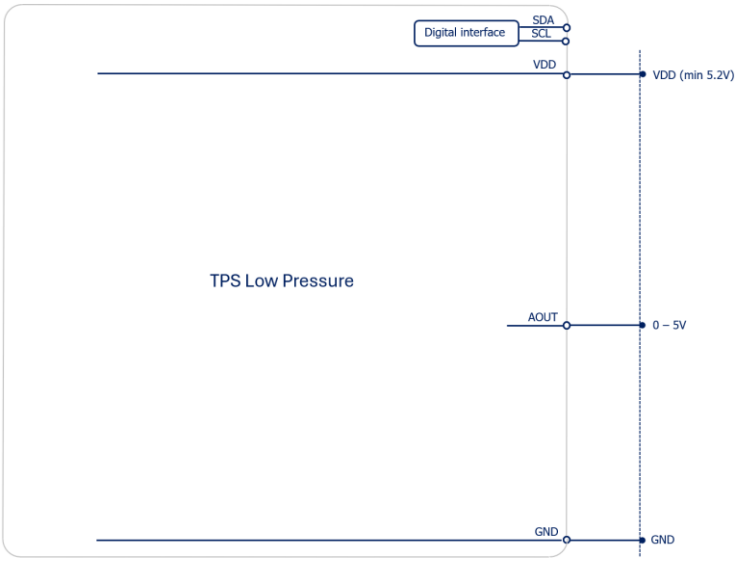


Figure 15: Absolute 5V analog output

The communication interface is set the same way as for Ratiometric analog output.

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4.4 Diagnostics

TPS Low Pressure has internal checks for:

1. Sensor bridge connections (sensor_error)
2. ADC overflow/underflow (adc_error)
3. Calculation engine saturation (overflow/underflow) (calc_error)
4. Pressure/temperature threshold (p/t high/low)
5. FIFO check (f*)
6. Communication check (crc_com)
7. Memory checks (crc_reg)

The effect of a diagnostic can be observed:

1. On the FIFO value stored (diagnostics are shown by 8 highest values of the communication)
2. By a read register command (direct access to the diagnostic bit)
3. On the analog output. In case of detection, the analog voltage is clamped either high or low

Sensor check is performed at the beginning of each conversion. The result is available after the checking period in front of the conversion and stays stable until the next conversion is triggered.

When “interrupt_mode” = 0, the errors are collected and persistent.

Since the diagnostic block does not know which conversion is run, the digital part must take care and collect them by the equivalent of a logical OR function on each group of the sensor_chk[15:0] after each single conversion triggered like:

$$int_2.sensor_chk[15:13] = int_2.sensor_chk[15:13]\ OR\ sensor_chk[15:13]\ (at\ the\ end\ of\ T2\ conversion)$$

$$int_2.sensor_chk[12:10] = int_2.sensor_chk[12:10]\ OR\ sensor_chk[12:10]\ (at\ the\ end\ of\ T1\ conversion)$$

$$int_2.sensor_chk[9:0] = int_2.sensor_chk[9:0]\ OR\ sensor_chk[9:0]\ (at\ the\ end\ of\ P\ conversion)$$

With that, we can insert sensor_error diagnostic code (0xFF_FF9) into proper FIFO data slice

When “interrupt_mode” = 1, each group must be updated after the conversion.
This way an analog sensor can recover from an error without any external action needed

$$int_2.sensor_chk[15:13]\ sensor_chk[15:13]\ (at\ the\ end\ of\ T2\ conversion)$$

$$int_2.sensor_chk[12:10] = sensor_chk[12:10]\ (at\ the\ end\ of\ T1\ conversion)$$

$$int_2.sensor_chk[9:0] = sensor_chk[9:0]\ (at\ the\ end\ of\ P\ conversion)$$

The register sensor_chk is where the results of the sensor bridge connection diagnostics are updated. The read value of sensor_chk should be 0x0000. Otherwise, the information (P / T1) read on the sensor cannot be trusted.

The diagnostics can be visible on the Analog output when the DAC_2 address (NVM address 4) with the bit “en_diag_ana” set to “1” and the bit “en_sensor_error” in INT_EN_0 is set to “1”.

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4.5 Interrupt & Interrupt mask register

An interrupt register, labelled as INT_0, is in place to alert the user of various conditions. These include completion of a conversion, FIFO status (empty/full/threshold), surpassing temperature or pressure limits, sensor diagnostics errors, ADC errors, and computation errors. Within INT_0, errors are grouped. If diagnostic errors occur, the INT_2 register provides detailed information, while all other errors can be found in INT_1.

User	Word name	Register Addr		Data [15:0]															
		Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
RW	INT_0	128	80			crc_com	crc_reg		adc_error	calc_error	sensor_error	phigh	plow	thigh	tlow	ffull	fempty	fthr	adc_done
RW	INT_1	129	81					adc_udfl_t2	adc_udfl_t1	adc_udfl_p	adc_ovfl_t2	adc_ovfl_t1	adc_ovfl_p	calc_udfl_t2	calc_udfl_t1	calc_udfl_p	calc_ovfl_t2	calc_ovfl_t1	calc_ovfl_p
RW	INT_2	130	82	sensor_chk[15:0]															

Table 22: Interrupt & Diagnostic registers

The signaling on AOUT can be enabled by setting “1” in the corresponding field of INT_EN_0. For grouped errors, the corresponding bit of INT_EN_0 must be enabled, and each error can be individually enabled in INT_EN_1. In addition, “general_int_en” must be set to “1”.

