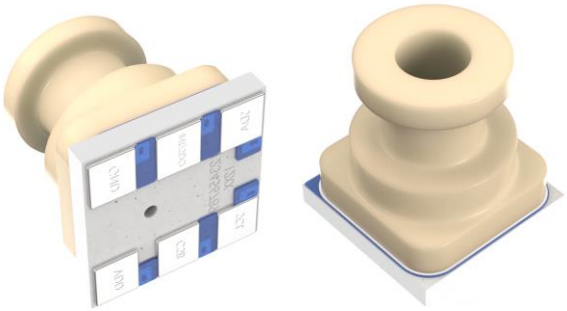

MS5547-02BD

Small differential (gage) SMD package 2 bar pressure sensor

Features

- High resolution module
- Fast conversion down to 0.37 ms
- Low power down to 0.34 µA (standby < 0.1 µA at 25°C)
- Ceramic-plastic package 4 x 4 x 3.03 mm3
- Supply voltage 1.6 V to 3.6 V
- Integrated digital pressure sensor (24 bits ΔΣ ADC)
- Operating range: -200/+2200 mbar, -20°C/+85 °C
- SPI or I2C interface
- No external components (Internal oscillator)
- Excellent long-term stability
- Built-in automatic conversion
- Signaling state by interrupt
- Programmable filter
- Built-in FIFO

Applications

- Air and non-corrosive gases pressure measurements
- Medical instruments
- E-cigarettes
- Wearables

Description

The MS5547 is a new generation of high-resolution gauge pressure sensors from TE Connectivity with SPI or I^2C bus interface.

The sensor module includes a high linearity pressure sensor and an ultra-low power 24-bits ΔΣ ADC with internal factory calibrated coefficients. It provides a precise digital 24-bits pressure and temperature value and different operation modes that allow the user to optimize for conversion speed and current consumption. The MS5547 can be interfaced to virtually any microcontroller.

Small dimensions of 4 mm x 4 mm x 3 mm and low power consumption allows easy integration in user applications. This new sensor module generation is based on leading MEMS technology and latest benefits from TE proven experience and know-how in high volume manufacturing of sensors modules, which have been widely used for over three decades.

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PERFORMANCE SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Supply voltage	V_{DD}		-0.3		+3.6	V
Storage temperature	T_S		-55		+150	°C
Proof pressure	proof	TBD			6	bar
Burst pressure	burst	TBD			10	bar
Maximum Soldering Temperature (1)	T_{max}	IPC/JEDEC J-STD-020E			250	°C
Moisture Sensitivity Level	MSL	IPC/JEDEC J-STD-020E		3		
ESD rating		Human Body Model	-4		+4	kV
Latch up		JEDEC standard No 78	-100		100	mA

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Operating Supply voltage	V_{DD}			1.6	3.0	3.6	V
Operating Temperature	T			-40	+25	+85	°C
Supply current (1 sample per sec.)	I_{DD}	OSR	6		16.74		µA
			5		8.41		
			4		4.25		
			3		2.16		
			2		1.12		
			1		0.60		
			0		0.34		
Peak supply current		during conversion			1.17		mA
Standby supply current		at 25°C (V_{DD} = 3.0V)			0.02	0.1	µA
VDD Capacitor		From V_{DD} to GND			100		nF

ANALOG DIGITAL CONVERTER (ADC)

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Output Word					24		bit
Conversion time (3)	t_c	OSR	6		16.40	18.04	ms
			5		8.24	9.07	
			4		4.16	4.58	
			3		2.12	2.34	
			2		1.10	1.22	
			1		0.59	0.65	
			0		0.33	0.37	

(3): Maximum values must be used to determine waiting times in I2C communication

PERFORMANCE SPECIFICATIONS (CONTINUED)

PRESSURE OUTPUT CHARACTERISTICS (VDD = 3 V, T = 25°C UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Typ.	Max	Unit
Operating Pressure Range	P_{range}	Full Accuracy	-200		+2200	mbar
Absolute Accuracy Temperature range: 0 … 85°C	-200mbar to 1200mbar			±5		
Absolute Accuracy Temperature range: -20 … 0°C				±15		
Absolute Accuracy Temperature range: 0 … 85°C	1200mbar to 2000mbar			±8		
Absolute Accuracy Temperature range: -20 … 0°C				±20		
Maximum error with supply voltage (1)	V_{DD} = 1.5 V … 3.6 V			±2		
Long-term stability				TBD		mbar/yr
Reflow soldering impact	IPC/JEDEC J-STD-020C			0.5		mbar
Recovering time after reflow (2)				2		days
Resolution RMS	OSR	6		0.023		mbar
		5		0.032		
		4		0.044		
		3		0.062		
		2		0.089		
		1		0.127		
		0		0.24		

TEMPERATURE OUTPUT CHARACTERISTICS (VDD = 3 V, T = 25°C UNLESS OTHERWISE NOTED)

Parameter	Conditions		Min.	Typ.	Max	Unit
Absolute Accuracy	0...85°C			±1		°C
	-40..0°C			±8		
Maximum error with supply voltage	V_{DD} = 1.5 V … 3.6 V			TBD		°C
Resolution RMS	OSR	6		0.0009		°C
		5		0.0009		
		4		0.0011		
		3		0.0016		
		2		0.0022		
		1		0.0033		
		0		0.007		

(1) With autozero at 3V point
(2) Time to recover at least 66% of the reflow impact.

PERFORMANCE SPECIFICATIONS (CONTINUED)

DIGITAL INPUTS (SCL, SDA)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock I2C	SCL				3.4	MHz
Serial data clock SPI				10	20[3]	MHz
Input high voltage	V_{IH}		80% V_{DD}		100% V_{DD}	V
Input low voltage	V_{IL}		0% V_{DD}		20% V_{DD}	V
Input leakage current	$I_{leak25°C}$ $I_{leak85°C}$	at 25°c at 85°C		0.01 0.25	0.14 1.40	µA µA

DIGITAL OUTPUTS (SDA)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Output high voltage	V_{OH}	I_{source} = 1 mA	80% V_{DD}		100% V_{DD}	V
Output low voltage	V_{OL}	I_{sink} = 1 mA	0% V_{DD}		20% V_{DD}	V

[3] Depending on the bus capacitive load

PRESSURE AND TEMPERATURE CALCULATION

GENERAL

The MS5547 consists of a piezo-resistive sensing element and an interface IC. The main function of the MS5547 is to provide a 24-bit pressure and temperature representation out of the uncompensated analog output voltage from the piezo-resistive sensing element.

FACTORY CALIBRATION

Every module is individually factory calibrated. As a result, 11 coefficients necessary to compensate for process variation are calculated and stored in sensor memory. These bits must be read by the microcontroller software and used in the program converting D1 and D2 into compensated pressure and temperature values.

PRESSURE AND TEMPERATURE COMPUTATION

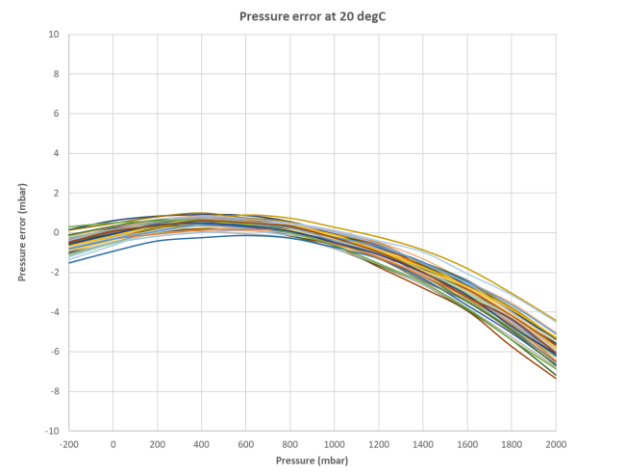
1. Read calibration data from memory
2. Read digital pressure and temperature data
3. Calculate pressure and temperature using the following formulas:

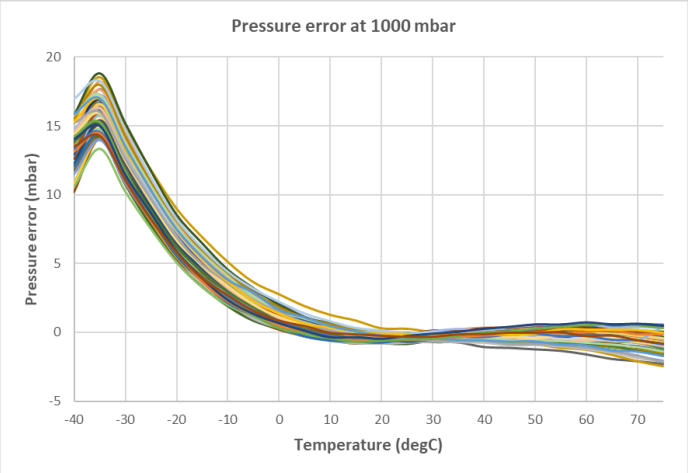
$$T[°C] = -C1 * 2^{-7} + [-C2 * 2^{-37} + 2 * 10^{-7}] * D1 + C3 * 2^{-29} * D2 - C4 * 2^{-54} * D2^2$$

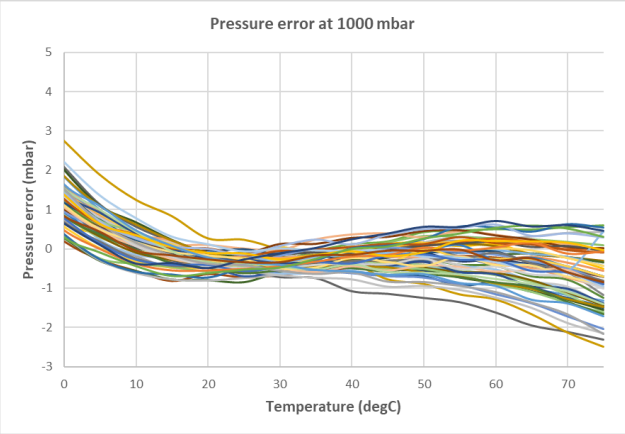
$$P[mbar] = -C5 * 2^{-3} + C6 * 2^{-26} * D1 - C7 * 2^{-26} * D2 + C8 * 2^{-55} * D1^2 - C9 * 2^{-53} * D2^2 + C10 * 2^{-49} * D1 * D2$$

SENSOR ACCURACY

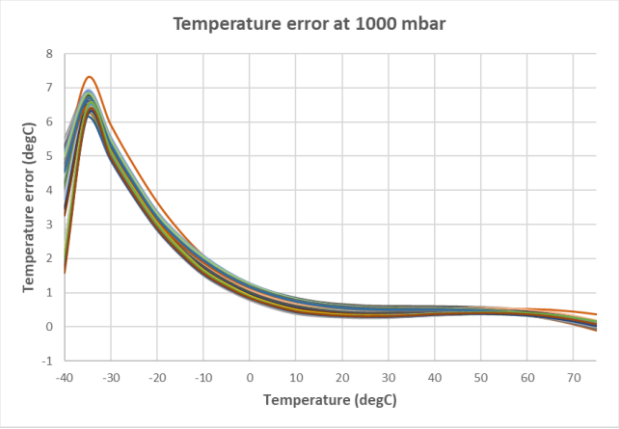
PRESSURE ERROR ACCORDING TO TEMPERATURE ON FULL PRESSURE RANGE

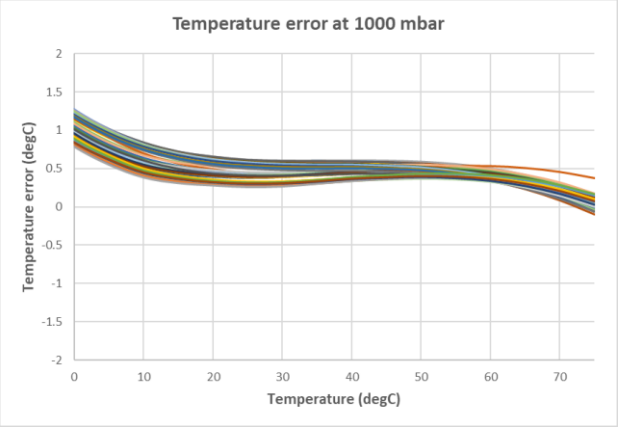






TEMPERATURE ERROR ACCORDING TO TEMPERATURE





POWER ON (PON)

MS5547 has a built-in power on circuit (PON). After the power up, the digital block will be in reset state and the NVM values are loaded into the digital part. CRC is calculated and compared with the programmed value. This sequence lasts about 100 to 260 µs. During the power on sequence, SDO is pulled low. Once initialization finished SDO goes high again to signal the chip is ready for operation. The same procedure of data reload will happen after a reset or refresh command.

MEMORY (NVM) MAPPING

Memory bits on the address 0 and 1 are reserved for the IC setting behavior. The memory is displayed as seen from the SPI and I2C interface.

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	Reserved															
1	Reserved															
2	Serial number															
3	Serial number															
4	C1 [15:0]															
5	C2 [15:0]															
6	C3 [15:0]															
7	C4 [15:0]															
8	C5 [15:0]															
9	C6 [15:0]															
10	C7 [15:0]															
11	C8 [15:0]															
12	C9 [15:0]															
13	C10 [15:0]															
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	CRC[7:0]							

Table 1: Memory mapping

C1 to C6 - Coefficients defined during factory calibration of each single sensor used to calculate compensated pressure and temperature

CRC[7:0] - CRC value of memory

REGISTERS

OPERATING REGISTER

Operating register allows to set various modes like the FIFO mode and the delay in automatic measurement mode.

Operating Mode	D[15:13]	D[12:8]	D[7:6]	D[5:4]	D[3:0]
Default	000	00000	00	00	0000
Code	**Spare**	**FIFO int threshold**	**FIFO mode**	**Not used**	**Delay**
0: 0000	0	off	off		off
1: 0001	1	1	full mode		5 ms
2: 0010	2	2	update mode		10 ms
3: 0011	3	3	update mode		20 ms
4: 0100	4	4			50 ms
5: 0101	5	5			0.1 sec
6: 0110	6	6			0.2 sec
7: 0111	7	7			0.5 sec
8: 1000		8			1 sec
9: 1001		9			2 sec
A: 1010		10			5 sec
B: 1011		11			10 sec
C: 1100		12			20 sec
D: 1101		13			60 sec
E: 1110		14			60 sec
F: 1111		15			60 sec
↓		↓			
1F: 11111		31			

Table 2: Operating Register content

FIFO interrupt threshold – triggers the interrupt if n measurements are ready in the FIFO
FIFO mode – is the FIFO operation: 0 = off; 1 = stop at FIFO full; 2,3 = overwrite at FIFO full
Delay – is the time between automatically triggered measurements

Delay bits [3:0] configures the time between the first measurement finished and the next is started. Measurement can be understood as a pair of pressure and temperature conversions, if so configured. The automatic mode does not start if the ratio of p and T are off in the Configuration Register.
During automatic measurement all user commands are accepted, except 'conversion' and 'write config' command. Automatic mode can be stopped by setting the **Delay** = off. In case off an already started conversion is running, automatic triggering of new conversion will be stopped, but started conversions will finish and ratio counter will be reset, after completing the requested started set of measurements (p, T).

As soon as the **Delay** bits are set, automatic measurement starts according to the setup selected.

Setting **FIFO mode** bits[7:6], starts FIFO operation according to the mode selected, until it will be switched off by resetting FIFO mode bits.

The **FIFO interrupt threshold** allows to program the number of samples stored before interrupt flag will be raised. If FIFO Interrupt Threshold bits are off, the interrupt flag is never activated.

CONFIGURATION REGISTER

To Write/Read in P_CONF_REG or in T_CONF_REG, the following address mapping are valid

	User Commands							
	7	6	5	4	3	2	1	0
Name	CMD	CMD	CMD	CMD/adr	CMD/adr	CMD/adr	CMD/adr	Stop
Write Config	0	0	1	0	0	adr1	adr0	x
Read Config	0	0	1	0	1	adr1	adr0	x

	Adr1	Adr0
P_CONF_REG	0	0
T_CONF_REG	0	1

Table 3: Write/Read Configuration Register Command

T/P config register	D[15:13]	D[12]	D[11]	D[10:8]	D[7:5]	D[4:3]	D[(2:0]
default	000	0	0	000	000	00	000
code	**Reserved**	**Reserved**	**Reserved**	**Ratio**	**Filter**	**Resolution**	**OSR**
000				off	off	24 bit	0
001				1	2	16 bit	1
010				2	4	8 bit	2
011				4	8	8 bit	3
100				8	16		4
101				16	32		5
110				32	32		6
111				32	32		6

Table 4: Configuration register

Filter – filter coefficient of the moving average: 0 = filter off

Resolution – defines the number of bit's sent when an ADC read command is executed

OSR – defines the oversampling ratio (accuracy of the conversion). The delay for automatic conversion is set in the operating mode register.

