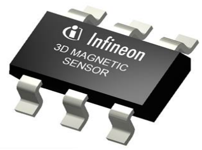
TLE493D-P3B6

XENSIV™ 3D Hall sensor with I^2C interface and Wake Up function

Datasheet



RoHS

AEC Qualified

ISO 26262 compliant

Features

- Best accuracy package-size fit
- Operating supply voltage 3.3 V and 5 V
- ISO 26262 SEooC for safety requirements up to ASIL B
- 3D magnetic field sensing of ±50, ±100 and ±160 mT
- Enables low power applications
- Integrated temperature measurement
- Operating temperature range T_j = -40°C to 125°C
- 1 MHz I^2C for measurement control and data read out

Potential applications

- Long stroke linear position measurement
- Angular position measurement
- Control elements: turn indicator, gear stick, joystick, thumbwheel...
- Pedal/valve position sensing

Benefits

- Component reduction due to 3D magnetic measurement principle
- Wide application range addressable due to high flexibility
- Platform adaptability due to device configurability
- Very low system power consumption due to Wake Up mode

Product validation

Qualified for automotive applications. Product validation according to AEC-Q100.

Description

This sensor measures the magnetic field in three orthogonal dimensions and operates as I^2C bus slave. An external I^2C master device, e.g. a microcontroller, is used to configure the sensor and read-out the measurement data. The sensor is developed according to ISO26262 and provides built-in diagnosis functions to support functional safety applications with ASIL-B. A Wake Up function provides the capability to wake up a sleeping system.

Product Type	Marking[1)]	Ordering Code	Default address 7 bit	Default address 8 bit write / read
TLE493D-P3B6 A0	E0	SP005427119	$5D_H$	BA_H / BB_H
TLE493D-P3B6 A1	E1	SP005427121	13_H	26_H / 27_H
TLE493D-P3B6 A2	E2	SP005427123	29_H	52_H / 53_H
TLE493D-P3B6 A3	E3	SP005427125	46_H	$8C_H$ / $8D_H$