User	Word name	Register Addr		Data [15:0]															
		Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
RW	INT_EN_0	115	73		general_int_en	en_crc_com	en_crc_reg		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
RW	INT_EN_1	116	74					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
RW	INT_EN_2	117	75	en_sensor_chk[15:0]															

Figure 16: Interrupt & Diagnostic enable bit in the NVM

This will allow the user to handle the interrupt, clear the corresponding flag and enable again the interrupt for further application. Before clearing the interrupt flag in INT_0, the user must clear the corresponding error in the sub register INT_1 or INT_2.

At startup, all bits of interrupt enable registers are set to “0”. The interrupt register can be read and reset by the user. The interrupt bit must be cleared by the user by writing a “1” into the according register bit himself after handling the interrupt.

Interrupt Registers INT_0:

- Can be read either with a ReadREG command or via the Read-Interrupt command
- In normal mode, writing a bit to ‘1’ to INT_0, INT_1 & INT_2 will clear the corresponding bit. As example, write-interrupt ‘0x0005’ will clear the FIFO empty and ADC done interrupt and leave all the others unchanged.
- In service unlock mode, writing these registers will update the entire registers value (true write)

Interrupt Enable Registers INT_EN_0:

- 0 = interrupt bit not seen/enabled at INT
- 1 = interrupt bit seen/enabled at INT

All interrupts (except sensor diagnostics) will be evaluated at the end of a complete T1/P sequence (including compensation algorithm. Only at the end of the whole sequence, temperature 1 will be evaluated against the limits and set the corresponding

The sequence looks like:

start T1 conversion -> wait end of T1 conversion, start P conversion -> wait end of P conversion, compute compensated T1/P, evaluate interrupt.

Depending on interrupt mode, we have:

1. interrupt_mode = 0. the errors are collected and persistent ('OR function of new and actual state->register')
2. interrupt_mode = 1, the errors are updated and not persistent (actual state ->register)

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4.6 Outputs Calculation

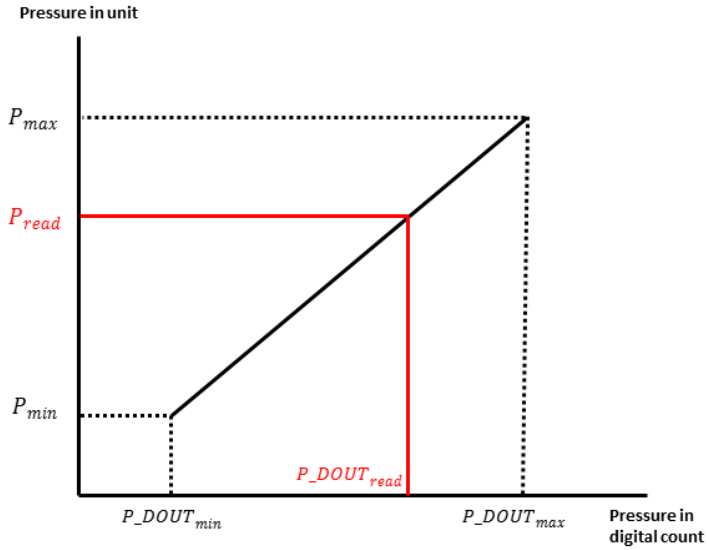
4.6.1 Pressure Calculation

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

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}.



For 20030258-00, calculation is as below:

P_{min} = 0mbar

P_{max} = 70mbar

$P_{DOUTmin}$: 1'677'721

$P_{DOUTmax}$: 15'099'485

For $P_{DOUTread}$= 8'388'603, you calculate $P_{read} = 0 + \frac{8388603-1677721}{15099485-1677721} * (70 - 0) = 35.0$mbar

For $P_{DOUTread}$= 10'000'000, you calculate $P_{read} = 0 + \frac{10000000-1677721}{15099485-1677721} * (70 - 0) = 43.4$mbar

4.6.2 Temperature Calculation

$T_{DOUTmin}$: 1'677'721

$T_{DOUTmax}$: 15'099'485

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

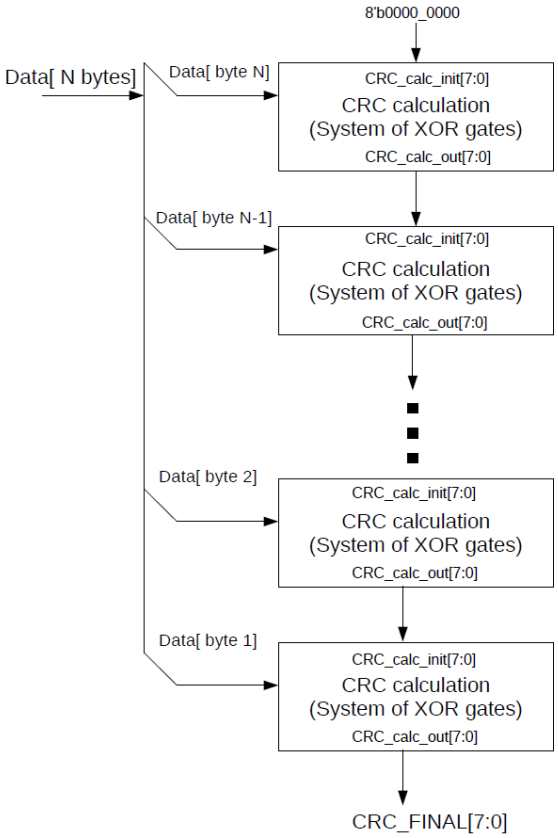
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5 CHECKSUM CALCULATION (CRC)

CRC is implemented in the digital core to check the integrity of the memory data & for the communication integrity.