Ratio – defines different combination of conversion ratios for temperature and pressure

Example:

Delay = 1 sec, p_reg_ratio = 1, T_reg_ratio = 4; yields in starting one pressure conversion every second for one temperature conversion every 4 seconds. In case of the FIFO mode selected, the latest temperature converted is always copied to store a pair of measurements in the FIFO.

FIFO: (p0, T0), (p1, T0), (p2, T0), (p3, T0), (p4, T4), (p5, T4), (p6, T4), (p7, T4), (p8, T8), ….

In the special case where in the automatic mode both ratios were bigger than one like for example p_reg_ratio = 2 and T_reg_ratio = 4 every second conversion is not done. The FIFO content will look like:

FIFO: (p0, T0), (p2, T0), (p4, T4), (p6, T4), (p8, T8), (p10, T8), (p12, T12), (p14, T12), (p16, T16), ….

In the phase where the timer triggers an event, but no conversion is scheduled due to all ratios >=2, MCLK will turn on for handling the state machine and SDO will show a short busy state.

The **Resolution** defines how many bits are sent to the controller when a Read ADC command is sent. This means if p_reg resolution = 24 and T_reg resolution = 16, the Read ADC_T 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.

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

While conversion is running or in the automatic mode, the ‘Write Config’ command is not accepted

LIMIT REGISTERS FOR PRESSURE & TEMPERATURE

Limit register may be used to program low and high threshold values for the pressure and temperature RAW data. If ADC results are outside these limits, the according flag in the interrupt register will be set, and if the mask is activated an interrupt will be raised at the INT pin. At startup the limits are set to 0000h for low and FFFFh for the high limits. Limit's stored in D[15:0] are compared with the 16 MSB's of the ADC results after filtering (if the filter is on).

Comparison is only done at the end of conversion with the limit value already available.

In case of the limit is updated after a finished conversion, comparison is not performed again. Also, in automatic mode if Ratio > 1, comparison is only done once.

	User Commands							
	7	6	5	4	3	2	1	0
Name	CMD	CMD	CMD	CMD/adr	CMD/adr	CMD/adr	CMD/adr	Stop
Write Limits	0	0	1	1	0	adr1	adr0	x
Read Limits	0	0	1	1	1	adr1	adr0	x

Addr	Limit Registers	D[15:0] (Default)
00	T_low	0000h
01	T_high	FFFFh
10	p_low	0000h
11	p_high	FFFFh

Table 5: Write/Read Limit Register command

INTERRUPT & INTERRUPT MASK REGISTER

MS5547 ASIC as the capability to raise an interrupt for some different conditions listed in Table 7. Interrupt (INT) external signal is only activated if the according interrupt mask enable bit is set.

At startup, all interrupt mask enable bits are set to 0.

Interrupt register may be read by the user. The interrupt flag must be cleared by the user by writing a one into the according register bit after handling the interrupt.

	User Commands							
	7	6	5	4	3	2	1	0
Name	CMD	CMD	CMD	CMD/adr	CMD/adr	CMD/adr	CMD/adr	Stop
Write Interrupt Mask	0	0	0	1	1	0	0	x
Read Interrupt Mask	0	0	0	1	1	0	1	x
Write Interrupt Reg	0	0	0	1	1	1	0	x
Read Interrupt Reg	0	0	0	1	1	1	1	x

Table 6: Write/Read interrupt mask and register

Register	7	6	5	4	3	2	1	0
Interrupt	CRC error	p_high	p_low	T_high	T_low	FIFO full	FIFO threshold	ADC done
Mask Enable default	0	0	0	0	0	0	0	0

Table 7: Interrupt register

CRC – register CRC check status: 0 = OK, 1 = CRC failed
p_high – pressure high limit, is set to 1 if the pressure conversion output > p_high
p_low – pressure low limit, is set to 1 if the pressure conversion output < p_low
T_high – pressure high limit, is set to 1 if the pressure conversion output > T_high
T_low – pressure low limit, is set to 1 if the pressure conversion output < T_low
FIFO full – is set to 1 of the FIFO contains 32 unread values
FIFO threshold – is set to 1 of the FIFO contains n unread values (n is set in the operation register)
ADC done – is set to 1 if the ADC conversion has finished

Mask Enable – enables the corresponding interrupt: 0 = interrupt not seen at INT; 1 = interrupt seen at INT

Write Interrupt '0000 0101' will clear the FIFO full and ADC done interrupt leaving the others untouched.

All interrupts will flag immediately when they appear. This means if a conversion T and p is requested by the

command, instantaneously after the T the T_high and T_low limits are updated in the interrupt register and the interrupt output INT is raised in case it is enabled, even the p conversion is pending. Reading T and p after a T_low or T_high interrupt will give the actual T_ADC but the previous pressure in case the pressure conversion has not finished yet.

This is also the case for the ADC done. If a T and p is requested already after the T is available the ADC done flag is set and also the interrupt output INT is raised if the ADC done mask is 1, also the p conversion is pending. Be careful, reading now just after the first interrupt the T and p will result in the latest T_ADC value and the previous p_ADC value.

The sequence looks like:

T1, p1 available -> run T and p -> start T -> ADC done raised -> T2, p1 available -> start p -> ADC done raised again (if cleared in between) -> T2, p2 available.

FIFO OPERATION

MS5547 FIFO Registers can store 32 pairs of temperature and pressure data. Reading is done as first in and first out.

There is two operating modes, configured by setting Operating Register bits[7:6] (See page 10).

- FIFO Full mode
- FIFO Update mode

In **Full mode**, the register is filled with all incoming conversions until the 32 pairs are completed.

In **Update mode**, once the register filling is completed, the 1st value stored are replaced by the new converted one, then the 2nd is replaced, and so on indefinitely.

FIFO storage capability may be used either in single conversion mode or in automatic storage mode.

Read ADC values from FIFO registers
Once a 'Read' command is received, data where read cursor is pointing to are send through the communication lines. After the reading procedure whether successful or interrupted, the read cursor position will stay until the next Read command is issued. In other words, the Read cursor is incremented at the beginning of the reading process. This means if the current reading is not properly performed, this value is lost, and the next FIFO access will return the following value.

In FIFO **Full mode**, it's possible to store and retrieve 32 values before FIFO register will start to discard newly converted values (see Figure 1).

In **Update mode**, it's only possible to retrieve 31 values. This avoid the Write and the Read cursor addressing the same FIFO value (see Figure 1).

FIFO threshold can be selected in Operating Register (refer to Table 2: Operating Register content). It is possible to set a FIFO threshold from 1…31. An interrupt upon FIFO threshold (refer to Table 7: Interrupt register) will be raised as soon as the FIFO reaches the number of data samples.

For example, if FIFO threshold = 5, the interrupt flag will be raised once Write cursor is 5 data samples ahead of the Read cursor; then 5 data samples may be read.

The **FIFO interrupts** can be set only after conversion finishes. The FIFO storage ill not stop once threshold is reached and continues to fill in the 32 positions until it will be full.

Switch off FIFO mode
FIFO mode is switched off by setting **FIFO mode** bits[7:6] (see Table 2: Operating Register content) to off in the operating register. Once done FIFO registers will be emptied and both cursors will be reset.

FIFO combined with automatic mode
Since automatic mode has been started, access to Configuration Registers is no more available, therefore configuration of both p & T should be set as expected, before activating automatic mode.

In automatic mode when **Ratio** is set for example p_reg_ratio = 1, T_reg_ratio = 4, a pressure conversion is done every cycle for only a temperature conversion every 4'th cycle. In this case the latest available temperature is copied to have always pairs of measurements in the FIFO.

Example:

FIFO: (p0, T0), (p1, T0), (p2, T0), (p3, T0), (p4, T4), (p5, T4), (p6, T4), (p7, T4), (p8, T8), ….

In the particular case where in the automatic mode both ratios are different than 1, like for example p_reg_ratio = 2 and T_reg_ratio = 4, every second conversion is not done. The FIFO content will look like:

FIFO: (p0, T0), (p2, T0), (p4, T4), (p6, T4), (p8, T8), (p10, T8), (p12, T12), (p14, T12), (p16, T16), ….

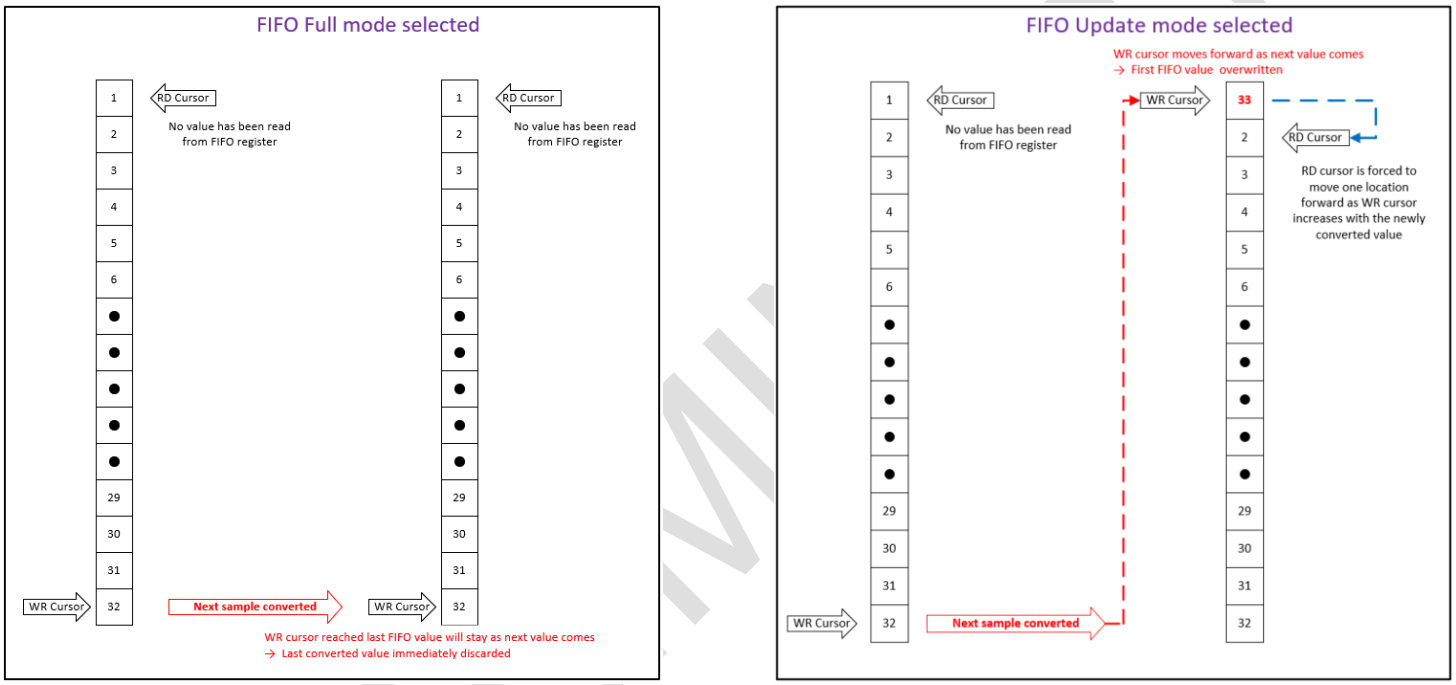


Figure 1: FIFO Modes

FILTER

MS5547 has built-in filter selectable from off (mode without filter) to 32 (maximum filtering). It calculates a moving average based on the filter coefficient.

$$y = y' - y'/k + x/k$$

Once the filter is switched on, the next conversion result of the ADC is used as start value. To restart the filter, it needs to be switched off and on again.

The settling time for a big jump to reach 90% of the final value is 2.2 x k samples. The rms noise is reduced by a factor of:

Filter	Noise reduction factor
off	1.00 +/- 0.00
2	1.73 +/- 0.07
4	2.65 +/- 0.21
8	3.87 +/- 0.50
16	5.54 +/- 1.00
32	7.80 +/- 2.00

Table 8: Filter noise reduction

SERIAL INTERFACES

COMMAND STRUCTURE

The MS5547 can be operated with the following commands

1. Reset
2. Refresh Register
3. Read / Write operating mode
4. Read / Write interrupt mask
5. Read / Write interrupt register
6. Read / Write configuration register
7. Read / Write threshold register
8. Start conversion
9. Read ADC result register
10. Read register

Size of each command is 1 byte (8 bits) as described in the Table 9 below.
ADC read command will return 24 bits result of the above requested finished conversion.
Same commands are used in both SPI and I²C modes.

	User Commands							
	7	6	5	4	3	2	1	0
Name	CMD	CMD	CMD	CMD/adr	CMD/adr	CMD/adr	CMD/adr	Stop
Reset	0	0	0	1	0	0	0	x
Refresh Register	0	0	0	1	0	0	1	x
Write Operating Mode	0	0	0	1	0	1	0	x
Read Operating Mode	0	0	0	1	0	1	1	x
Write Interrupt Mask	0	0	0	1	1	0	0	x
Read Interrupt Mask	0	0	0	1	1	0	1	x
Write Interrupt Reg	0	0	0	1	1	1	0	x
Read Interrupt Reg	0	0	0	1	1	1	1	x
Write Config	0	0	1	0	0	adr1	adr0	x
Read Config	0	0	1	0	1	adr1	adr0	x
Write Limits	0	0	1	1	0	adr1	adr0	x
Read Limits	0	0	1	1	1	adr1	adr0	x
Conversion	0	1	0	0	T	P	x	x
Read ADC	0	1	0	1	T	P	x	x
Read Register	1	1	1	adr3	adr2	adr1	adr0	x

Table 9: User commands table

SPI INTERFACE

The serial interface is a 4-wire SPI bus, operating as a slave. CSB (chip select bar), SCL (serial clock), SDA (serial data in), and SDO (serial data out) are used to interact with the SPI master. Communication with the chip starts when CSB is pulled to low and ends when CSB is pulled to high. SCL is controlled by the SPI master and idles low (SCL low on CSB transitions, mode 0). A mode where the clock alternatively idles high is also supported (mode 3).

As detailed in the following chapters, SDO is usually going low when a correct command is accepted and going high again when the chip is idle. If the chip is busy (SDO = low) and another command is sent, SDO stays low and is not able to indicate the command acceptance.

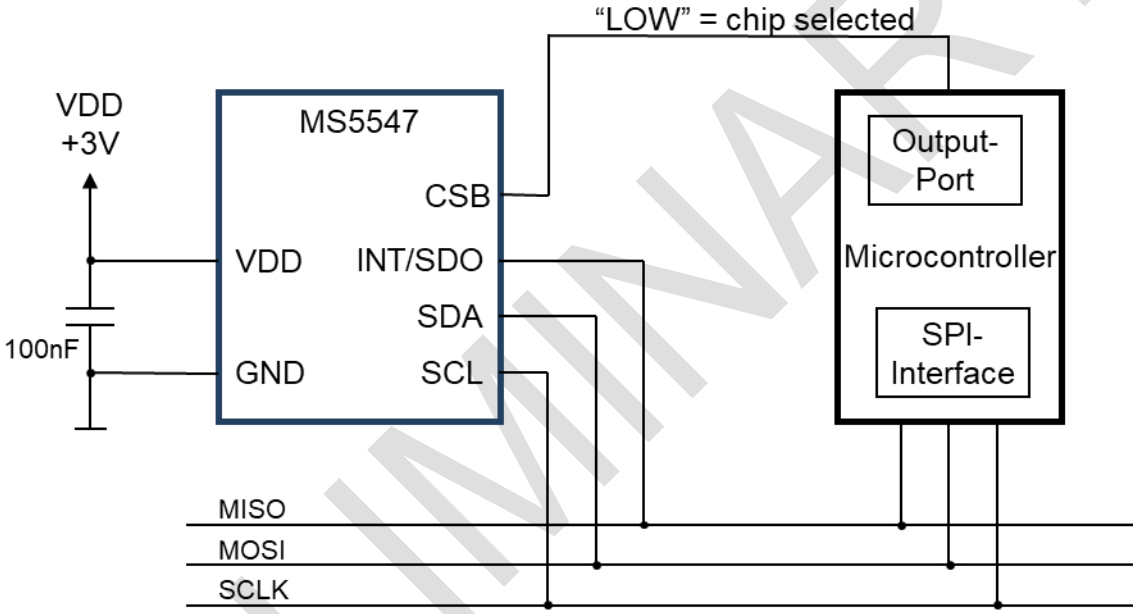


Figure 2: SPI protocol application circuit

POWER ON BEHAVIOR

MS5547 includes an internal power on circuit, which triggers when VDD has reached the operating level. Once the level reached, an internal procedure load and check the data from the NVM. User application must wait until this process finishes, before any command is allowed. Keeping CSB low allows to check when the startup has been completed. It's not mandatory to keep CSB low during startup. Loading time is depending on the setup of the CRC and reload bit and is in the range of 70 to 300 us.