1 Engineering samples are marked with "SA".

Table of contents

1 Block diagram

The main functions and its cooperation is shown in the block diagram

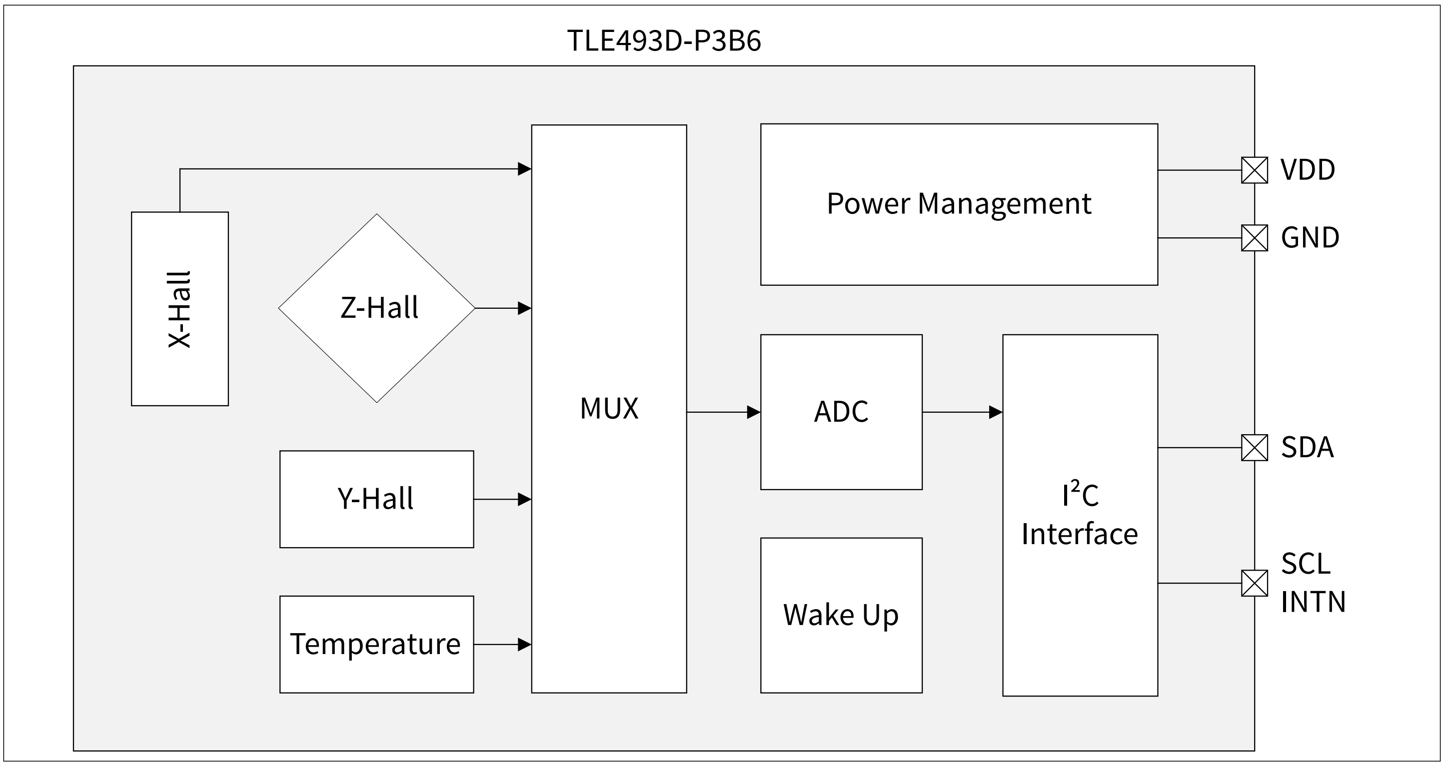


Figure 1 **Block Diagram**

2 Pin Configuration, Definition of Magnetic Field and Sensitive Area

The sensor's electrical and magnetical connecting point to the application are the pin configuration, the definition of the magnetic field direction and the sensitive area, which are listed in the following subchapters.

2.1 Pin Configuration

The pinout of the sensor is the following:

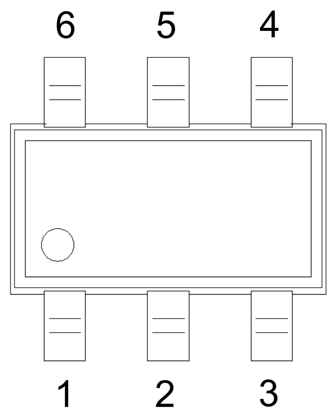


Figure 2 Sensor pinout

Table 1 TSOP6-6-8 pin description and configuration (see Figure 2)

Pin number	Name	Description
1	SCL (INTN)	Interface serial clock pin (input) Interrupt pin, signals a finished measurement cycle, open-drain (output)
2	GND	Must be connected to GND-pin 3 externally
3	GND	Ground pin
4	VDD	Supply pin
5	GND	Must be connected to GND-pin 3 externally
6	SDA	Interface serial data pin (input/output), open-drain

2.2 Definition of the magnetic field

A positive field is considered as south-pole facing the corresponding Hall element. Figure 3 shows the definition of the magnetic field directions X, Y and Z of the 3D-Hall sensor.

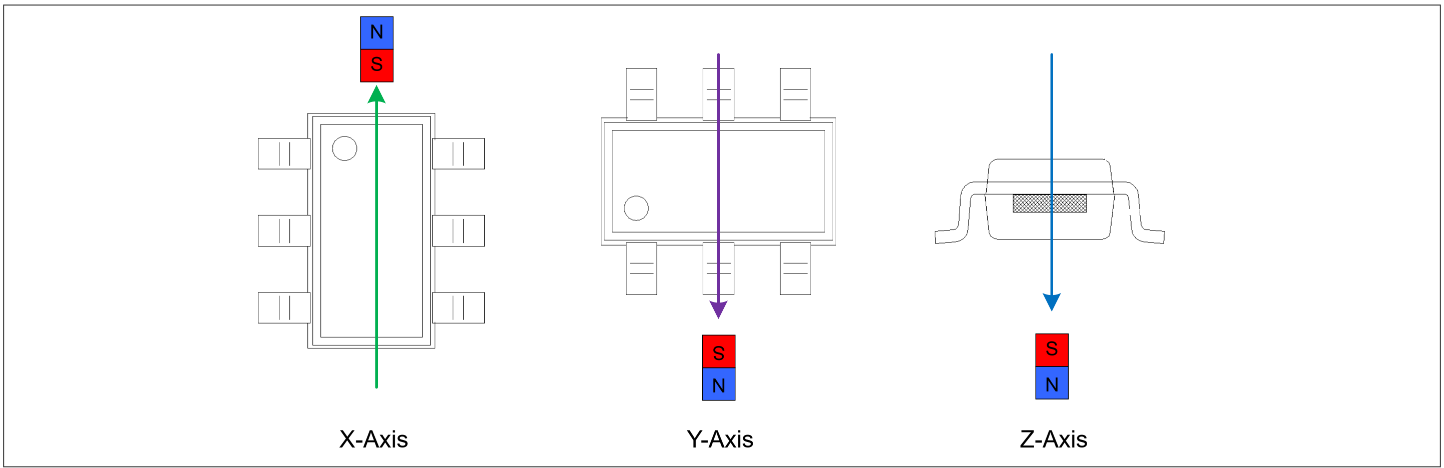


Figure 3 **Definition of magnetic field direction**

2.3 Sensitive Area

The magnetic sensitive area for the Hall measurement is shown in Figure 4.