CRC is calculated for each 8-bit data, i.e., one byte of data as the minimum data size over which CRC is executed. For N-byte data, the calculation will be done in N steps. This can be illustrated below.



Its properties are displayed in table below.

Property	Value
Width	8 bits
Protected data	Read and/or write data
Polynomial	0x31 (x8 + x5 + x4 + 1)
Initialization	0x00
Reflect input	False
Reflect output	False
Final XOR	0x00
Examples	CRC (0xBEEF) = 0x13

Memory CRC is calculated (if enabled) and takes 2x32 master clocks:

1. starting with the upper byte of the lowest address and ending with the lower byte of the second-highest address
2. The lower byte of the highest address is the CRC result byte & upper byte of the highest address is ignored

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6 APPLICATION CIRCUIT

6.1 Manifold I2C

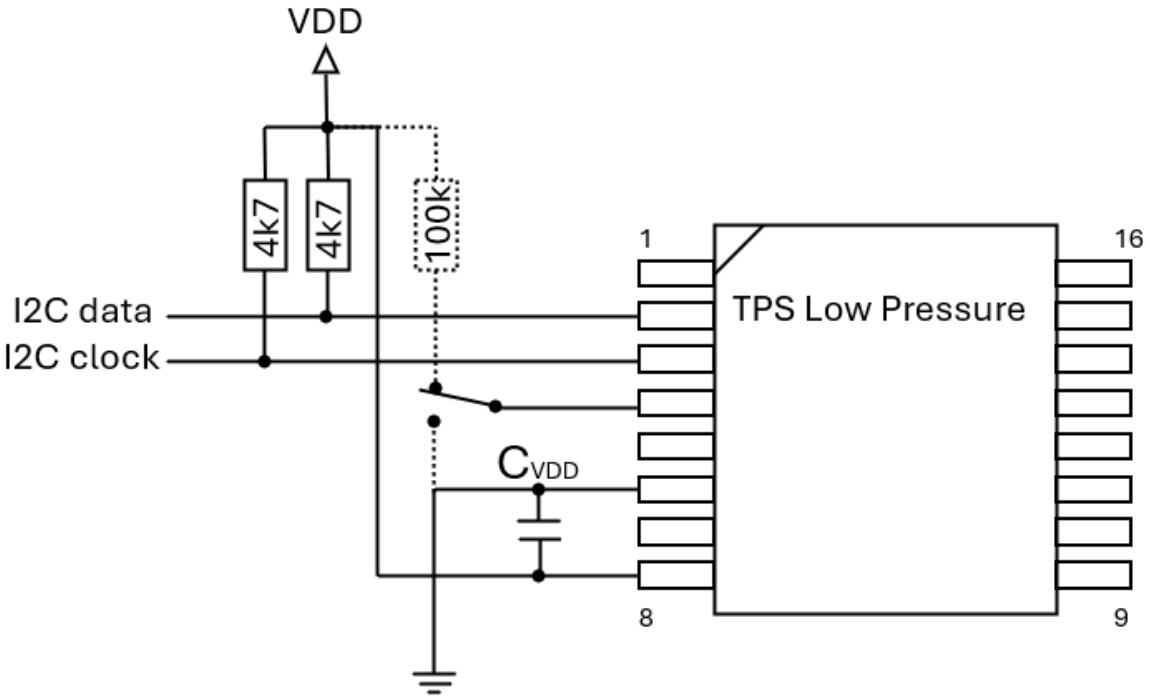


Figure 17: Application circuit for Manifold I2C

Note: The switch is to select the last digit of the I2C address as pin 4 of Manifold is CSB.

6.2 Dual-port I2C

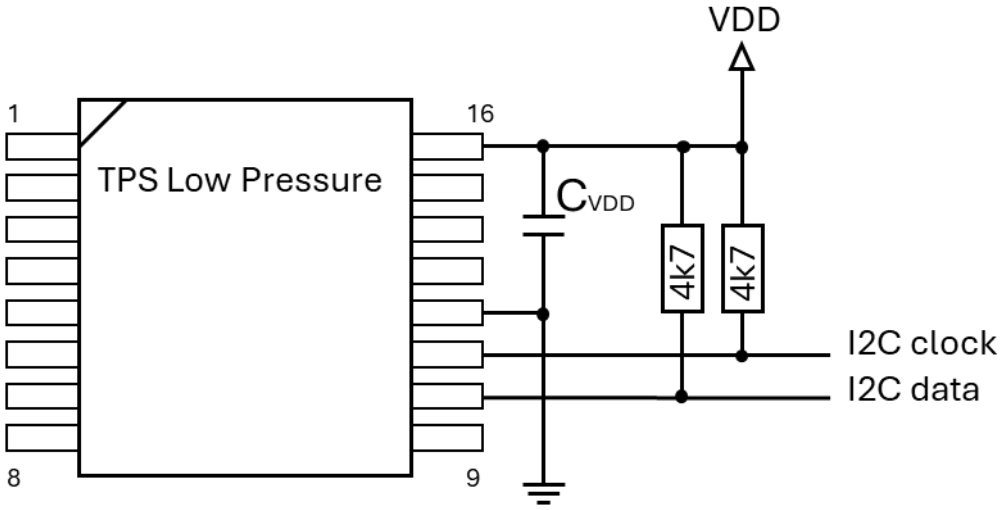


Figure 18: Application circuit Dual-port I2C

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7 OPERATION

TPS Low-Pressure sensor can operate in either:

1. **Command mode:** it's reacting on commands from interface
2. **Automatic mode:** fully autonomous, according to the setup stored into the memory and OPER.delay[3:0] different from 0b0000. The sensor starts operating as soon as the start sequence is finished. TPS Low Pressure is still reacting to digital commands in this mode.