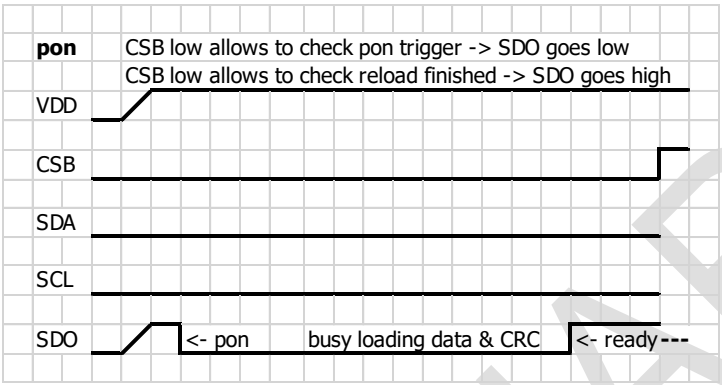


Figure 3: Power on behavior

RESET

The Reset sequence shall be sent once after power-on to make sure that the calibration data gets loaded into the internal register. It can be also used to reset the device from an unknown condition.
The reset can be sent at any time. If power on reset is not a successful, maybe caused by the SDA being blocked by the module in the acknowledge state, the only way to get the MS5547 to function is to send several SCLs followed by a reset sequence or to perform a power OFF-ON cycle.

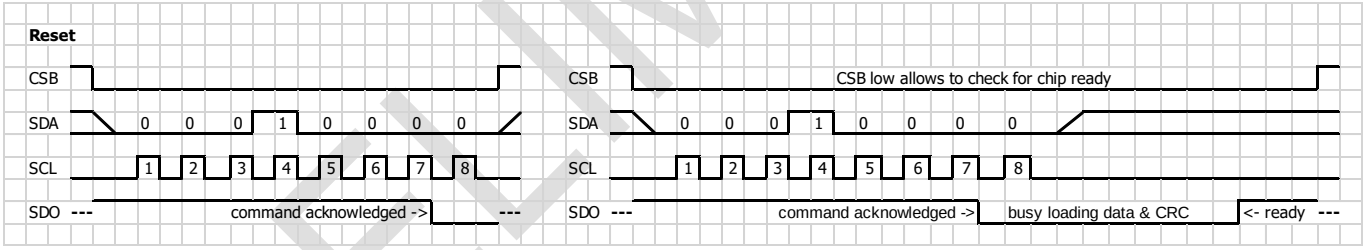


Figure 4: Reset in SPI mode 0

SDO going low indicates the command has been acknowledged. Keeping CSB low allows to check on SDO going high when the reset procedure finished, and the sensor is ready for operation. Loading time is depending on the setup of the CRC and reload bit and is in the range of 70 to 300 us.

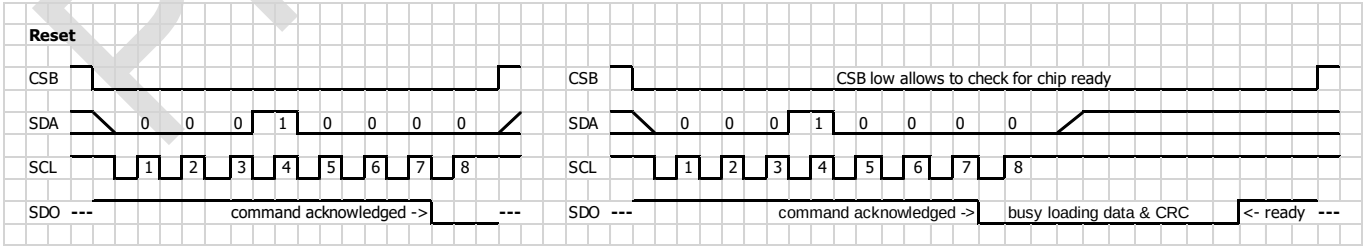


Figure 5: Reset in SPI mode 3

REFRESH REGISTER

During a refresh register command, the NVM data is transferred to the register. The internal data like configuration, operation mode and interrupt registers are not affected.

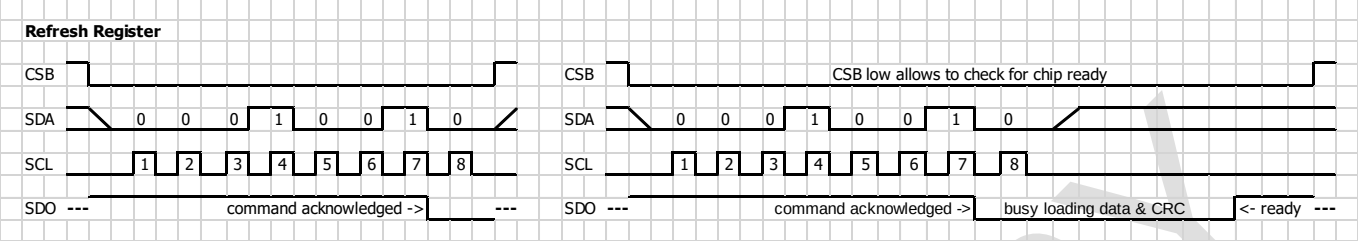


Figure 6: Refresh Register in SPI mode 0

SDO going low indicates that the command has been acknowledged. Keeping CSB low allows to check on SDO going high when the reset procedure has finished, and the chip is ready for operation. The loading time is also depending on the setup of the CRC and reload bit and is in the range of 70 to 300 us.

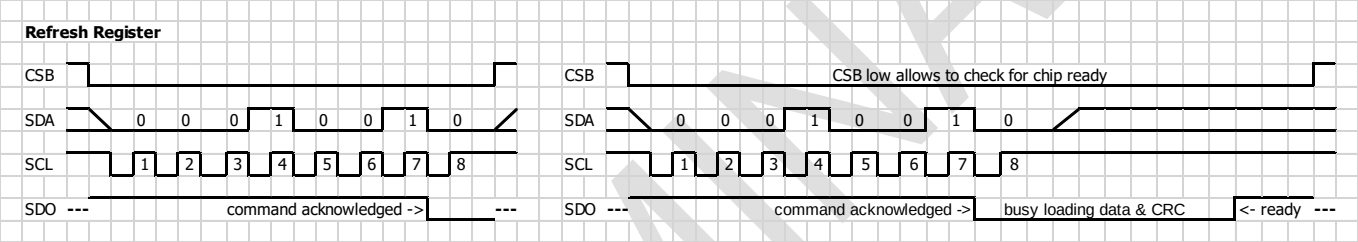


Figure 7: Refresh Register in SPI mode 3

WRITE OPERATION MODE

With the write operation mode command, the behavior of the FIFO and the automatic mode can be controlled.

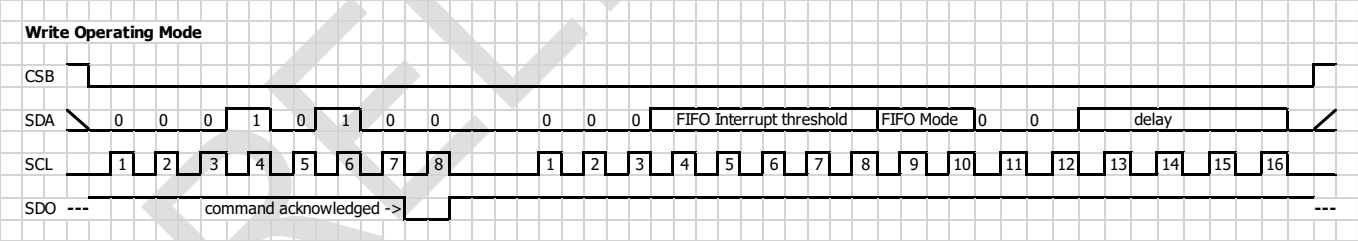


Figure 8: Write Operation Mode in SPI mode 0

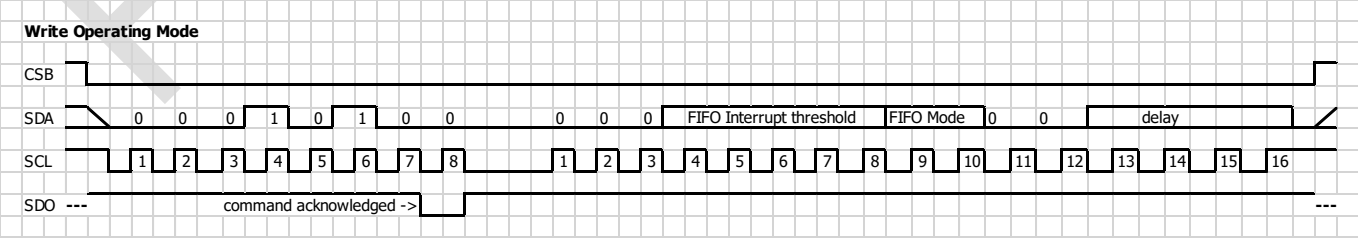


Figure 9: Write Operation Mode in SPI mode 3

READ OPERATION MODE

With the read operation mode command, the current setup can be read.

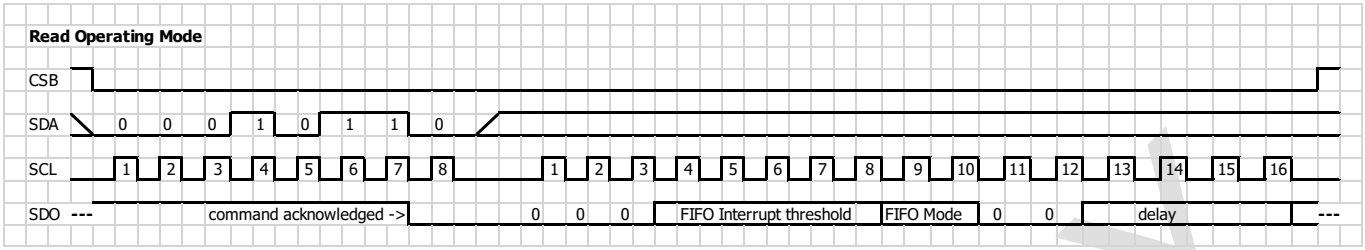


Figure 10: Read Operation Mode in SPI mode 0

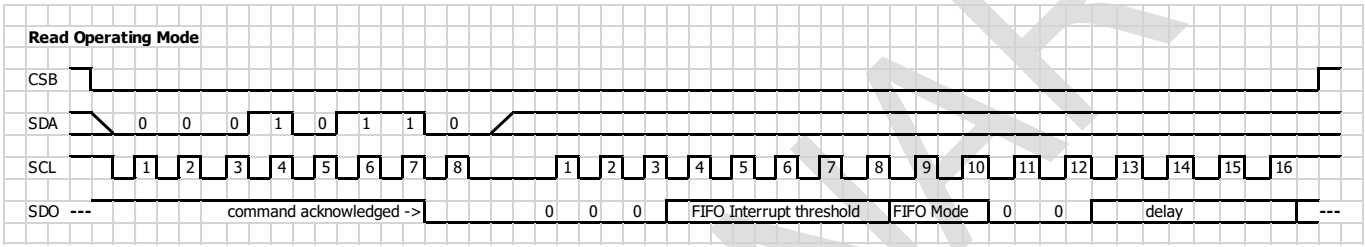


Figure 11: Read Operation Mode in SPI mode 3

WRITE INTERRUPT MASK

Write Interrupt Mask command allow to enable interruptions. Enabled interrupts are routed to the INT output pin which may trigger the user application to execute specific actions.

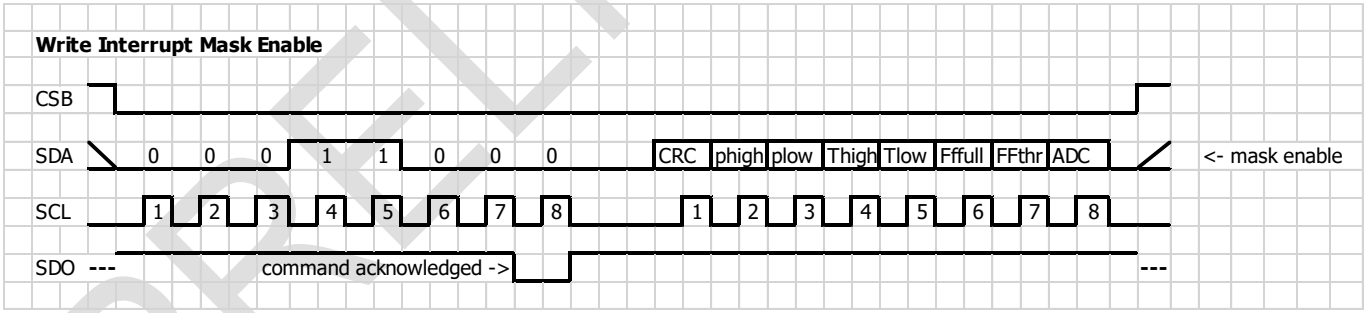


Figure 12: Write Interrupt Mask in SPI mode 0

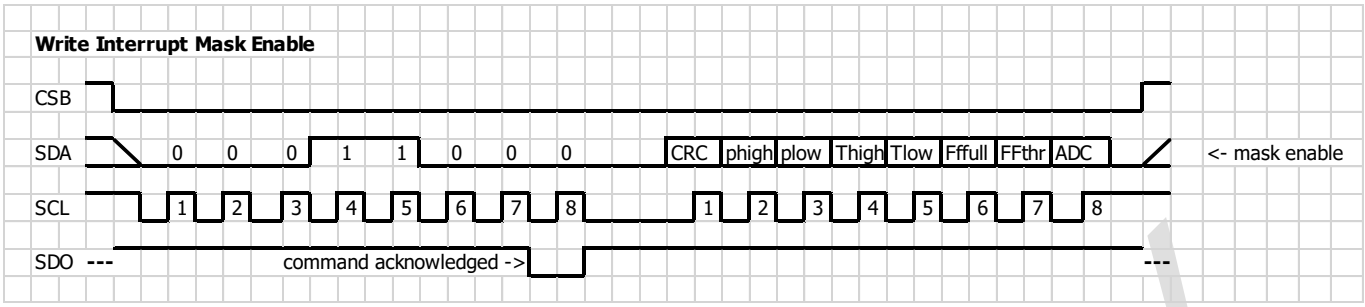


Figure 13: Write Interrupt Mask in SPI mode 3

READ INTERRUPT MASK

Read Interrupt Mask command allows to read the current configuration data in the interrupt mask register.

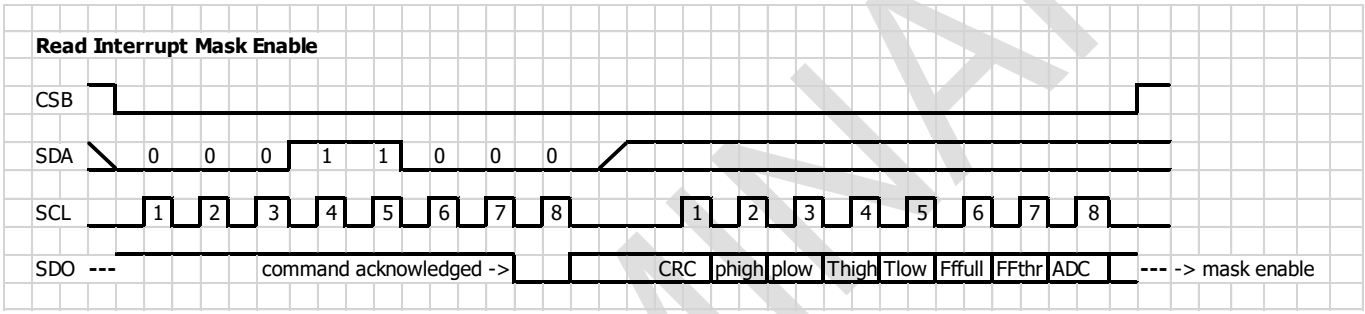


Figure 14: Read Interrupt Mask in SPI mode 0

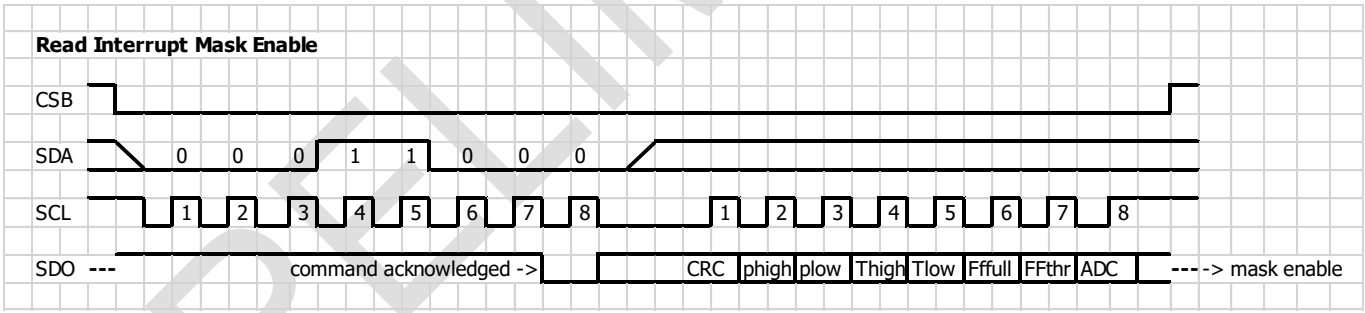


Figure 15: Read Interrupt Mask in SPI mode 3

WRITE INTERRUPT REGISTER

Write Interrupt Register command is used to clear the interrupts by the user application. Interrupts are not cleared automatically while reading the register, they must be cleared by writing a '1' to the desired position in the interrupt register.