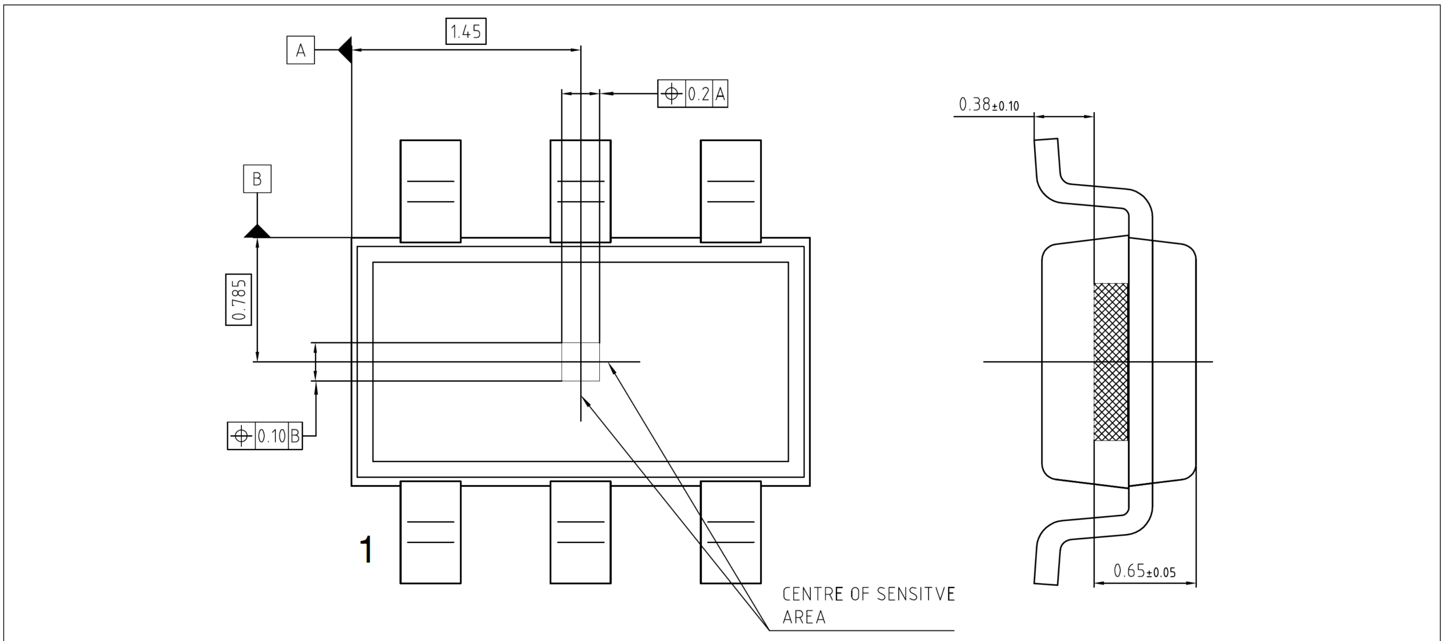


Figure 4 **Center of sensitive Area (dimensions in mm)**

3 General Product Characteristics

This chapter describes the environmental conditions required by the device (magnetic, thermal and electrical).

3.1 Absolute maximum ratings

Stresses above those listed under Table 2 may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Junction temperature	T_j	-40	–	150	°C	
Voltage on any pin to GND	V_{max}	-0.3	–	6	V	
Voltage range on SDA and SCL (INTN) to GND	V_{IO_max}	–	–	V_{DD} + 0.5	V	
Magnetic field	B_{max}	–	–	±1	T	

Table 3 ESD robustness

Ambient temperature T_a = 25°C

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
ESD robustness (HBM)	$V_{ESD\text{-}HBM}$	-4	–	4	kV	For all pins [2]
ESD robustness (CDM)	$V_{ESD\text{-}CDM\_corner}$	-0.75	–	0.75	kV	For corner pins [3]
ESD robustness (CDM)	$V_{ESD\text{-}CDM}$	-0.5	–	0.5	kV	For all pins [3]

3.2 Functional range

This sensor is designed to operate within the conditions described in this chapter.

Table 4 Functional Range

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating temperature	T_j	-40	–	125	°C	
Operating supply voltage	V_{DD}	2.8	–	5.5	V	
Register reset level	V_{res}	1	–	2.3	V	
Register reset level hysteresis	$V_{res\text{-}hys}$	25	50	–	mV	
ADC restart level	V_{ADCr}	2.3	2.6	2.8	V	min. ADC operating level
ADC restart hysteresis	$V_{ADCr\text{-}hys}$	25	50	–	mV	

(table continues...)

2 Human Body Model (HBM) robustness: Class HBM 2 according to AEC-Q100-002.
3 Charged Device Model (CDM) robustness: Class C2a according to AEC-Q100-011.