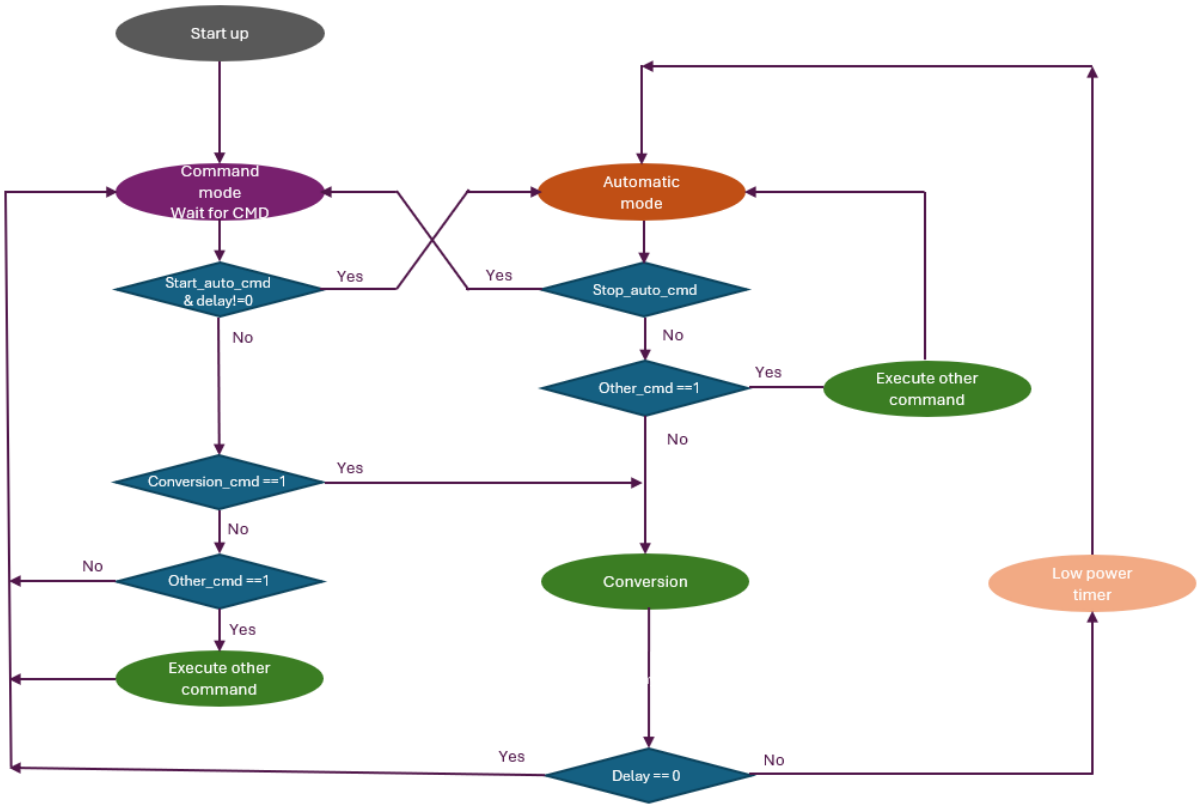


Figure 19: Operation Diagram

In parallel with the execution of conversions, and during waiting time in automatic modem, the communication interface is still looking for commands and might be executed depending on the acceptance table described in §8.2

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8 SERIAL DIGITAL INTERFACE

The 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 commands.

Commands 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.

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8.1 Command Structure

The size of each command is 1 byte (8 bits) as described in Table 23 below.
ADC read command will return 24 bits result of the above requested finished conversion (P, T1).
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	0	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 23: User commands

** Read ADC with all 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

8.2 Commands acceptance

	Command Mode		Automatic Mode		Special phases			
User commands	Conv. Busy	Conv. Ready	Conv. Busy	Conv. Ready	PON Busy	Reset cmd Busy	Refresh Busy	WR or ERS NVM Busy
Read Sensor ID	YES	YES	YES	YES	NO	NO	NO	NO
Reset	YES	YES	YES	YES	YES	YES	YES	NO
Refresh	NO	YES	NO	NO	NO	NO	/	NO
Write Operating Mode	YES	YES	YES	YES	NO	NO	NO	NO
Read Operating Mode	YES	YES	YES	YES	NO	NO	NO	NO
Start automatic mode	YES	YES	YES	YES	NO	NO	NO	NO
Stop automatic mode	YES	YES	YES	YES	NO	NO	NO	NO
Write Config	NO	YES	NO	NO	NO	NO	NO	NO
Read Config	YES	YES	YES	YES	NO	NO	NO	NO
Conversion	NO	YES	NO	NO	NO	NO	NO	NO
Read ADC	YES	YES	YES	YES	NO	NO	NO	NO
Write Interrupt Mask	YES	YES	YES	YES	NO	NO	NO	NO
Read Interrupt Mask	YES	YES	YES	YES	NO	NO	NO	NO
Write Interrupt Reg	YES	YES	YES	YES	NO	NO	NO	NO
Read Interrupt Reg	YES	YES	YES	YES	NO	NO	NO	NO
Write NVM	NO	YES	NO	NO	NO	NO	NO	NO
Erase NVM	NO	YES	NO	NO	NO	NO	NO	NO
Read NVM	NO(2)	YES	NO	NO	NO	NO	NO	NO
Write Limits	YES	YES	YES	YES	NO	NO	NO	NO
Read Limits	YES	YES	YES	YES	NO	NO	NO	NO
Write REG	NO	YES	NO	NO	NO	NO	NO	NO
Read REG	YES	YES	YES	YES	NO	NO	NO	NO

Table 24: Commands acceptance

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8.3 CRC during communication

CRC 8 is implemented for all commands and can be activated by utilizing the least significant bit (LSB). This CRC-8 functionality applies to the I2C communication protocol and maintains a consistent structure.