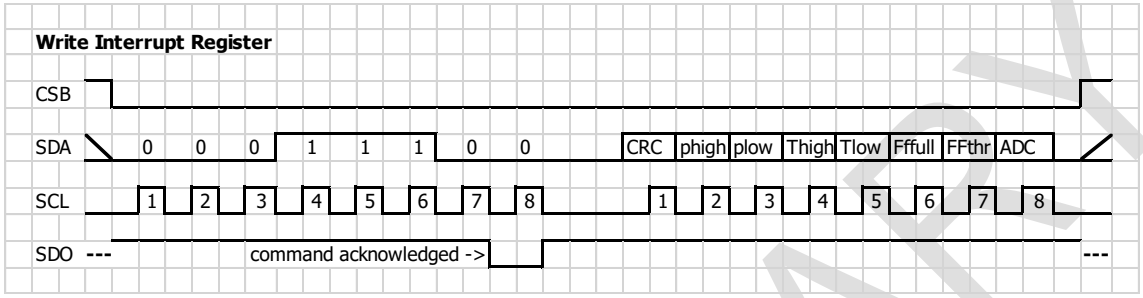


Figure 16: Write Interrupt Register in SPI mode 0

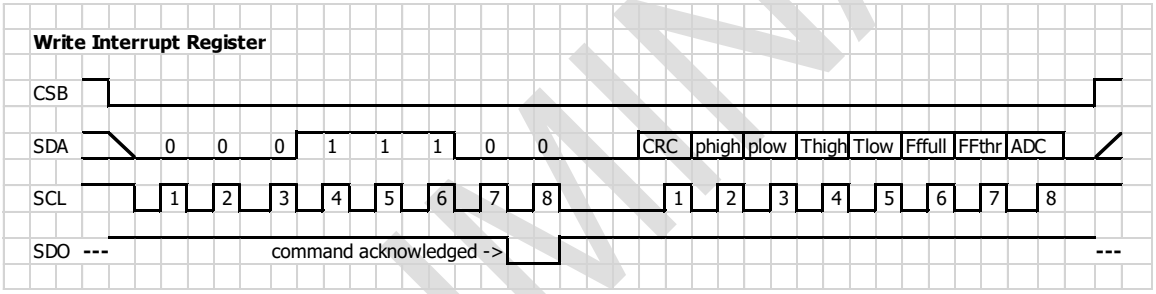


Figure 17: Write Interrupt Register in SPI mode 3

READ INTERRUPT REGISTER

Read Interrupt Register allows the user application to test what was the cause of the interruption raised signal at the INT output pin, or if the interrupt is not enabled to check what action has happened.

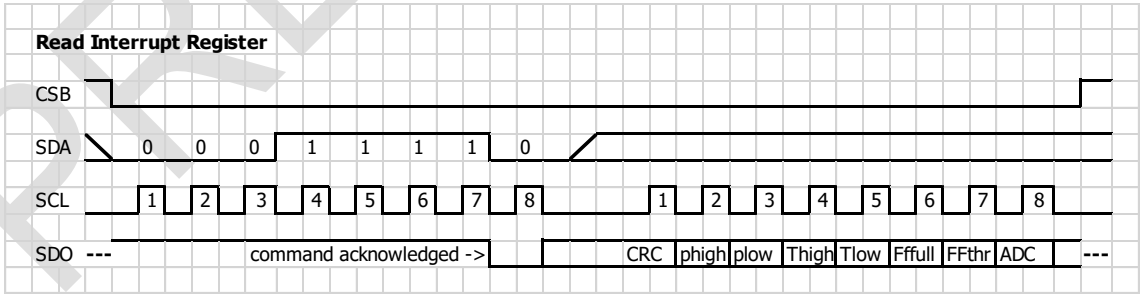


Figure 18: Read Interrupt Register in SPI mode 0

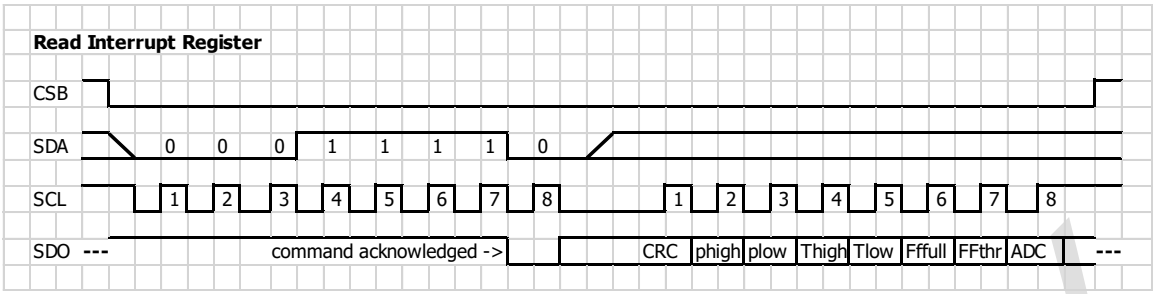


Figure 19: Read Interrupt Register in SPI mode 3

WRITE CONFIG

Write Config command allows to configure the ratio, filter, read resolution and OSR of each measurement type separately.
This command is not accepted during an ongoing conversion.

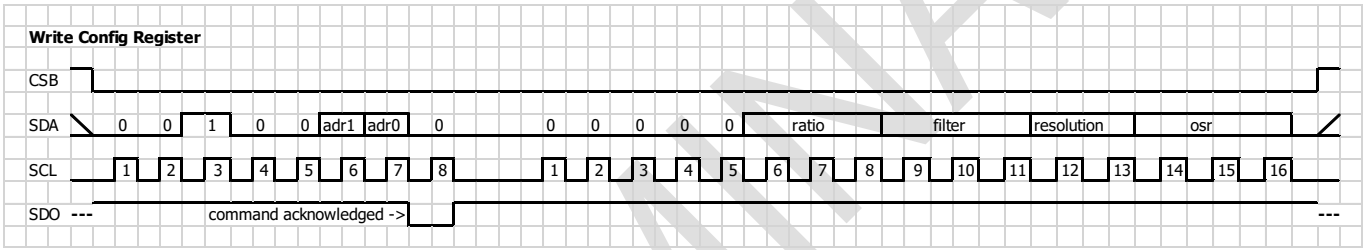


Figure 20: Write Config Register in SPI mode 0

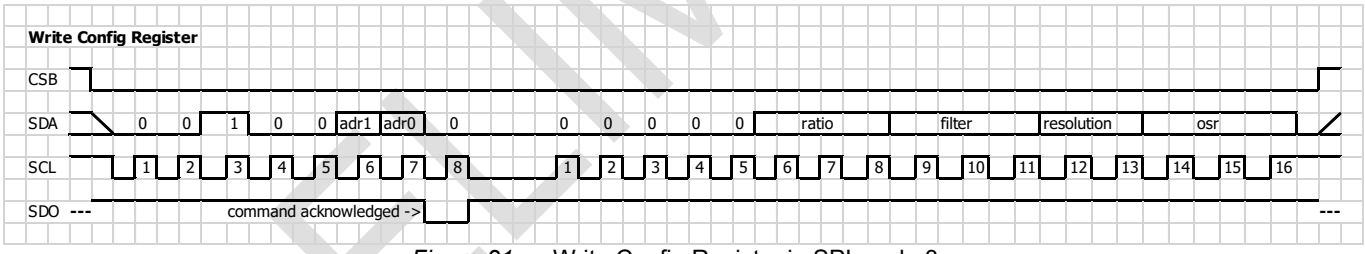


Figure 21: Write Config Register in SPI mode 3

READ CONFIG

Read Config command allows to verify the programmed configuration.

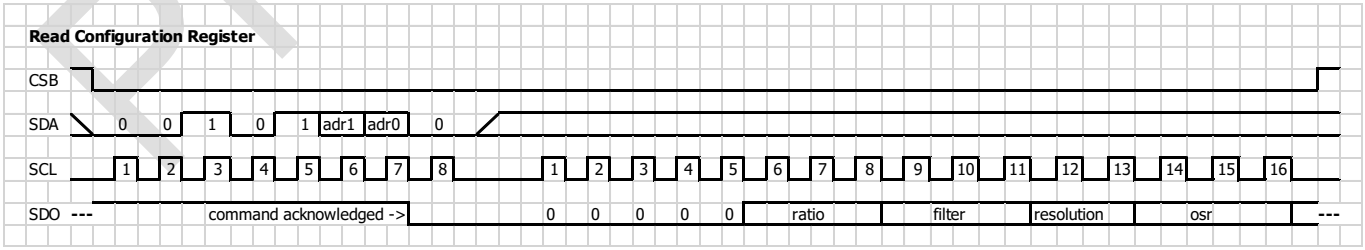


Figure 22: Read Config in SPI mode 0

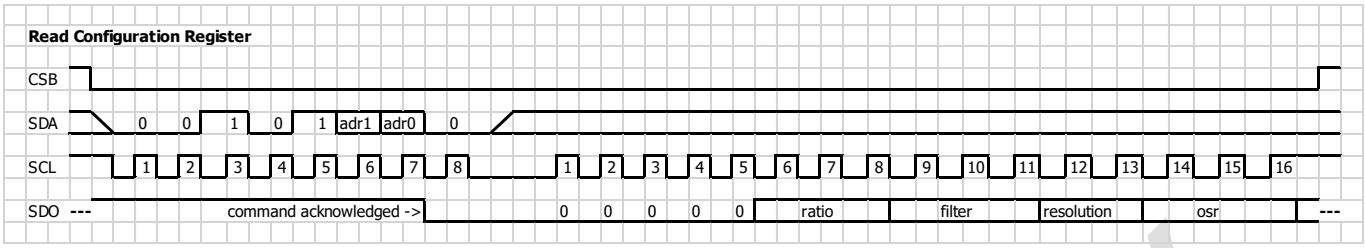


Figure 23: Read Config in SPI mode 3

WRITE LIMITS

Write Limits command gives allow to automatically rise an interrupt if one or both converted values does exceed the limits programmed in the registers. Only the 16 MSB's can be programmed and compared to the ADC results.

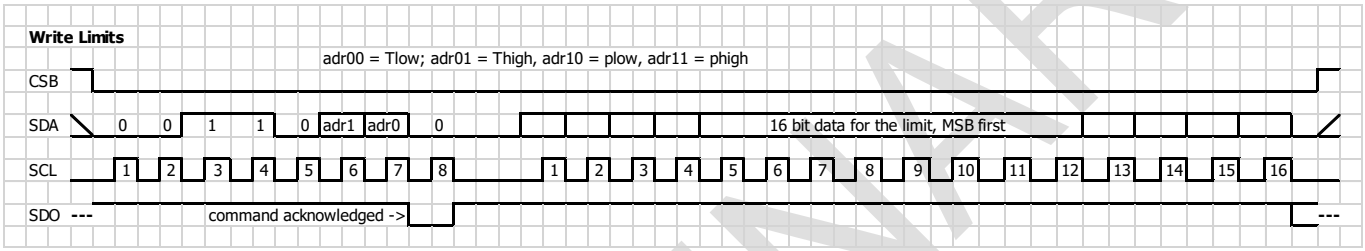


Figure 24: Write Limits in SPI mode 0

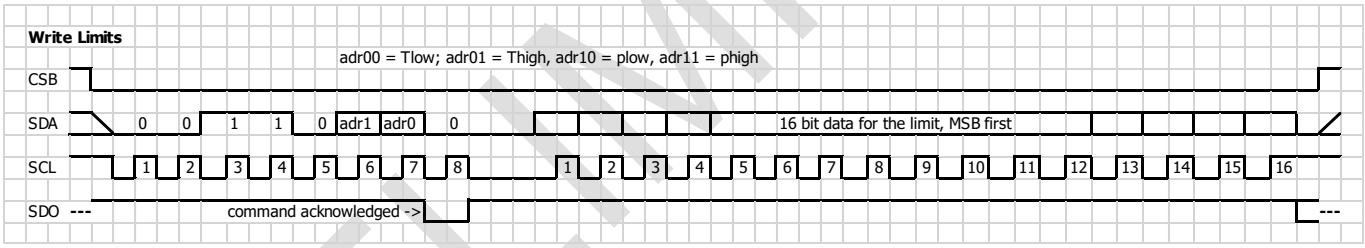


Figure 25: Write Limits in SPI mode 3

READ LIMITS

Read Limits command allows to check programmed set limits.

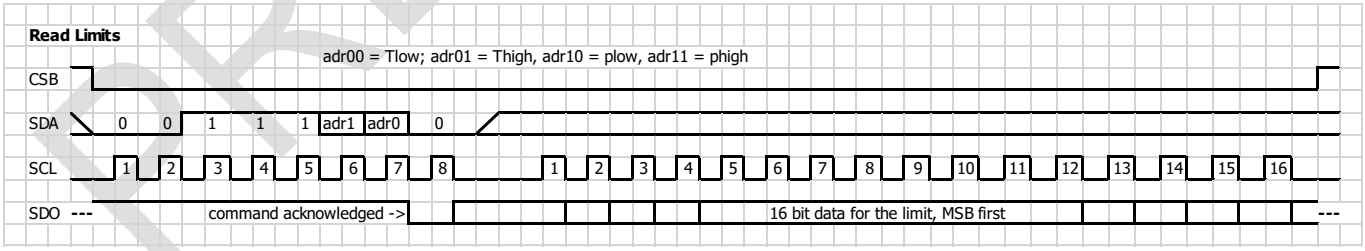


Figure 26: Read Limits in SPI mode 0

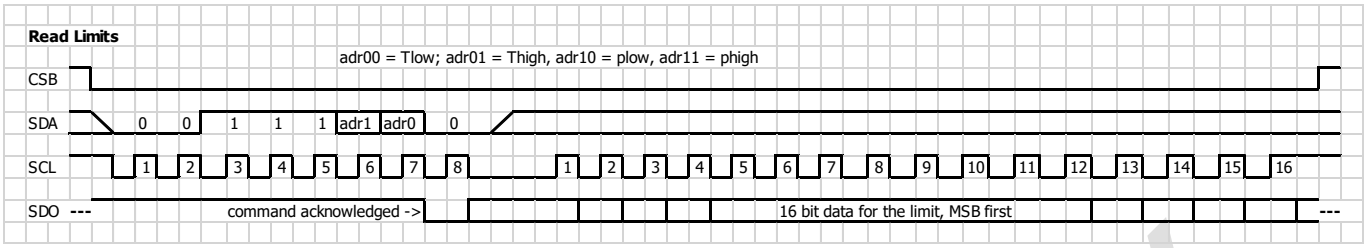


Figure 27: Read Limits in SPI mode 3

CONVERSION

Pressure or temperature conversion is started by sending conversion command. If the command is recognized by the ASIC an ACK is sent to the microcontroller and SDO goes low during the time needed to convert the analogic signal. SDO goes high again once conversion is completed. Conversion time depends on the bits P & T selected within the command and the OSR selected. After the conversion, result value is transferred to the data register. SDO line may be monitored to get the time when the operation is finished. This command is not accepted during an ongoing conversion.

Once conversion performed, converted data can be accessed by sending a Read command Conversions are internally done according to the T & P bit's set in a serial order. First value converted is temperature followed by pressure.

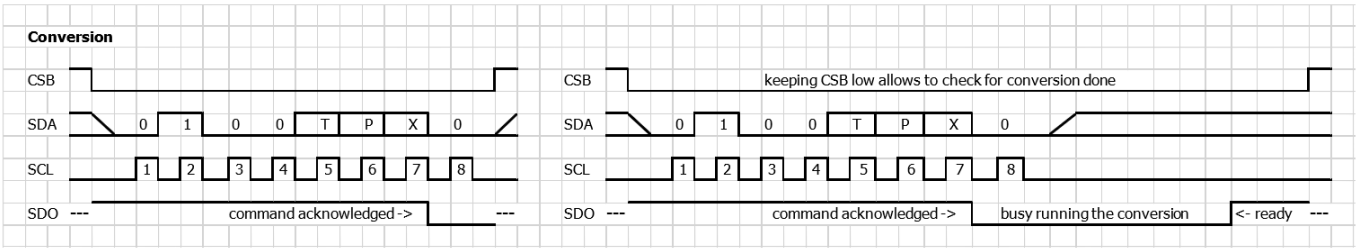


Figure 28: Conversion in SPI mode 0

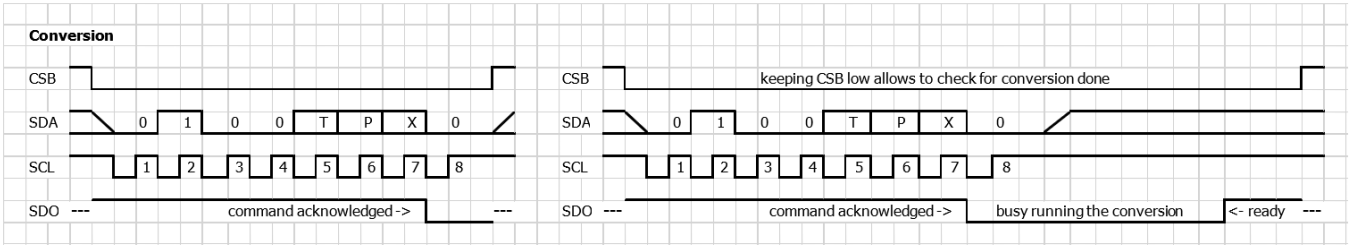


Figure 29: Conversion in SPI mode 3

READ ADC

Once conversion performed, Read ADC command allow to transfer converted pressure and temperature value to the application microcontroller. Number of bit's transmitted is fixed according to the configuration register. In FIFO off mode, at startup read ADC without any conversion done will return all one's. After a finished conversion the last converted result will be read. If the FIFO is empty, all one's will be read. Reading can be stopped any time by putting CSB high.