Table 4 (continued) Functional Range

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Magnetic range (full range)	B_{XYZ}	-160	–	160	mT	
Magnetic range (short range)	B_{XYZ_SR}	-100	–	100	mT	
Magnetic range (extra short range)	B_{XYZ_XSR}	-50	–	50	mT	

If the supply voltage V_{DD} drops below the "register reset" the sensor enters an undefined state. If the supply voltage V_{DD} recoveres above the "register reset" threshold the sensor registers are reset to their default values. This register reset is indicated with the "rst_flg" bit.

As long as V_{DD} remains above the sensors "register reset" threshold the digital interface is working as specified.

After a register reset the sensor enters the following state:

- INTN disabled
- Low power mode with f_{Update} = 1 kHz (typ.)
- Collision avoidance disabled
- Full range
- 1-byte read protocol

3.3 Current Consumption and Pin Characteristics

The electrical parameters are listed in Table 5.

Table 5 Electrical Pin Characteristics

All voltages with respect to ground, positive current flowing into pin

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Supply current Power Down	I_{DD_pd}	–	500	1000	nA	T_j = 25°C; supply current at VDD pin in power down; no communication and no floating pins at the interface
Supply current Power Down @ 85°C	I_{DD_pd}	–	–	6	µA	T_j = 85°C; supply current at VDD pin in power down; no communication and no floating pins at the interface
Supply current active	I_{DD_active}	–	4.2	6	mA	Supply current at VDD pin while ADC active
Supply current at power up	I_{DD_pu}	–	–	8.5	mA	Supply current at VDD pin during power up
Input voltage low threshold	V_{IL}	30	–	–	% V_{DD}	all input pads
Input voltage high threshold	V_{IH}	–	–	70	% V_{DD}	all input pads
Input voltage hysteresis	V_{IHYS}	5	–		% V_{DD}	all input pads
Output voltage low level	V_{OL}	–	–	0.4	V	all output pads, static load, I_{OL} = 5 mA
IO pin leakage current	$I_{leakage\_IO}$	-1	–	1	µA	0 V ≤ V_{IO} ≤ V_{DD}
SDA, SCL(INTN) pin capacitance	C_{SDA}, C_{SCL}	–	–	10	pF	

$$I_{DD\_avg} \approx f_{Update} \cdot \left(I_{DD_{active}} \cdot t_{ADC} + I_{DD\_pd} \cdot \left(\frac{1}{f_{Update}} - t_{ADC} \right) \right)$$

Equation 1 Measurement cycle averaged, typical I_{DD} current consumption estimation formula

Timing details are described in chapter Measurement Timing.

3.4 Sensor reset

This sensor provides internal and external reset functionality.

Internal:

- Register reset, resets the sensor after power up or under voltage events.
- ADC restart, refreshes a measurement in case of inefficient supply voltage.

External:

- Software reset, provides a software driven reset via I²C.

Software reset

The operation to perform a sensor reset is the following:

- microcontroller sets the soft_rst bit to '1'

4 Product Features

The ability of the magnetic and thermal measurements are described as well as the Wake Up feature. Diagnosis features are available with each measurement in contrary to test functions, which needs to be triggered by the microcontroller independent from any measurement.

4.1 Measurement

This sensor is intended to provide a space saving 3DHall solution. This implies that the sensor provides uncompensated raw data which can be compensated in a microcontroller. The equations and explanations, needed for the compensation, are described in the chapter "Compensation and calibration". In this chapter are also provided information for further improvement of the measurement accuracy, which can be achieved with a end of line calibration of the sensor.

The nomenclature of the used symbols is illustrated in the following holistic figure.