If an incorrect CRC is detected, the command is not executed, and an interrupt is generated. It is important to note that in I2C, the command and remaining data continue to be acknowledged even if the CRC is wrong, and the command is not executed.

Two CRC checks are planned: one for verifying the command's integrity and another for verifying the integrity of the data. If a CRC issue arises, either the master or the slave can stop the communication.

8.4 I2C Interface

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

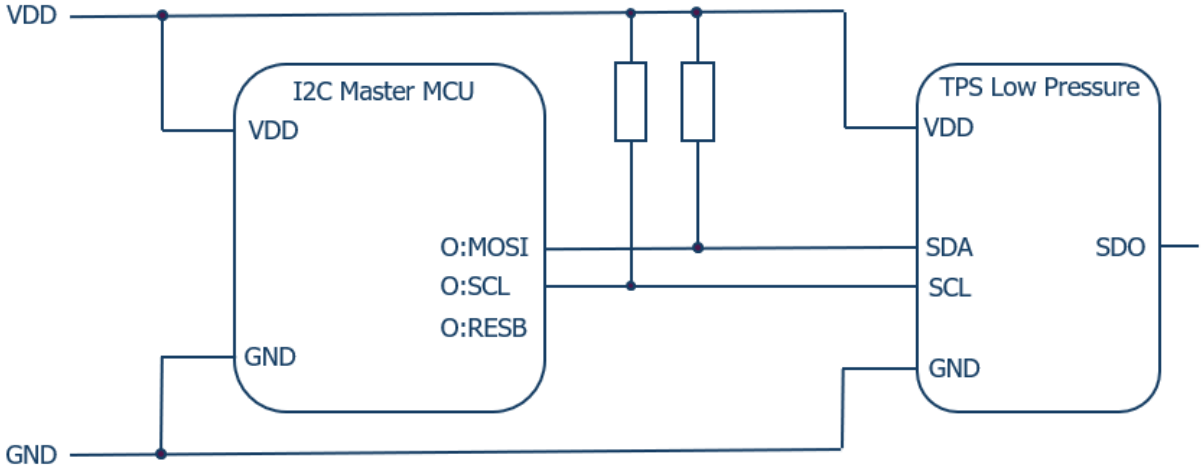


Figure 20: TPS Low Pressure sensor I2C application circuit

TPS Low Pressure sensor has a hard coded I2C address following the Table 25 and Table 26.

Manifold	Bin	Decimal	Hexadecimal
Standard I2C address	1110'10$\overline{c}$	116 or 117	x74 or x75
Alternative I2C address	0100'01$\overline{c}$	34 or 35	x22 or x23

Table 25: Manifold I2C address

The $\overline{c}$ 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	Bin	Decimal	Hexadecimal
Standard I2C address	1110'100	116	0x74
Alternative I2C address	0100'010	34	0x22

Table 26: Dual-Port I2C address

In I2C mode, the I2C command write(R/W=0) with a valid address will always be acknowledged (ACK). However, an invalid command will not be accepted, as described in Table 23. The command acceptance result will be reflected on SDO output.

For I3C information, please contact TE representative for support.

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Detailled Commands

8.4.1 Read sensor ID

The sensor ID is stored into 4 words in the memory and can be directly accessed through this command.

User	Word name	Register Addr		Data [15:0]															
		Dec	Hex	[15]	[14]	[13]	[12]	[11]	[10]	[9]	[8]	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]
RO	MAN_ID_1	24	18	manufacturer id1: part number [31:16]															
RO	MAN_ID_2	25	19	manufacturer id2: part number [15:0]															
RO	MAN_ID_3	26	1A	manufacturer id3: serial number															
RO	MAN_ID_4	27	1B	manufacturer id4: wafer number															

Figure 21: Sensor ID

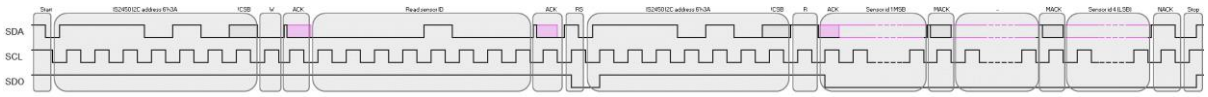


Figure 22: I2C Read Sensor ID

A unique ID for each sensor is generated by combining four memory words (MAN_ID_1..4). The first two memory words contain the part number. MAN_ID_3 contain the sensor serial number and MAN_ID_4 contain the sensor wafer number.

The part number is coded with one 32-bit word composed of part number LSB and part number MSB (part number [31:16] and part number [15:0]).