If a temperature and pressure conversion are requested by the conversion command, temperature will be run first and pressure after. Reading when the T has finished, and p is still on going, will yield in reading the latest temperature value, but the previous pressure value in case the pressure conversion is still on going.

This will look like:

T1, p1 available -> run T and p -> start T -> T done -> T2, p1 available -> start p -> p done -> T2, p2 available.

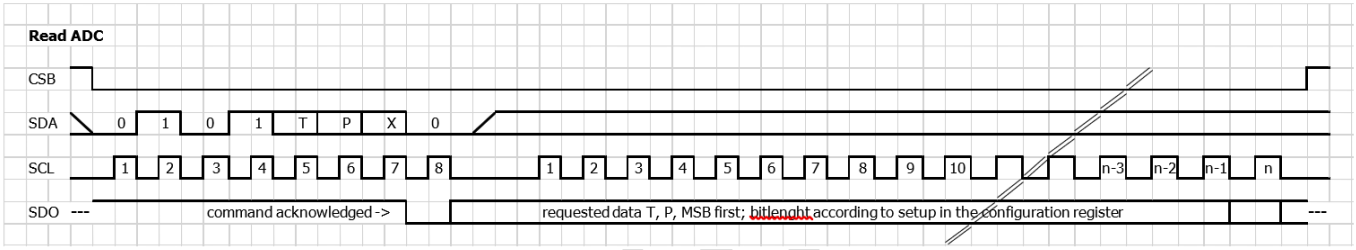


Figure 30: ADC Read in SPI mode 0

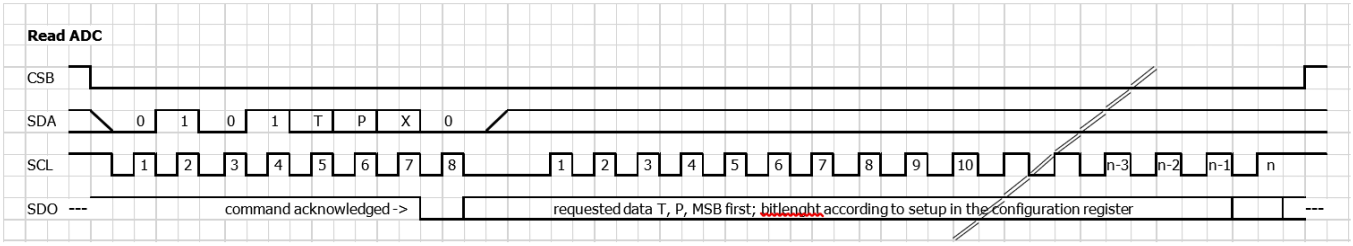


Figure 31: ADC Read in SPI mode 3

READ REGISTER

Read Register command is used to download coefficients programmed in the memory during factory calibration. These values need to be used in the pressure and temperature algorithm to calculate the compensated measurements.

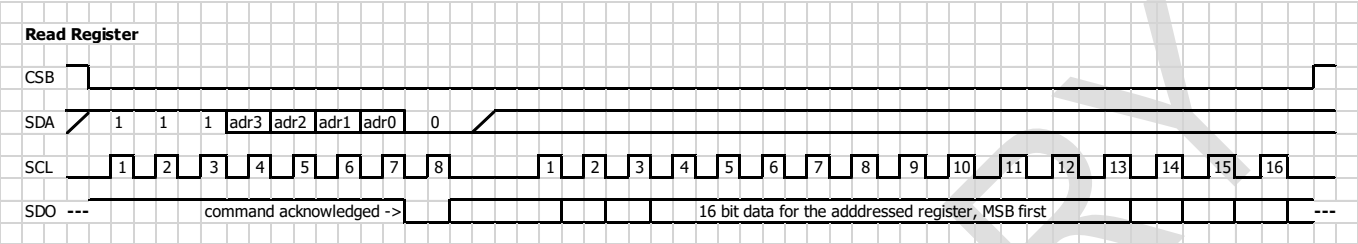


Figure 32: Read Register in SPI mode 0

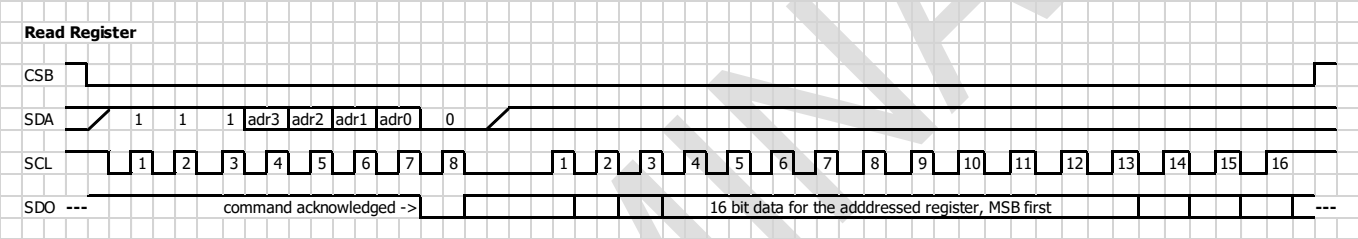


Figure 33: Read Register in SPI mode 3

I²C INTERFACE

The external microcontroller clocks in the data through the input SCL (Serial CLock) and SDA (Serial DAta). The sensor responds on the same pin SDA which is bidirectional for the I²C bus interface. This interface type uses only 2 signal lines and does not require a chip select.

Each I²C communication message starts with the start condition and it is ended with the stop condition. Each command consists of two bytes: the address byte and command byte. The MS5547 address is 1110'11**C̄**x. The **C̄** 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 1110'110x, while if the CSB=0 then the address will be 1110'111x. This allows, that two MS5547 may operate on the same I²C bus. To communicate with this mode, I²C pin must be connected to VDD.

Module ref	Mode	Pins used	Address (7 bits)	CSB	I2C
MS5547	I²C	SDA, SCL, CSB, I2C	0x76 (1110110 b)	1	1
			0x77 (1110111 b)	0	1

Table 10: I²C addresses

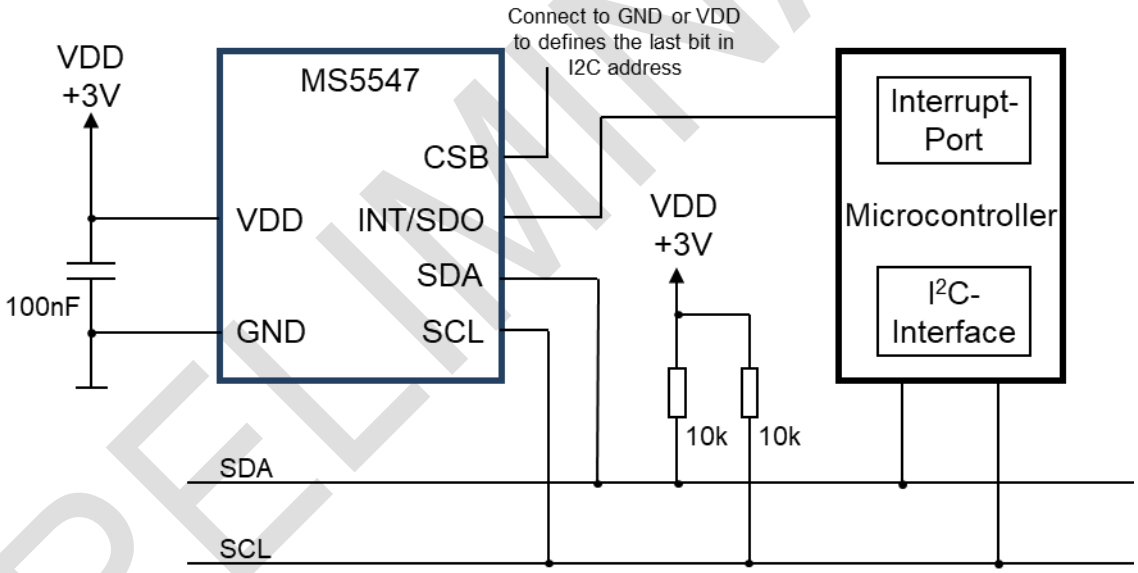


Figure 34: Typical I2C application circuit

Commands for I2C and SPI are similar. Content of command bytes are the same as the SPI one.

SDO output will react the same way as in SPI mode.

RESET

The Reset sequence shall be sent once after power-on to make sure that the calibration data gets loaded into the internal register. It can be also used to reset the device from an unknown condition.
The reset can be sent at any time. If power on reset is not a successful, maybe caused by the SDA being blocked by the module in the acknowledge state, the only way to get the MS5547 to function is to send several SCLs followed by a reset sequence or to perform a power OFF-ON cycle.

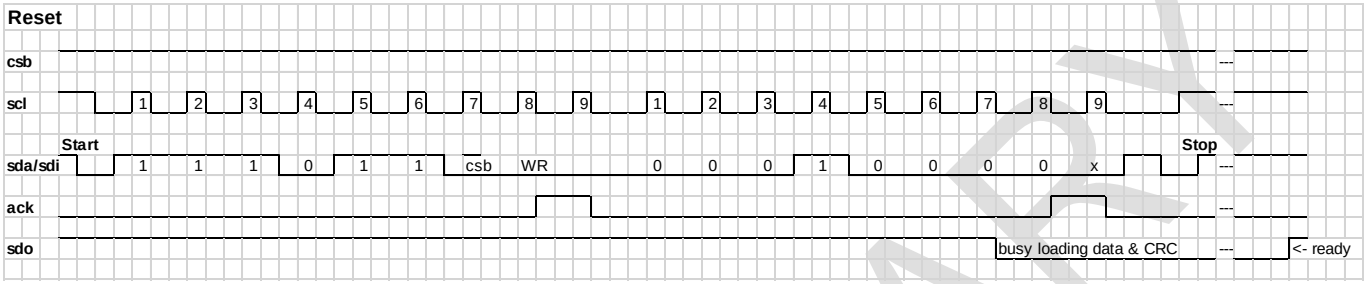


Figure 35: I2C Reset Command

REFRESH REGISTER

During a Refresh Register command, NVM data are transferred to the registers. The internal data like configuration, operation mode and interrupt registers are not affected.
SDO going low indicates that the command has been acknowledged or chip is busy with certain operation assigned by master.

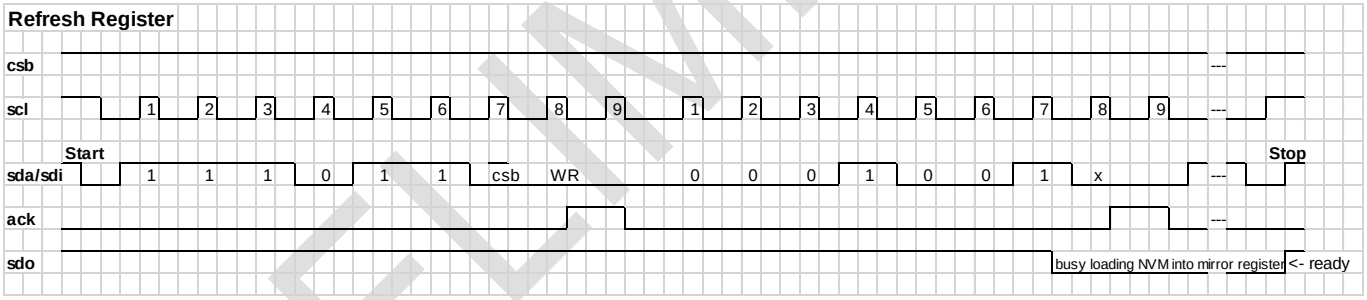


Figure 36: I2C Refresh register command

WRITE OPERATION MODE

With the Write Operation Mode command, the behavior of the FIFO and the automatic mode can be controlled.

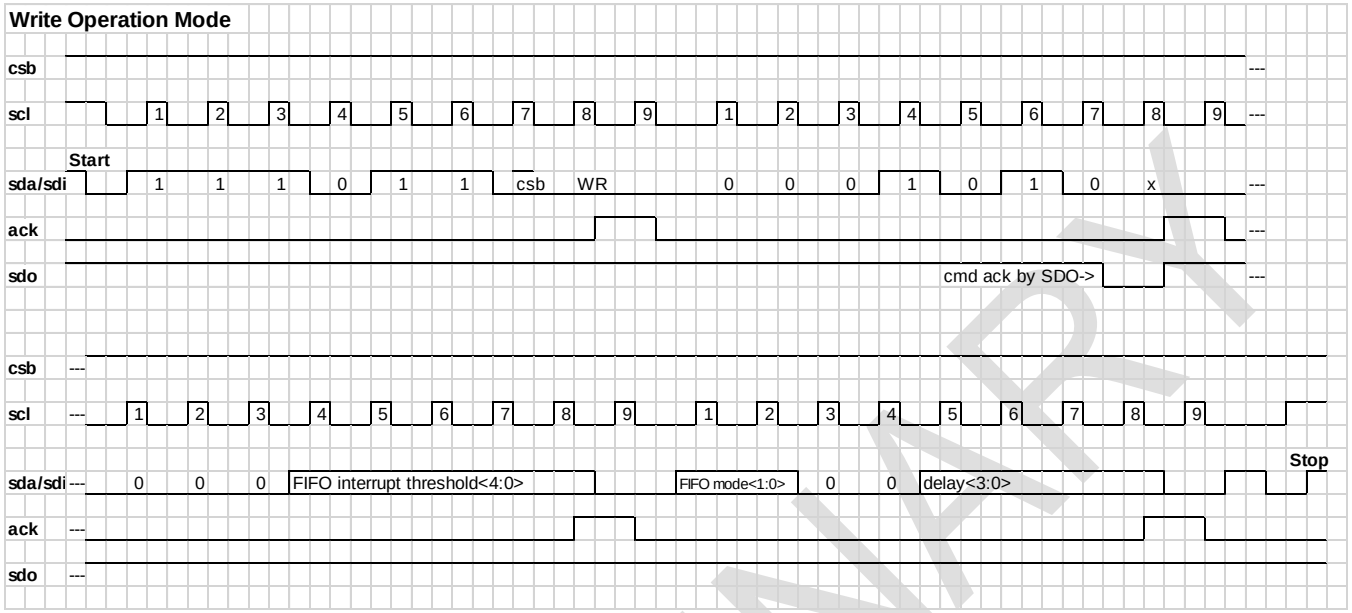


Figure 37: Write Operation mode

READ OPERATION MODE

With the Read Operation Mode command, the current setup can be read.