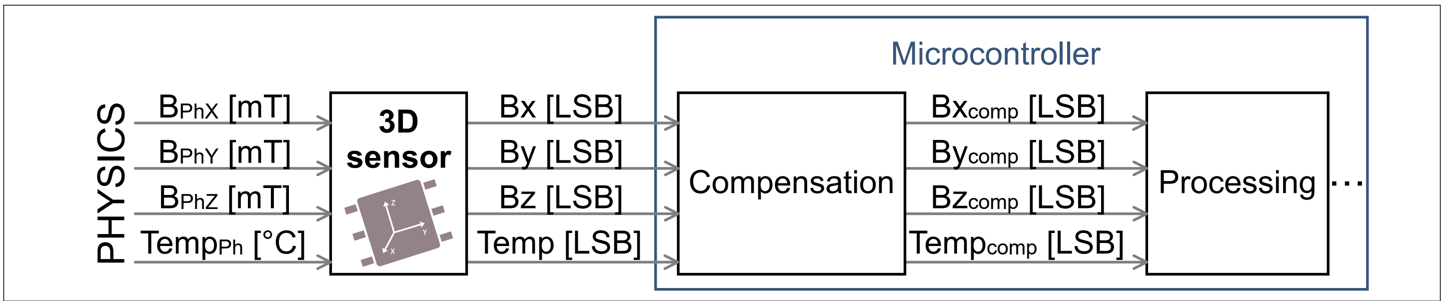


Figure 5 **Measurement symbol definition**

Table 6 **Measurement symbol definition**

Physical values	Sensor raw measurement values	Compensated measurement values
B_{PhX} [mT]	Bx [LSB]	Bx_{comp} [LSB]
B_{PhY} [mT]	By [LSB]	By_{comp} [LSB]
B_{PhZ} [mT]	Bz [LSB]	Bz_{comp} [LSB]
$Temp_{Ph}$ [°C]	Temp [LSB]	$Temp_{comp}$ [LSB]

The compensation in the microcontroller can be implemented according to the chapter Compensation and calibration.

4.1.1 Magnetic measurements

The magnetic measurement values are provided in the two's complement with 14 bit resolution in the registers with the symbols Bx, By and Bz.

Table 7 Initial magnetic characteristics

Values for 0 h and T_j = 25°C (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Sensitivity X, Y, Z (full range)	S_X, S_Y, S_Z	23	29.5	38	LSB_{14}/mT	
Sensitivity X, Y, Z (short range)	S_{X_SR}, S_{Y_SR}, S_{Z_SR}	46	59	76	LSB_{14}/mT	
Sensitivity X, Y, Z (extra short range)	S_{X_XSR}, S_{Y_XSR}, S_{Z_XSR}	92	118	152	LSB_{14}/mT	
Offset X, Y, Z (all ranges)	O_X, O_Y, O_Z	-0.5	±0.2	0.5	mT	B_{Ph} = 0 mT
X to Y magnetic matching (all ranges)	M_{XY}	-5	±1	5	%	
X/Y to Z magnetic matching (all ranges)	$M_{X/YZ}$	-15	±5	15	%	

Table 8 Compensated magnetic drift characteristics

Drifts are changes from the initial characteristics due to external influences.
Values for all range settings, static magnetic field within full magnetic linear range (unless otherwise specified).
All values are compensated according Compensation and calibration.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Sensitivity drift X, Y, Z	$S_{X\_D\_comp}$, $S_{Y\_D\_comp}$, $S_{Z\_D\_comp}$	-9	–	9	%	T_j = -40...85°C
		-10	±5	10		T_j = -40...105°C
		-10.5	–	10.5		T_j = -40...125°C
Offset drift X, Y, Z	$O_{X\_D\_comp}$, $O_{Y\_D\_comp}$, $O_{Z\_D\_comp}$	-0.3	–	0.3	mT	T_j = -40...85°C, B_{Ph} = 0 mT
		-0.3	–	0.3		T_j = -40...105°C, B_{Ph} = 0 mT
		-0.3	–	0.3		T_j = -40...125°C, B_{Ph} = 0 mT
X to Y magnetic matching drift	$M_{XY\_D\_comp}$	-1.65	–	1.65	%	T_j = -40...85°C
		-1,7	-	1,7		T_j = -40...105°C
		-1.9	–	1.9		T_j = -40...125°C
X/Y to Z magnetic matching drift	M_{X/YZ_D_comp}	-6.5	–	6.5	%	T_j = -40...85°C
		-6.75	–	6.75		T_j = -40...105°C
		-8	–	8		T_j = -40...125°C

Table 9 **Raw magnetic drift characteristics**

Drifts are changes from the initial characteristics due to external influences.

Values for T_j = -40°C to 105°C, all ranges, static magnetic field within full magnetic linear range (unless otherwise specified). Without compensation.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Sensitivity drift X, Y, Z	S_{X_D}, S_{Y_D}, S_{Z_D}	-12.7	–	12.7	%	
Offset drift X, Y, Z	O_{X_D}, O_{Y_D}, O_{Z_D}	-0.35	–	0.35	mT	B_{Ph} = 0 mT
X to Y magnetic matching drift	M_{XY_D}	-1.7	–	1.7	%	
X/Y to Z magnetic matching drift	M_{X/YZ_D}	-7.5	–	7.5	%	