So, for example:

In the two first memory words of “read sensor ID”, the following values are read:

$MAN_ID_1 = 30565_{10} = 0x7765_{16}$
$MAN_ID_2 = 55660_{10} = 0xD96C_{16}$

To compute the Part Number, the mathematical operation is:

$$Part\ Number = MAN_ID_1 * 65536 + MAN_ID_2$$

The last step is to separate the 2 last digits of the result (in this example 2 003 163 500) in decimal to find 20031635-00

8.4.2 Refresh

During a refresh command, the register's values are updated. The data like configuration, operation mode, limits and interrupt enable are not changed.

The refresh command typically takes 800 µs. Please be aware of letting this time free of operation with the sensor.

To allow the slave to compute the CRC correctly right before the 8th rising edge, the integrity of the master’s data must be guaranteed.

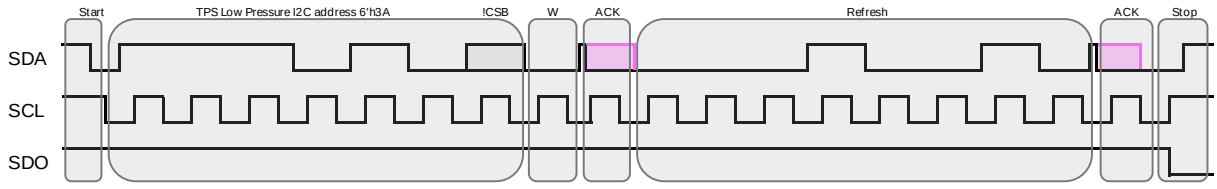


Figure 23: I2C Refresh command

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8.4.3 Reset

During a reset, the NVM data is transferred to the Register (see memory mapping for more details).

The reset command typically takes 800 µs. Please be aware of letting this time free of operation with the sensor.

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

Bit 8 of the command is sensitive to outside conditions and not fully covered by the communication CRC check. If bit 8 is corrupted, the following cases can appear:

1. 1 becoming 0 => reset will be executed immediately. The master will get the wrong CRC and therefore know that something went wrong. The chip configuration will be overridden by the content of NVM.
2. 0 becoming 1 => the reset will not be executed since clocks should be given by the master to check CRC. Neither the slave nor the master will know that the reset was not executed.

To allow the slave to compute the CRC before the 8th rising edge, the data from the master must be well setup and guaranteed.

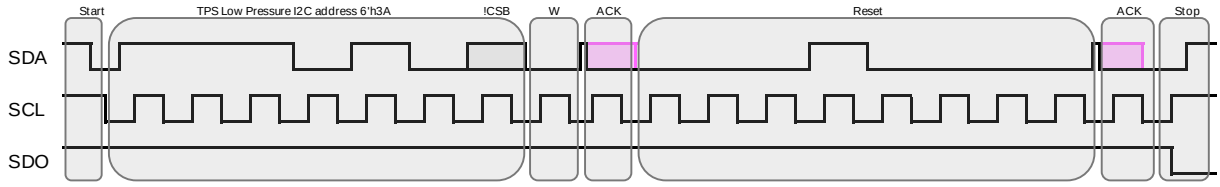


Figure 24: I2C Reset command

8.4.4 Write Config

Write config allows to configure 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	-	-	-	-	-
1	1	-	-	-	-	-

Table 27: Write config command address vs register address

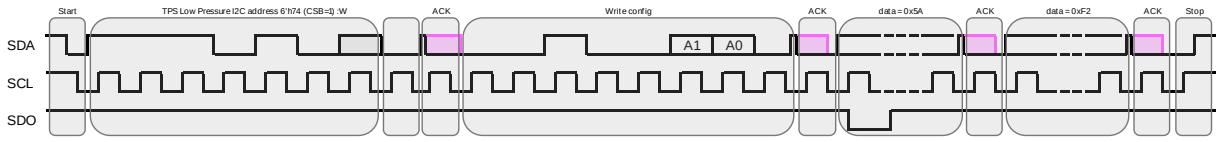


Figure 25: I2C write configuration register command

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8.4.5 Read Config

Read config allows verification of 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	-	-	-	-	-
1	1	-	-	-	-	-

Table 28: read config command address vs register address

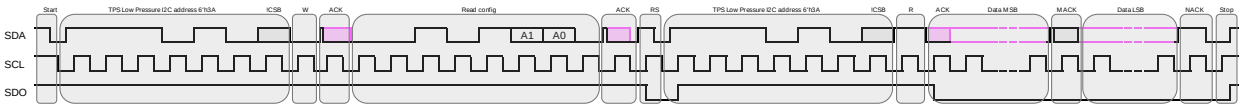


Figure 26: I2C read configuration register command

8.4.6 Start automatic mode

Start automatic mode from the command mode. To correctly start the automatic mode, the delay needs to be set beforehand to something different than 0.

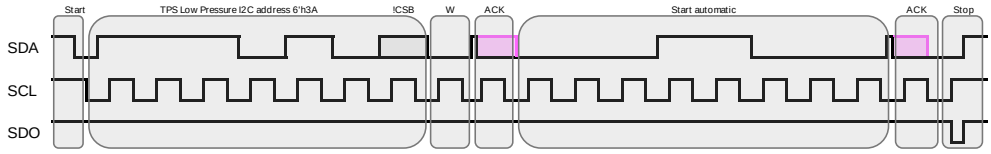


Figure 27: I2C start automatic mode command

8.4.7 Stop automatic mode

Stop automatic mode while TPS Low Pressure is continuously operating.