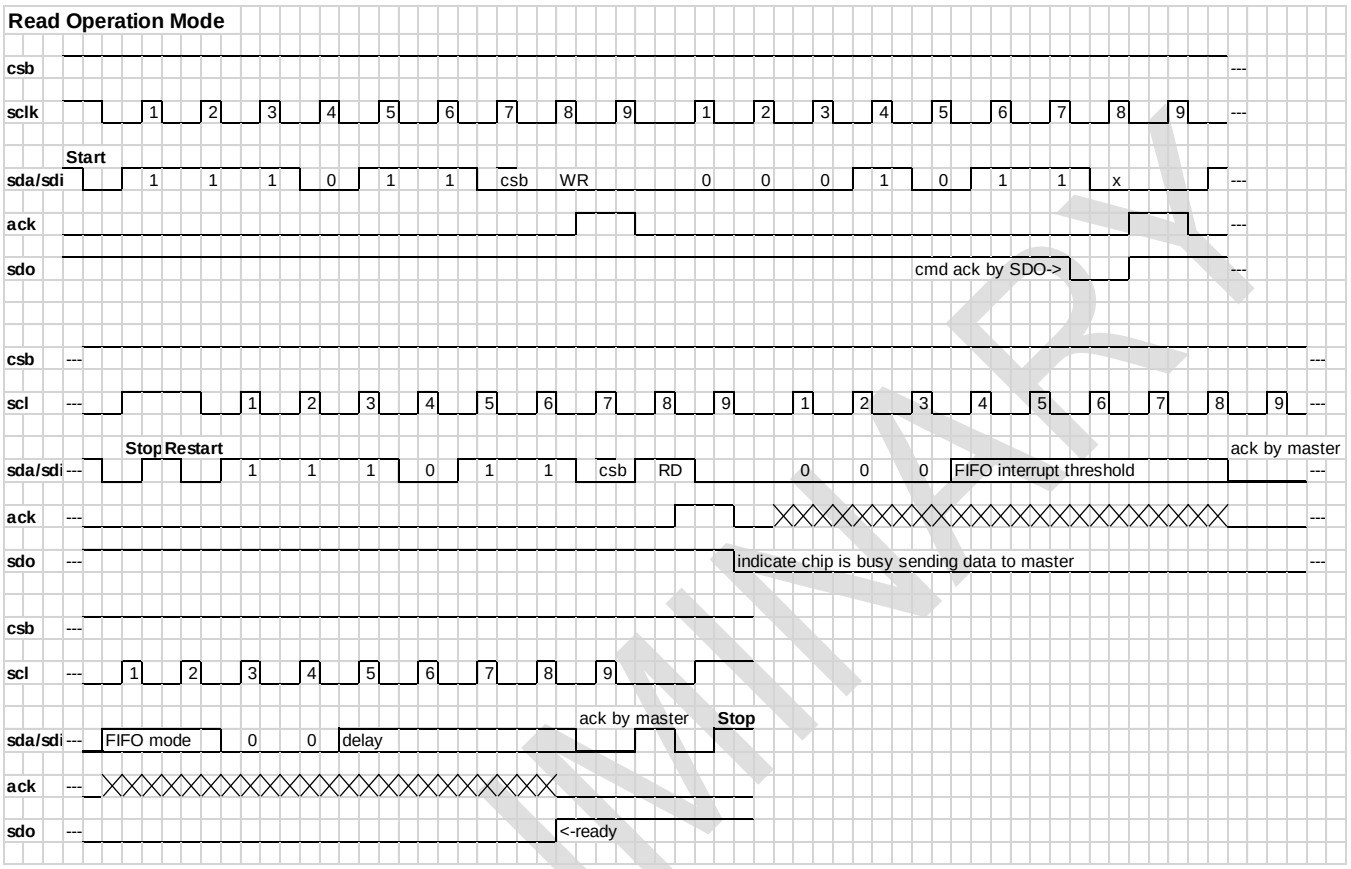


Figure 38: Read Operation mode

WRITE INTERRUPT MASK

Write Interrupt Mask command allow to enable interruptions. Enabled interrupts are routed to the INT output pin which may trigger the user application to execute specific actions.

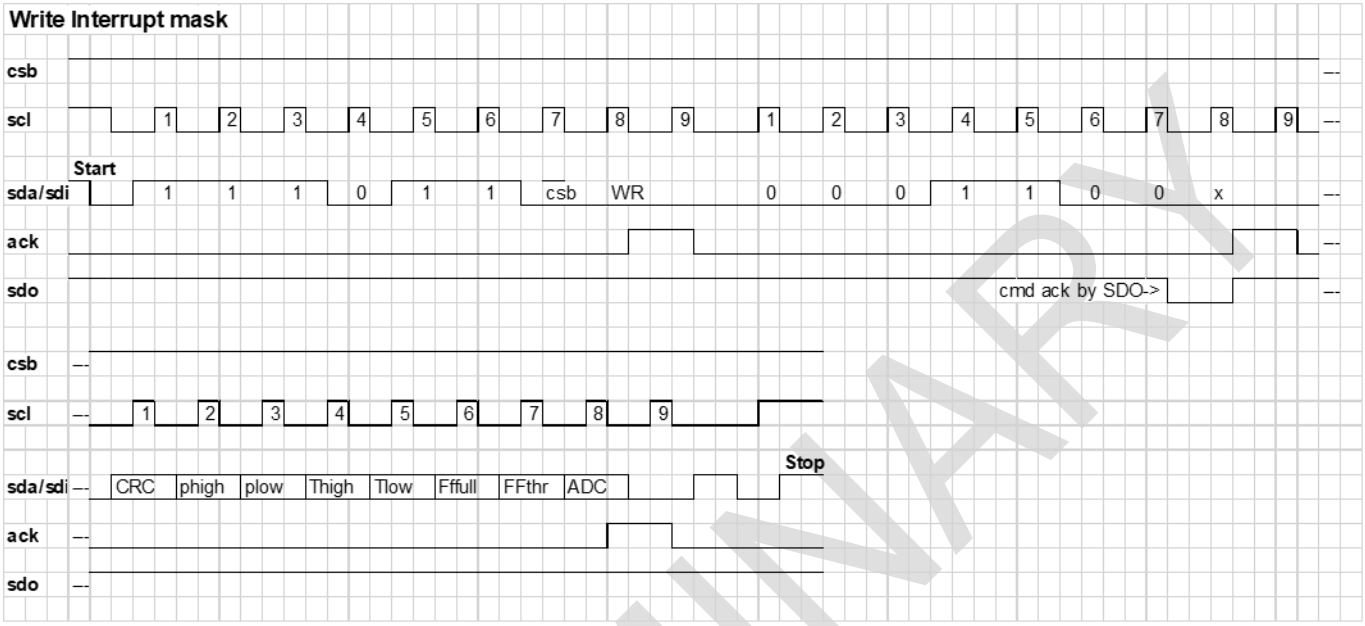


Figure 39: Write Interrupt mask

READ INTERRUPT MASK

Read Interrupt Mask command allows to read the current configuration data in the interrupt mask register.

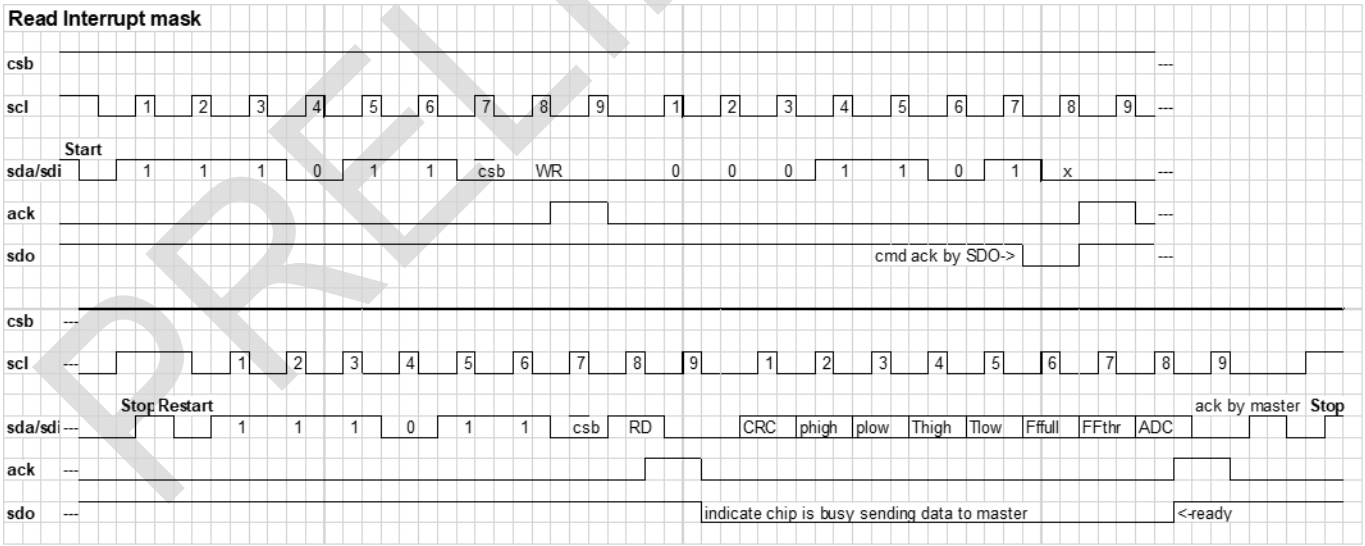


Figure 40: Read Interrupt mask

WRITE INTERRUPT REGISTER

Write Interrupt Register command is used to clear the interrupts by the user application. Interrupts are not cleared automatically while reading the register, they must be cleared by writing a '1' to the desired position in the interrupt register.

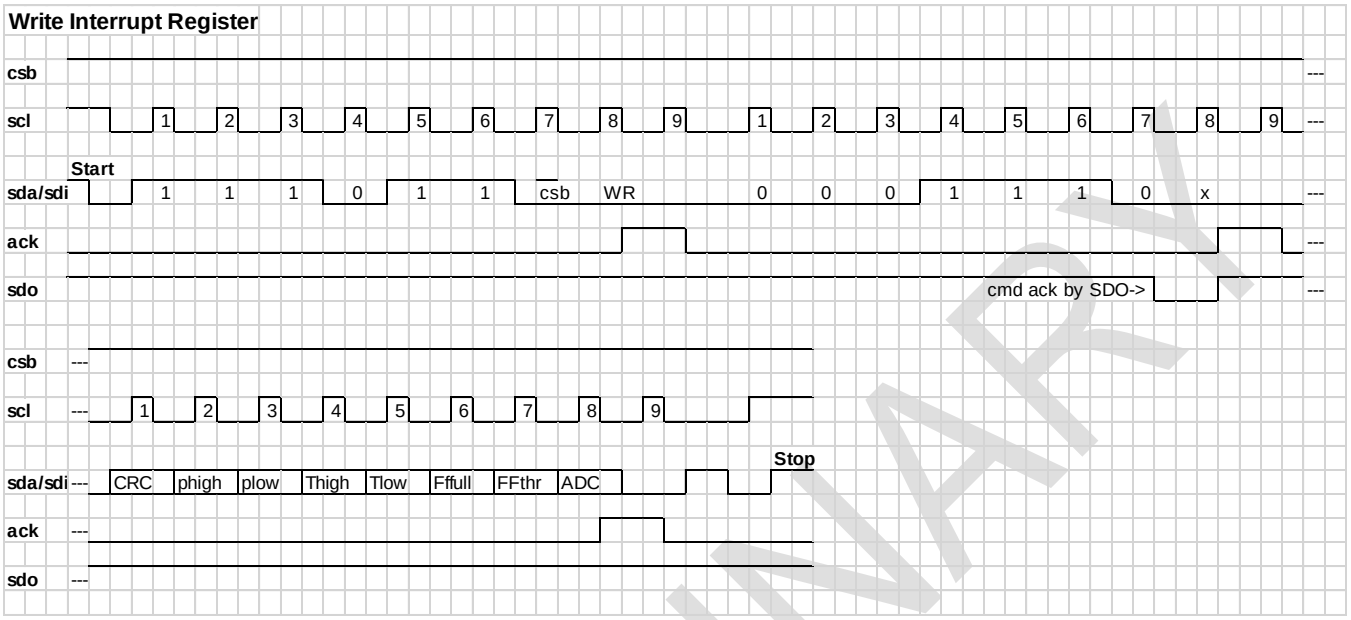


Figure 41: Write Interrupt register

READ INTERRUPT REGISTER

Read Interrupt Register allows the user application to test what was the cause of the interruption raised signal at the INT output pin, or if the interrupt is not enabled to check what action has happened.

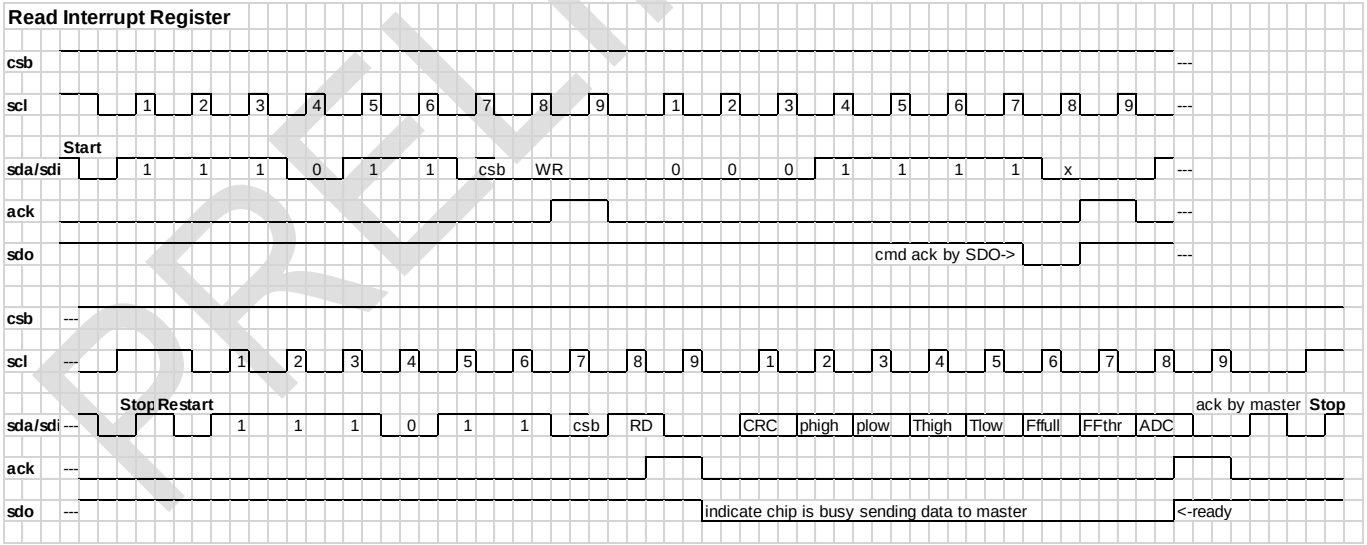


Figure 42: Read Interrupt register

WRITE CONFIG

Write Config command allows to configure the ratio, filter, read resolution and OSR of each measurement type separately.
This command is not accepted during an ongoing conversion.

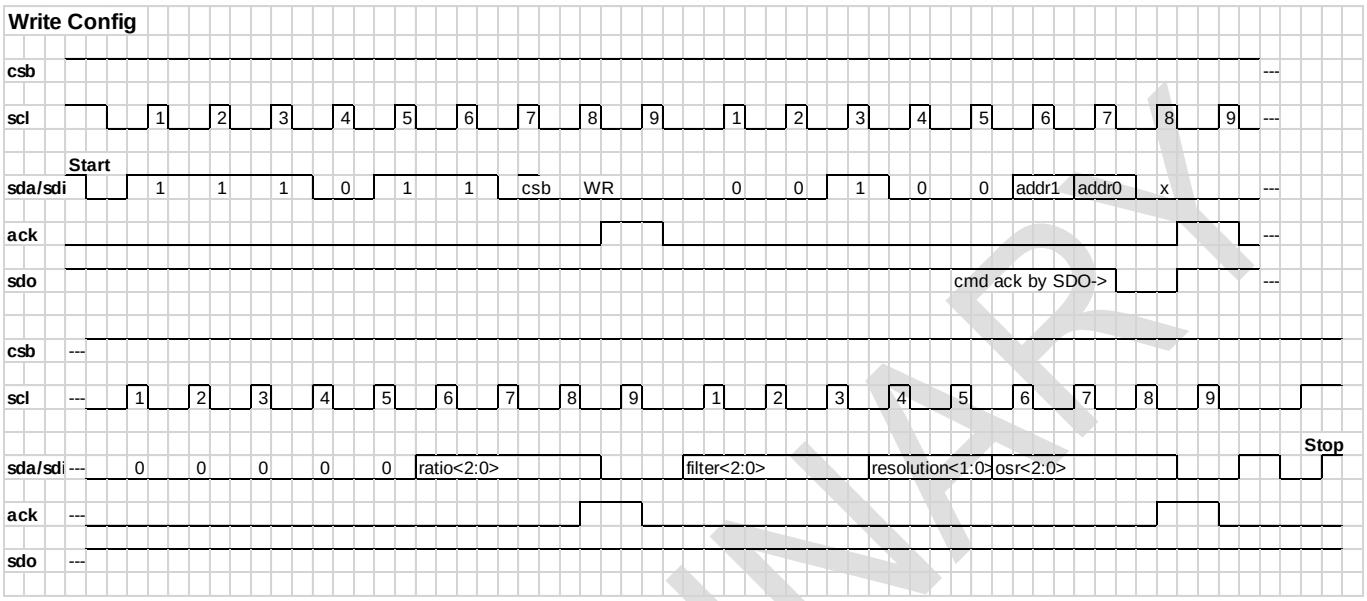


Figure 43: Write Config

READ CONFIG

Read Config command allows to verify the programmed configuration.