Table 10 **Magnetic non-linearity and noise**

Values for T_j = -40°C to 105°C (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Integral non linearity (full range)	INL	-40	–	40	LSB_{14}	Bx, By and Bz
Integral non linearity (short range)	INL_{SR}	-80	–	80	LSB_{14}	Bx, By and Bz
Integral non linearity (extra short range)	INL_{XSR}	-160	–	160	LSB_{14}	Bx, By and Bz
Differential non linearity (full range)	DNL	-16	–	16	LSB_{14}	Bx, By and Bz
Differential non linearity (short range)	DNL_{SR}	-32	–	32	LSB_{14}	Bx, By and Bz
Differential non linearity (extra short range)	DNL_{XSR}	-64	–	64	LSB_{14}	Bx, By and Bz
Z-magnetic noise (full range, rms)	B_{NeffZ}	–	–	173	µT	rms = 1 sigma
XY-magnetic noise (full range, rms)	B_{NeffXY}	–	–	250	µT	rms = 1 sigma
Z-magnetic noise (short range, rms)	B_{NeffZ_SR}	–	–	122	µT	rms = 1 sigma
XY-magnetic noise (short range, rms)	B_{NeffXY_SR}	–	–	176	µT	rms = 1 sigma
Z-magnetic noise (extra short range, rms)	B_{NeffZ_XSR}	–	–	86	µT	rms = 1 sigma
XY-magnetic noise (extra short range, rms)	B_{NeffXY_XSR}	–	–	125	µT	rms = 1 sigma

$$M_{XY} = 100 \cdot 2 \cdot \frac{S_X - S_Y}{S_X + S_Y} \; [\%]$$

Equation 2 **Equation for parameter "X to Y magnetic matching"**

$$M_{X/YZ} = 100 \cdot 2 \cdot \frac{S_X + S_Y - 2 \cdot S_Z}{S_X + S_Y + 2 \cdot S_Z} \; [\%]$$

Equation 3 **Equation for parameter "X/Y to Z magnetic matching"**

4.1.2 Temperature measurement

The sensor provides an internal temperature measurement proportional to the junction temperature. The result can be read out from the Temp register with 14 bit resolution.

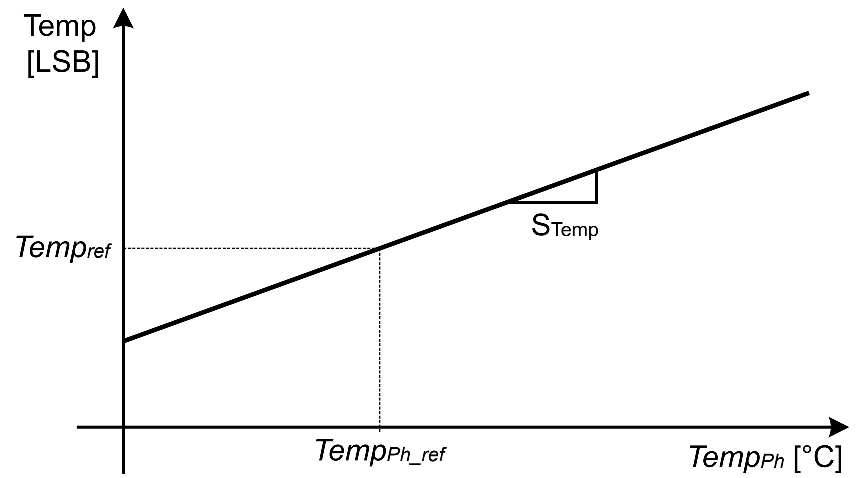


Figure 6 Temperature measurement

The temperature information is used in the external compensation to improve the accuracy of the magnetic measurement over the full temperature range.

It is further possible to utilize the temperature sensor data in the application. Note that the measured temperature is proportional to the junction temperature and may deviate from the respective ambient temperature.

Table 11 Temperature measurement characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Temperature sensitivity	S_{Temp}	13.3	15.2	17.2	LSB_{14}/K	referring to T_j
Temp reference value	$Temp_{ref}$	3880	4200	4500	LSB_{14}	$Temp_{Ph} = Temp_{Ph\_ref}$
Physical temperature reference	$Temp_{Ph\_ref}$	–	25	–	°C	

4.1.3 Compensation and calibration

The values $Bxyz_{comp}$ must be calculated with the following equations out of the sensors raw data Bxyz.

$$
\begin{aligned}
Bx_{comp} &= r \cdot (O_{0x} + O_{1x} \cdot Temp + O_{2x} \cdot Temp^2 + O_{3x} \cdot Temp^3) + \\
&\quad Bx \cdot (L_{0x} + L_{1x} \cdot Temp + L_{2x} \cdot Temp^2 + L_{3x} \cdot Temp^3) \\
By_{comp} &= r \cdot (O_{0y} + O_{1y} \cdot Temp + O_{2y} \cdot Temp^2 + O_{3y} \cdot Temp^3) + \\
&\quad By \cdot \left(L_{0y} + L_{1y} \cdot Temp + L_{2y} \cdot Temp^2 + L_{3y} \cdot Temp^3\right) \\
Bz_{comp} &= r \cdot (O_{0z} + O_{1z} \cdot Temp + O_{2z} \cdot Temp^2 + O_{3z} \cdot Temp^3) + \\
&\quad Bz \cdot (L_{0z} + L_{1z} \cdot Temp + L_{2z} \cdot Temp^2 + L_{3z} \cdot Temp^3)
\end{aligned}
$$