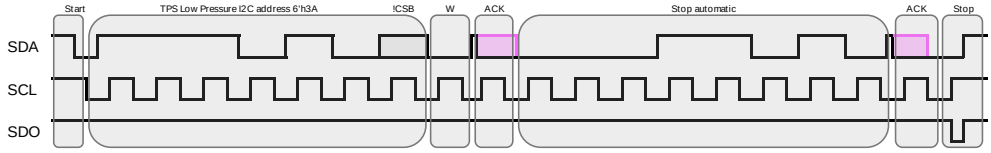


Figure 28: I2C stop automatic mode command

8.4.8 Write operating mode

With the write operating mode command, the behavior if the FIFO and the automatic mode can be controlled.

Data corresponds to the OPER register stored in the registers (address 0x64)

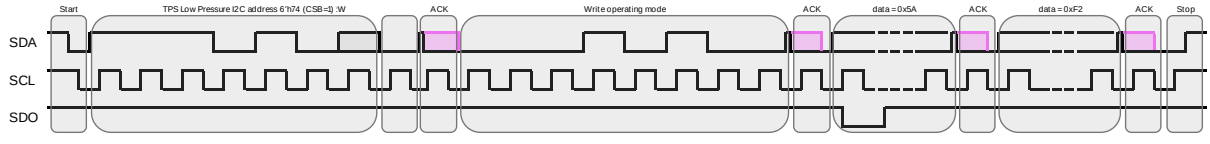


Figure 29: I2C write operating mode command

8.4.9 Write REG

This command allows writing into the register map. The address range for this command is from 96 to 127.

Burst mode is implemented for this command.

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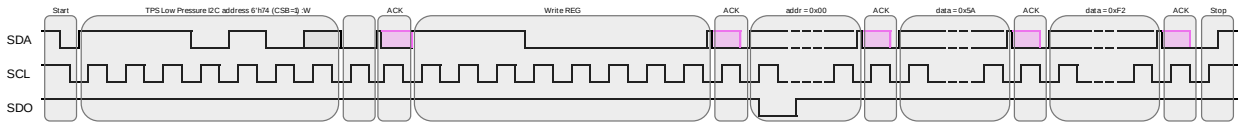


Figure 30: I2C write REG command

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

8.4.10 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.

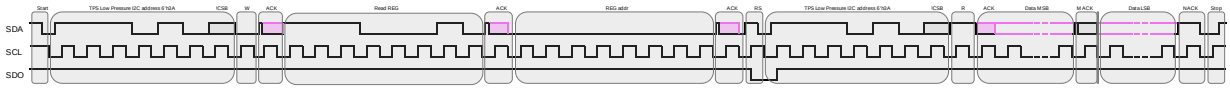


Figure 31: I2C read REG command

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 …

8.4.11 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.

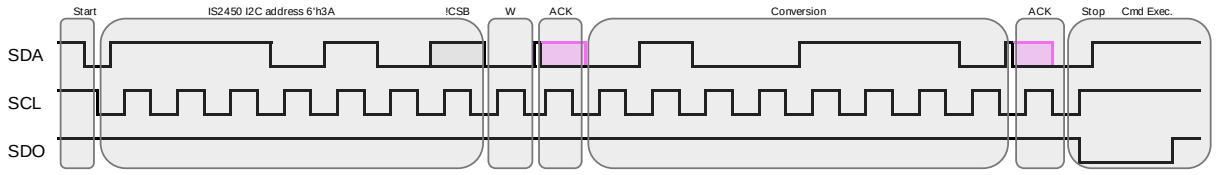


Figure 32: I2C conversion command

8.4.12 Read ADC

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

- The settings of the T1, and P flags within the command itself.

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, the 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 two 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 been fully completed.

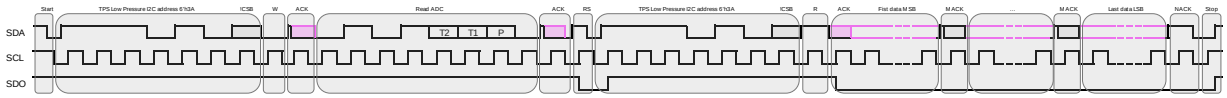


Figure 33: I2C read ADC

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8.4.13 Erase NVM

The Erase NVM command deletes the 16-bit data at the selected address. After erasing the 16-bit, the data is undefined and must be programmed to 0 or 1 before a reading can be done on the specific address.

In the following command, the chip autonomously erases the data which takes an additional time of 1.5 ms typical to 3 ms maximum where the chip is busy.

No burst mode was implemented for this command.

Erase NVM address range goes from 0 to 31. All MSBs of the address are ignored.

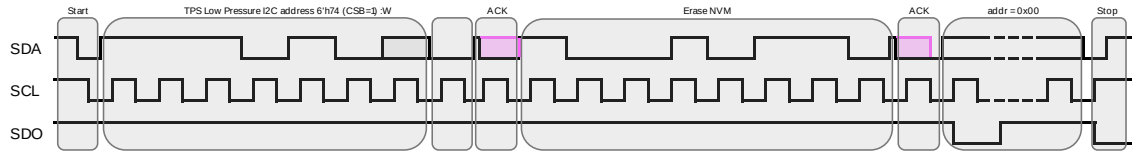


Figure 34: I2C erase NVM command

8.4.14 Write NVM

The write command for NVM consists of two parts. The first part sets the chip into the Write NVM-Mode and transfers the data to be written. After that, the chip autonomously programs the data to the NVM which takes an additional time of 1.5 ms typical to 3 ms maximum where the chip is busy.

No burst mode was implemented for this command.

Write NVM address range goes from 0 to 31. All MSBs of the address are ignored.