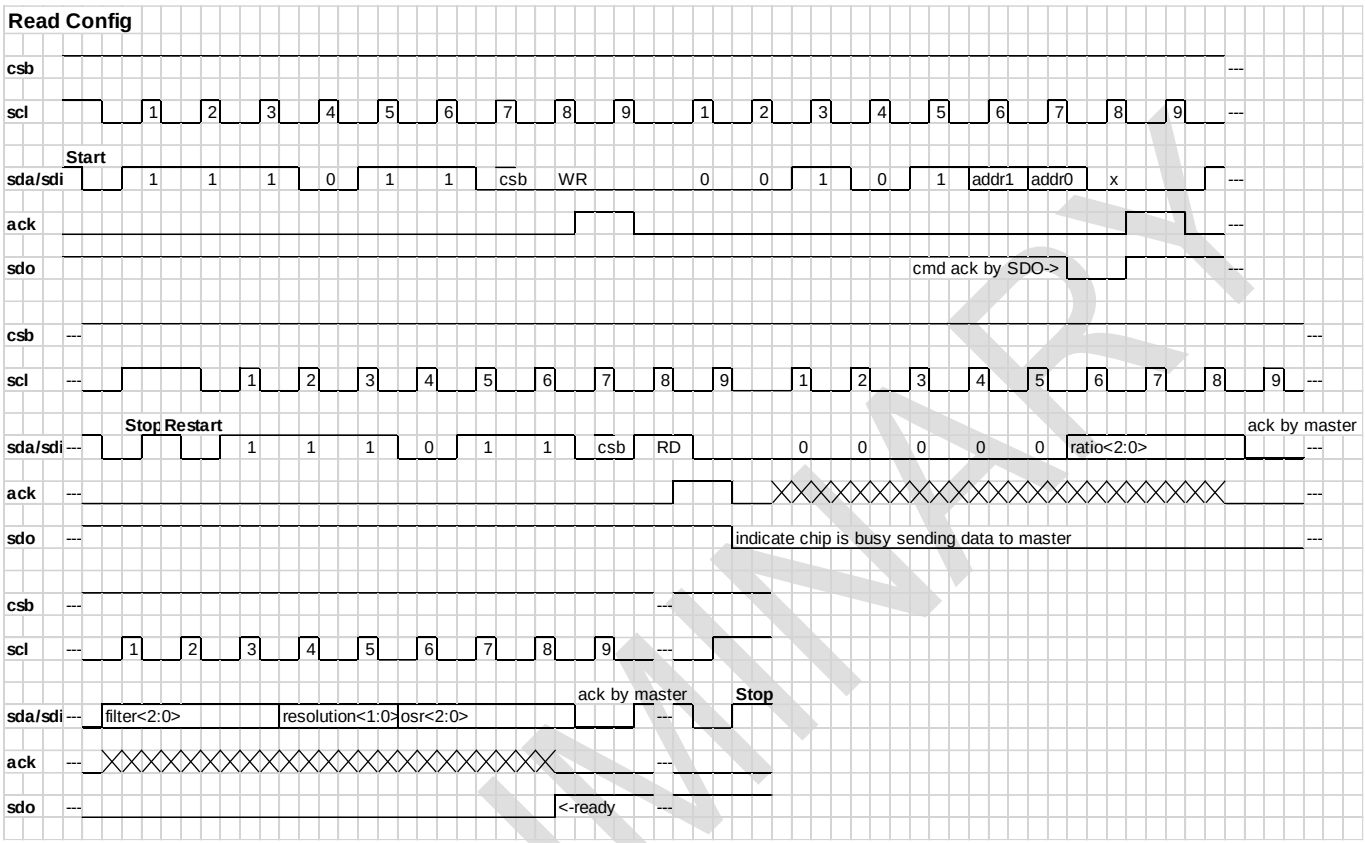


Figure 44: Read Config

WRITE LIMITS

Write Limits command gives allow to automatically rise an interrupt if one or both converted values does exceed the limits programmed in the registers. Only the 16 MSB's can be programmed and compared to the ADC results.

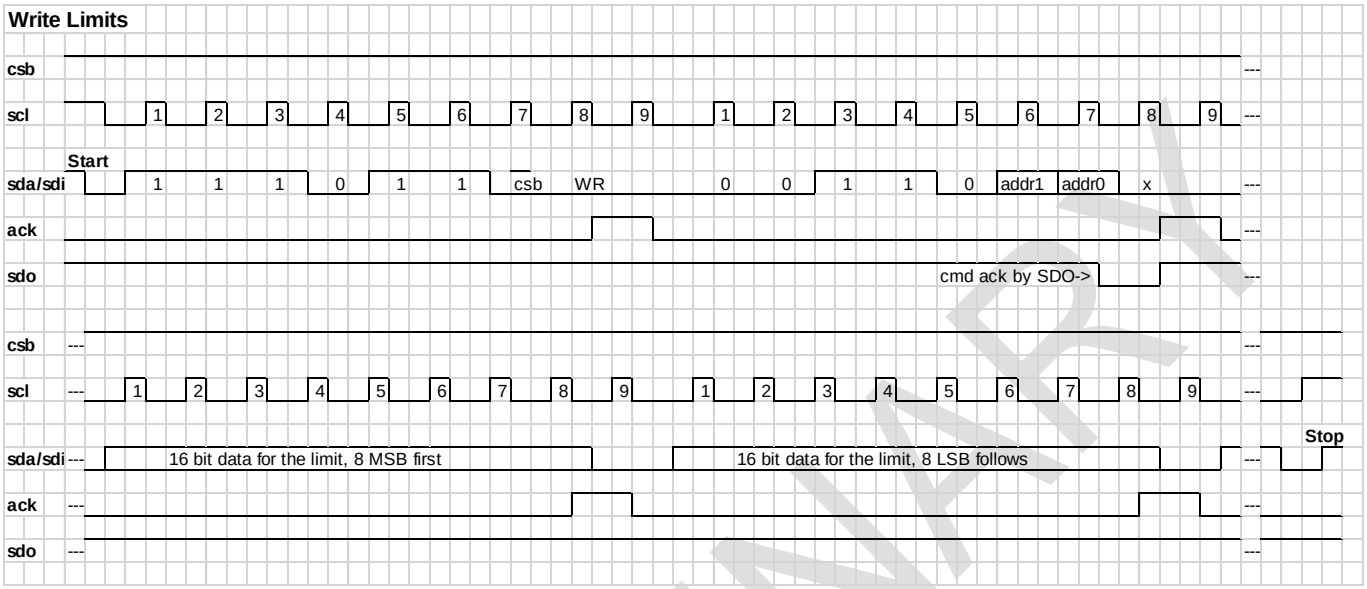


Figure 45: Write Limits

READ LIMITS

Read Limits command allows to check programmed set limits.

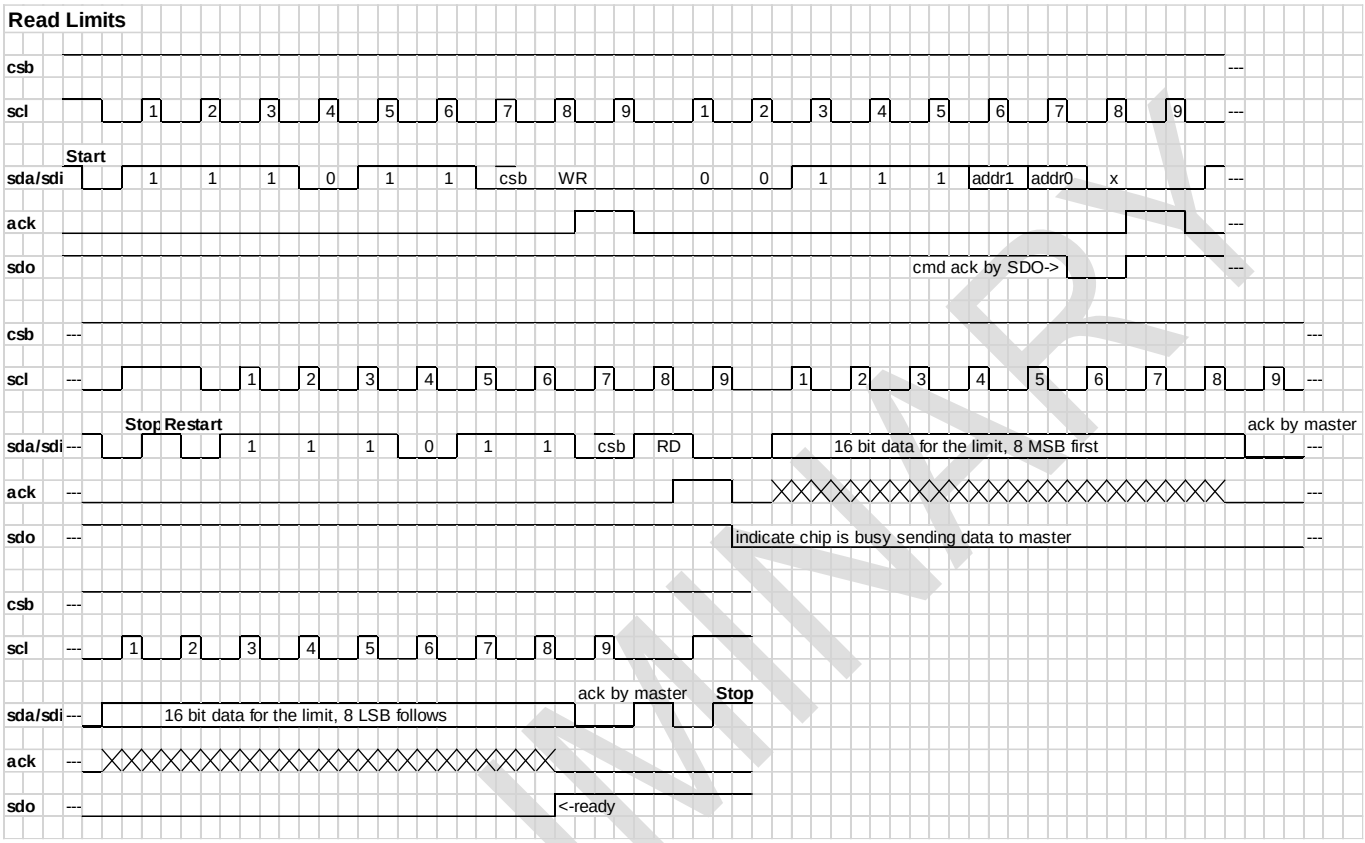


Figure 46: Read Limits

CONVERSION

Pressure or temperature conversion is started by sending conversion command. If the command is recognized by the ASIC an ACK is sent to the microcontroller via SDA pin and SDO goes low during the time needed to convert the analogic signal. SDO goes high again once conversion is completed. Conversion time depends on the bits P & T selected within the command and the OSR selected. After the conversion, result value is transferred to the data register. SDO line may be monitored to get the time when the operation is finished. This command is not accepted during an ongoing conversion.

Once conversion performed, converted data can be accessed by sending a Read command. After ASIC acknowledge, user microcontroller may start to send 24 SCLK cycles to get all result bits. Every 8 bit the system waits for acknowledge from the master. If the acknowledge is not sent the data clocking out of the chip stops.

Conversions are internally done according to the T & P bit's set in a serial order. First value converted is temperature followed by pressure.

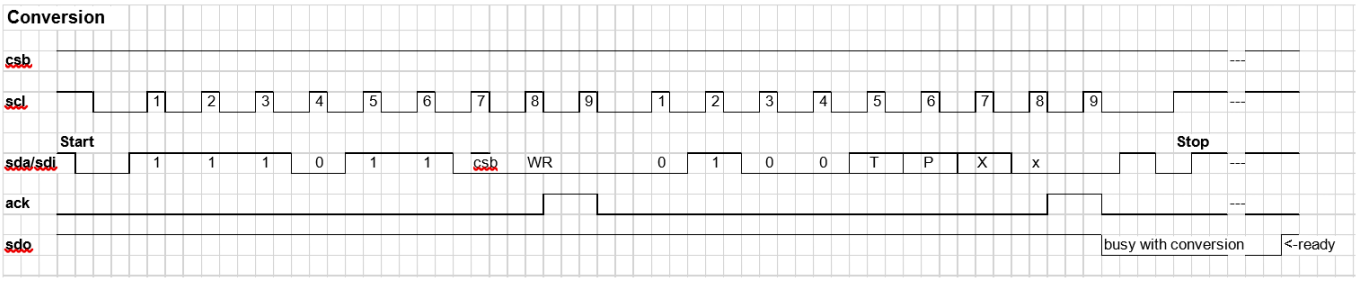


Figure 47: Conversion

READ ADC

Once conversion performed, Read ADC command allow to transfer converted pressure and temperature value to the application microcontroller. Number of bit's transmitted is fixed according to the configuration register. In FIFO off mode, at startup read ADC without any conversion done will return all one's. After a finished conversion the last converted result will be read. If the FIFO is empty, all one's will be read. Reading can be stopped at any time by sending STOP or NACK sequence from the microcontroller.

If a temperature and pressure conversion are requested by the conversion command, temperature will be run first and pressure after. Reading when the T has finished, and p is still on going, will yield in reading the latest temperature value, but the previous pressure value in case the pressure conversion is still on going.

This will look like:

T1, p1 available -> run T and p -> start T -> T done -> T2, p1 available -> start p -> p done -> T2, p2 available.

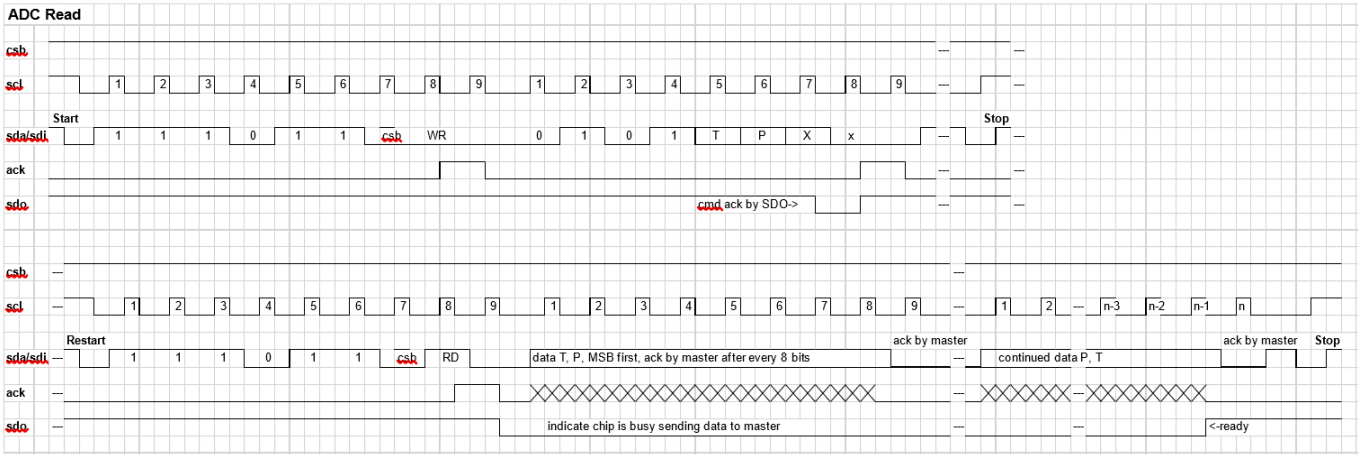


Figure 48: ADC Read

READ REGISTER

Read Register command is used to download coefficients programmed in the memory during factory calibration. These values need to be used in the pressure and temperature algorithm to calculate the compensated measurements.