Equation 4

Table 12 Compensation range factors

Factor	Full range	Short range	Extra short range
r	1	2	4

Table 13 Compensation coefficients

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Coefficient O0x	O_{0x}	–	52.46501931	–	–	
Coefficient O1x	O_{1x}	–	$-30.828402 \cdot 10^{-3}$	–	–	
Coefficient O2x	O_{2x}	–	$6.06444 \cdot 10^{-6}$	–	–	
Coefficient O3x	O_{3x}	–	$-4.20546 \cdot 10^{-10}$	–	–	
Coefficient L0x	L_{0x}	–	-2.109359211	–	–	
Coefficient L1x	L_{1x}	–	$2.248525 \cdot 10^{-3}$	–	–	
Coefficient L2x	L_{2x}	–	$-5.25818 \cdot 10^{-7}$	–	–	
Coefficient L3x	L_{3x}	–	$3.99648 \cdot 10^{-11}$	–	–	
Coefficient O0y	O_{0y}	–	7.574714985	–	–	
Coefficient O1y	O_{1y}	–	$-4.602293 \cdot 10^{-3}$	–	–	
Coefficient O2y	O_{2y}	–	$8.61016 \cdot 10^{-7}$	–	–	
Coefficient O3y	O_{3y}	–	$-7.47545 \cdot 10^{-11}$	–	–	
Coefficient L0y	L_{0y}	–	-2.106808409	–	–	
Coefficient L1y	L_{1y}	–	$2.234594 \cdot 10^{-3}$	–	–	
Coefficient L2y	L_{2y}	–	$-5.22864 \cdot 10^{-7}$	–	–	
Coefficient L3y	L_{3y}	–	$3.97614 \cdot 10^{-11}$	–	–	
Coefficient O0z	O_{0z}	–	9.233258372	–	–	
Coefficient O1z	O_{1z}	–	$-3.911673 \cdot 10^{-3}$	–	–	
Coefficient O2z	O_{2z}	–	$7.01838 \cdot 10^{-7}$	–	–	
Coefficient O3z	O_{3z}	–	$-4.38542 \cdot 10^{-11}$	–	–	
Coefficient L0z	L_{0z}	–	-0.96458813	–	–	
Coefficient L1z	L_{1z}	–	$1.445091 \cdot 10^{-3}$	–	–	
Coefficient L2z	L_{2z}	–	$-3.42739 \cdot 10^{-7}$	–	–	
Coefficient L3z	L_{3z}	–	$2.63 \cdot 10^{-11}$	–	–	

4.1.4 Measurement Timing

For a good adaptation on application requirements this sensor is equipped with 2 modes:
- Low Power Mode: In this mode the measurements are triggered sensor internally.
- Master Controlled Mode: In this mode the measurements are triggered externally.

In both modes, in between the measurements, the sensor is in Power Down.

The measurement modes can be configured for a
- 3 dimensional and temperature measurement
- 2 dimensional measurement
- 1 dimensional and temperature measurement for X and Z

An overview is listed in Table 14.

Table 14 Overview of modes

<table>
<tr><th>Mode</th><th>Measurement</th><th>Typ. f_{Update}</th><th>Description</th></tr>
<tr><td>Power Down</td><td>No measurements</td><td>-</td><td>Lowest possible supply current I_{DD_pd}.</td></tr>
<tr><td rowspan="4">Low Power Mode (full range, short range and extra short range)</td><td>Bx, By, Bz, Temp</td><td rowspan="4">16 Hz
31 Hz
125 Hz
1000 Hz</td><td rowspan="4">Self triggered cyclic measurements.
f_{Update} is valid with the second conversion after power up and/or register reset.</td></tr>
<tr><td>Bx, By</td></tr>
<tr><td>Bx, Temp</td></tr>
<tr><td>Bz, Temp</td></tr>
<tr><td rowspan="4">Master Controlled Mode (full range)</td><td>Bx, By, Bz, Temp</td><td>Up to 3.7 kHz</td><td rowspan="12">Measurements are triggered by the microcontroller.</td></tr>
<tr><td>Bx, By</td><td rowspan="3">Up to 7 kHz</td></tr>
<tr><td>Bx, Temp</td></tr>
<tr><td>Bz, Temp</td></tr>
<tr><td rowspan="4">Master Controlled Mode (short range)</td><td>Bx, By, Bz, Temp</td><td>Up to 2.7 kHz</td></tr>
<tr><td>Bx, By</td><td rowspan="3">Up to 5.3 kHz</td></tr>
<tr><td>Bx, Temp</td></tr>
<tr><td>Bz, Temp</td></tr>
<tr><td rowspan="4">Master Controlled Mode (extra short range)</td><td>Bx, By, Bz, Temp</td><td>Up to 1.8 kHz</td></tr>
<tr><td>Bx, By</td><td rowspan="3">Up to 3.6 kHz</td></tr>
<tr><td>Bx, Temp</td></tr>
<tr><td>Bz, Temp</td></tr>
</table>

The sequence of the measurement is always the same, independent of the measurement configuration. The timing of a measurement depends on the selected configuration. From measurement timing point of view important contributors are:

- measurement range (full range, short range, extra short range)
- configured measurements (3 dimensional and temperature or 2 dimensional or 1 dimensional and temperature)

The configuration of the measurement modes (Low Power Mode or Master Controlled Mode) influences the update frequency of the measurement results.