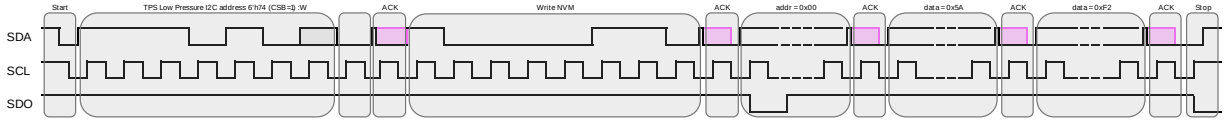


Figure 35: I2C Write NVM command

8.4.15 Read NVM

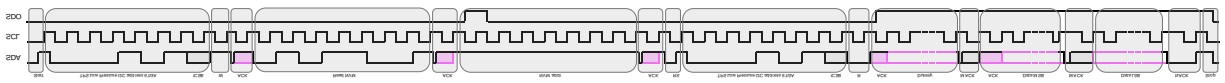
The read NVM command consists of two parts. The first Part sets the chip into the Read NVM-Mode. The user must wait just after the first command byte, “0.5 µs + Tosc_on(= 11.3 to 17.6us)“ until the chip has internally transferred the data from the NVM to the read-out register. This is signalled to the user by SDO going high after the command and address have been sent. After SDO goes high (data ready) a dummy byte (eight SCL clocks) is needed before the real output data is available on SDO.

No burst mode implemented for this command.

Read NVM address range goes from 0 to 31. All MSBs of the address are ignored.

Prior to any read operation, it is recommended to have the bit fast_start set to 1 in the registers to reduce the latency by removing Tosc_on from the waiting time.

Warning: Performing a read operation after an Erase is invalid as both floating gates of the differential storage have been initialized to the off state



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. Part description

Part Description

TPS-xxxMx-xAxN-00-T

Product family

TPS	TE Pressure Sensor

Maximum pressure

025	25
040	40
050	50
070	70
100	100

Pressure unit

M	mbar

Pressure Type

Y	Asymetric differential[1]
D	Symmetric Differential[2]
G	Gage[3]

Package Type and Porting

C	SOIC-16 w/ dual vertical porting
B	SOIC-16 w/ dual horizontal porting
K	SOIC-16 w/ manifold port

Shipment

T	Tape & Reel

Counter for custom options

00	Standard

Special protection

N	None

Output

1	Standard I^2C address
2	Alternative I^2C address
B	Standard I^2C address / Analog

Supply voltage

A	3-5V

Notes :

1. **Minimum pressure is -5 mbar as standard.**
2. **Minimum pressure is negative value of maximum pressure**
3. **Minimum pressure is 0 mbar.**

For specific part request, please contact TE representative for support.

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Table of Figures

Figure 1: Digital Output / %FS Output 4
Figure 2 Measurement cycles 16
Figure 3 Measurement cycles 16
Figure 4: Filter behavior of a noise signal jumping from 0 to 100 using k=0.8 and 32 16
Figure 5: FIFO principle 18
Figure 6. FIFO full mode operation 19
Figure 7: Measurement cycles for example 1 21
Figure 8: FIFO content for example 1 21
Figure 9: Measurement cycle for example 2 22
Figure 10: FIFO content for example 2 22
Figure 11: DAC clipping voltage on the low side 24
Figure 12: DAC clipping voltage on the high side 24
Figure 13: Ratiometric analog output 25
Figure 14: Absolute 3V analog output 26
Figure 15: Absolute 5V analog output 26
Figure 16: Interrupt & Diagnostic enable bit in the NVM 28
Figure 17: Application circuit for Manifold I2C 31
Figure 18: Application circuit Dual-port I2C 31
Figure 19: Operation Diagram 32
Figure 20: TPS Low Pressure sensor I2C application circuit 35
Figure 21: Sensor ID 36
Figure 22: I2C Read Sensor ID 36
Figure 23: I2C Refresh command 36
Figure 24: I2C Reset command 37
Figure 25: I2C write configuration register command 37
Figure 26: I2C read configuration register command 38
Figure 27: I2C start automatic mode command 38
Figure 28: I2C stop automatic mode command 38
Figure 29: I2C write operating mode command 38
Figure 30: I2C write REG command 39
Figure 31: I2C read REG command 39
Figure 32: I2C conversion command 39
Figure 33: I2C read ADC 39
Figure 34: I2C erase NVM command 40
Figure 35: I2C Write NVM command 40

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List of Tables

Table 1: User memory 12
Table 2: Memory content 13
Table 3: OPER register 14
Table 4: Operating register definition 14
Table 5: Delay 14
Table 6: Configuration register 15
Table 7: Configuration register definition 15
Table 8 the ratio between pressure and temperature in automatic mode. 15
Table 9 IIR filter. 17
Table 10: Over sampling ratio (accuracy of the conversion) 17
Table 11: COM register 18
Table 12: COM register definition 18
Table 13: OPER register 18
Table 14: FIFO mode 18
Table 15: FIFO Interrupt threshold 20
Table 16: FIFO example 1 configuration 21
Table 17: FIFO example 2 configuration 22
Table 18: dac_mode[2:0] 23
Table 19: dac_clip_h[2:0] 24
Table 20: dac_clip_l[2:0] 24
Table 21: Error & Interrupt signaling 25
Table 22: Interrupt & Diagnostic registers 28
Table 23: User commands 34
Table 24: Commands acceptance 34
Table 25: Manifold I2C address 35
Table 26: Dual-Port I2C address 35
Table 27: Write config command address vs register address 37
Table 28: read config command address vs register address 38

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