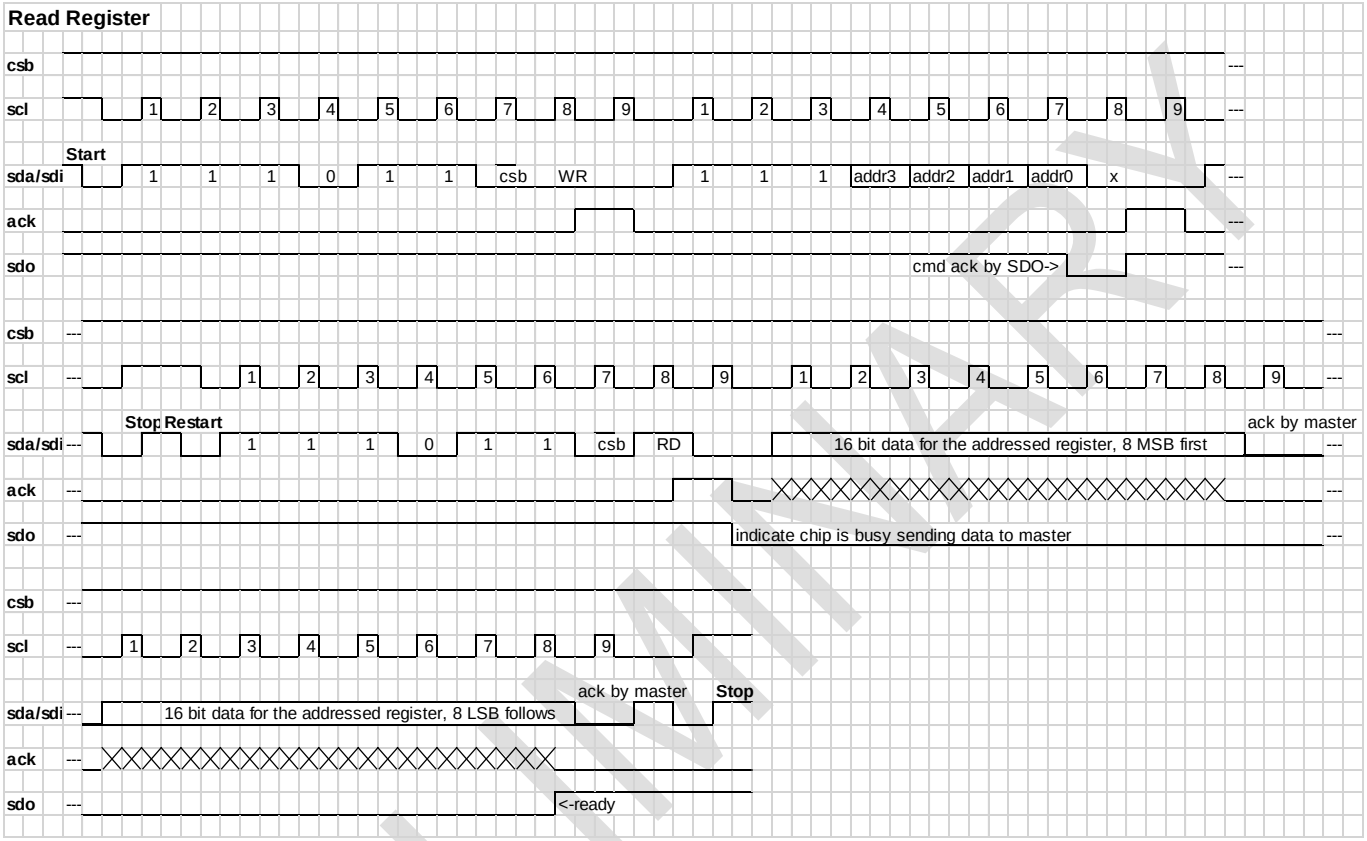
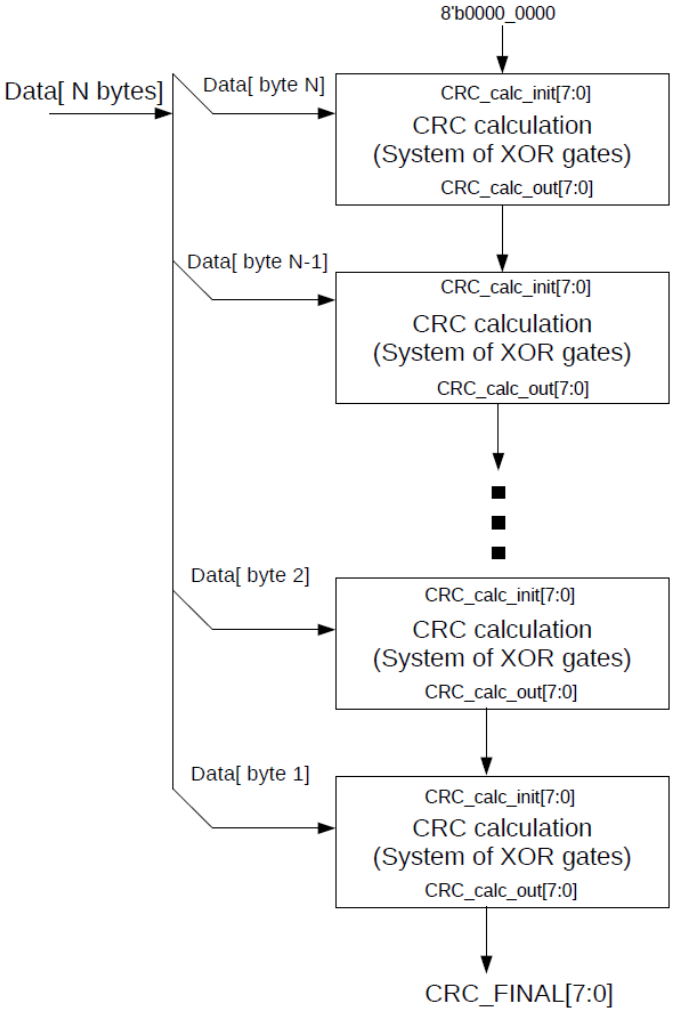


Figure 49: Read Register

CYCLIC REDUNDANCY CHECK (CRC)

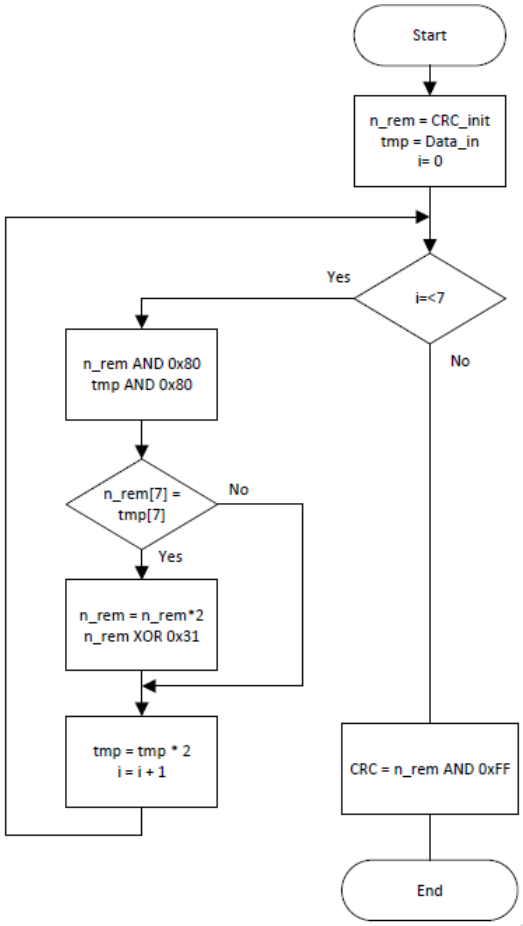
MS5547 contains 256 bits of NVM memory.
CRC is implemented in the digital core to check the integrity of the memory data.

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



Property	Value
Width	8 bits
Protected data	Read and/or write data
Polynomial	0x31 ($x_8 + x_5 + x_4 + 1$)
Initialization	0x00
Reflect input	False
Reflect output	False
Final XOR	0x00
Examples	CRC (0xBEEF) = 0x13

8 BITS CRC CALCULATION FLOW CHART



EXCEL Calculation function

```
Function CRC_calc(Data_in, CRC_init)
    ' Polynom 0x31 = 49 decimal
    n_rem = CRC_init
    tmp = Data_in

    For i = 0 To 7        '// Length of data_in
        msb_crc = n_rem And 128
        msb_data = tmp And 128

        If (msb_crc Xor msb_data) Then
            n_rem = LeftShift(n_rem, 1) Xor 49
        Else
            n_rem = LeftShift(n_rem, 1)
        End If

        tmp = LeftShift(tmp, 1)
    Next i

    CRC_calc = n_rem And 255

End Function
```

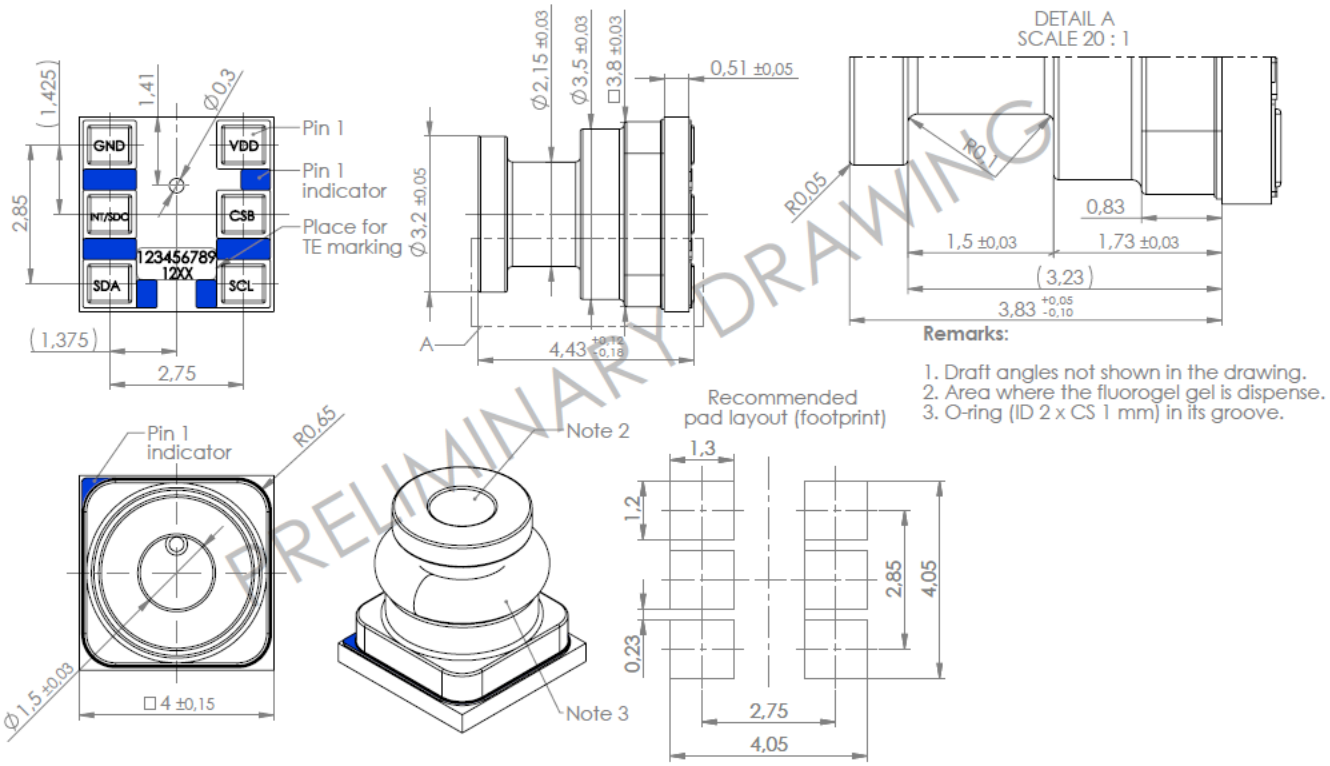
Figure 50: CRC8 calculation flowchart & Excel Calculation function

Example:

Memory word		Format change			CRC		
Addr	Data[hex]	Data[dec]	Data[15:8]	Data[7:0]	CRC_init	CRC_MSB	CRC_LSB
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	940	2368	9	64	0	136	254
9	057A	1402	5	122	254	104	33
10	B616	46614	182	22	33	174	6
11	7F64	32612	127	100	6	112	135
12	795A	31066	121	90	135	157	208
13	3100	12544	49	0	208	240	130
14	5AA5	23205	90	165	130	189	250
15	C34D	49997	195	77	250	77	0
						CRC[hex]	00

PIN CONFIGURATION AND DEVICE PACKAGE OUTLINE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS. GENERAL TOLERANCE ± 0.1



Pin	Name	Type	Function
1	VDD	P	POSITIVE SUPPLY VOLTAGE
2	CSB	I	I2C ALT. ADDR./SPI CHIP SELECT
3	SCL	I	CLOCK
4	SDA	I/O	I2C DATA/SPI DATA INPUT
5	INT/SDO	O	I2C INTERRUPT/SPI DATA OUTPUT
6	GND	P	GROUND

Figure 51: Package outline and pin configuration

RECOMMENDED PAD LAYOUT

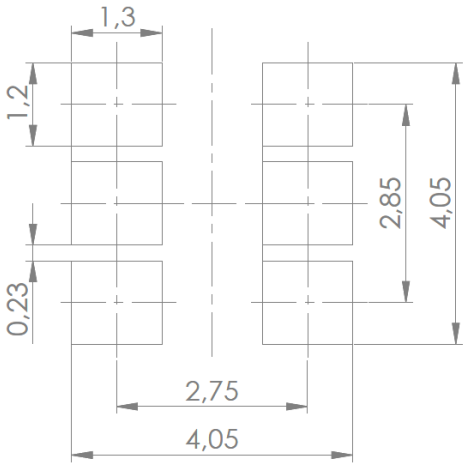
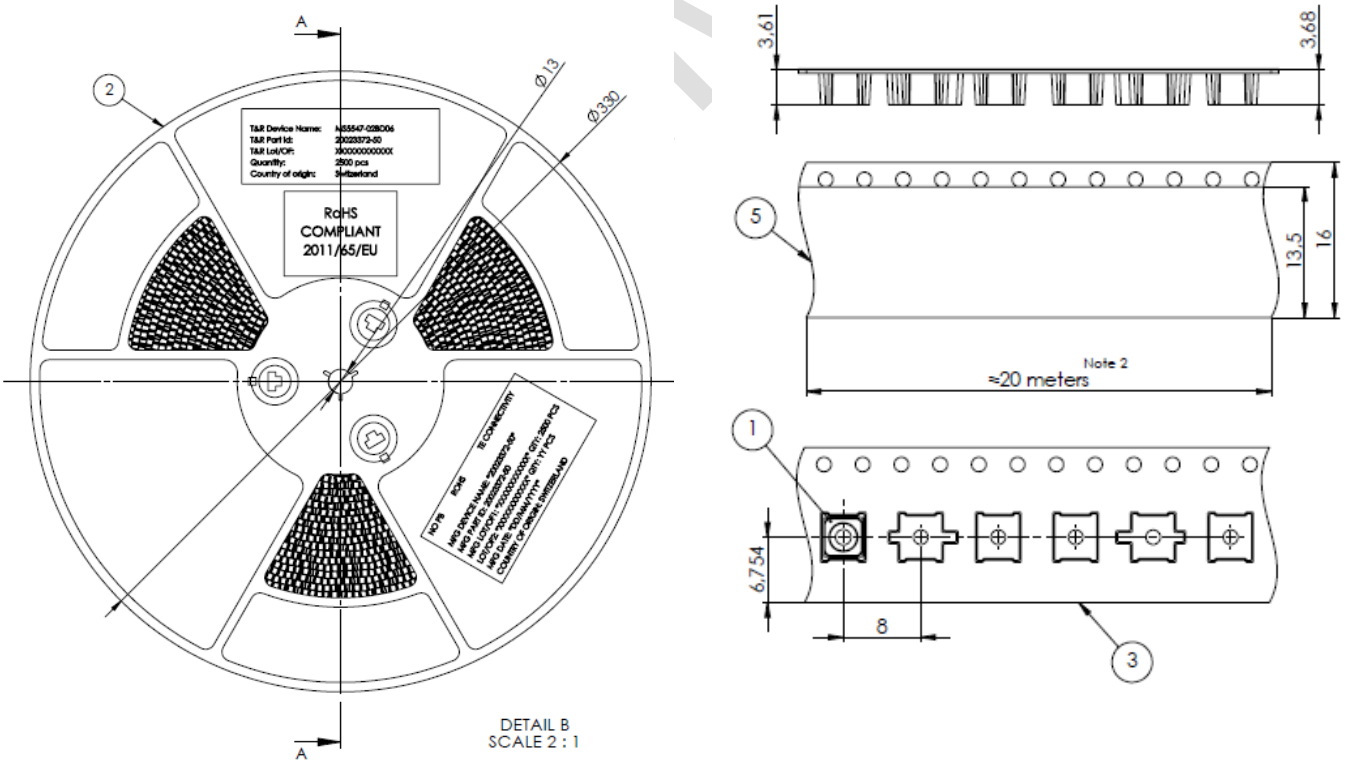


Figure 52: PCB footprint

SHIPPING PACKAGE

MS5547 is delivered in 16mm tape and reel.

Number of sensors per reel: 2500pcs



MOUNTING AND ASSEMBLY CONSIDERATIONS

SOLDERING

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

MOUNTING

The MS5547 can be placed with automatic pick & place equipment using vacuum nozzles. It will not be damaged by the vacuum. Due to the low stress assembly the sensor does not show pressure hysteresis effects.

CONNECTION TO PCB

The package outline of the module allows the use of a flexible PCB. This is ideal for small-sized applications.

CLEANING

The MS5547 has been manufactured under clean-room conditions. It is therefore recommended to assemble the sensor under class 10'000 or better conditions. Should this not be possible, it is recommended to protect the sensor opening during assembly from entering particles and dust. To avoid cleaning of the PCB, solder paste of type "no-clean" shall be used.
Warning: cleaning might damage the sensor.

ESD PRECAUTIONS

The electrical contact pads are protected against ESD up to 4 kV HBM (human body model). It is therefore essential to ground machines and personal properly during assembly and handling of the device. The MS5547 is shipped in antistatic transport boxes. Any test adapters or production transport boxes used during the assembly of the sensor shall be of an equivalent antistatic material.

DECOUPLING CAPACITOR

Particular care must be taken when connecting the device to the power supply. A minimum of 100nF ceramic capacitor must be placed as close as possible to the MS5547 VDD pin. This capacitor will stabilize the power supply during data conversion and thus, provide the highest possible accuracy.

ORDERING INFORMATION

PART NUMBER	DESCRIPTION
20023372-50	MS5547-02BD I2C T&R SEN
20024496-50	MS5547-02BD SPI T&R SEN

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