ADC restart

In case of a voltage drop during t_{ADC} ($V_{res} < V_{DD} < V_{ADCr}$) the measurement is aborted and as soon as the supply voltage recovers $V_{DD} > V_{ADCr}$ the full measurement is restarted at the beginning of t_{ADC}. The "measurement success flag" indicates a successfully finished measurement.

The timings of a measurement (t_{Bx}, t_{By}, t_{Bz}, t_{Temp}, t_{trig_d}, t_{INTN_d}, t_{INTN}, $1/f_{Update}$) are shown in the following picture, as well as the points in time when measurement values for Bx, By, Bz and Temp are available in the registers.

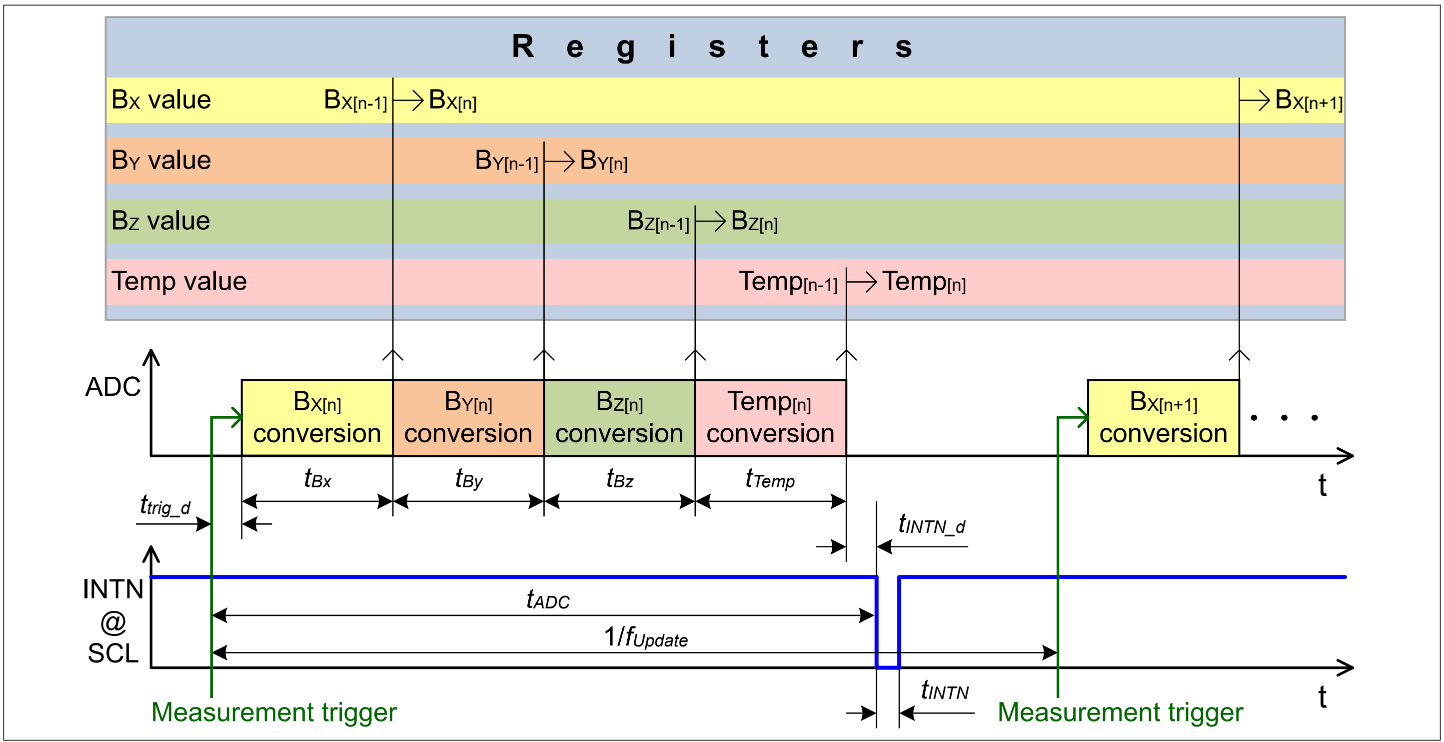


Figure 7 **Measurement timing**

Measurement triggers are described in

- ADC trigger before reading data
- ADC trigger at the stop condition

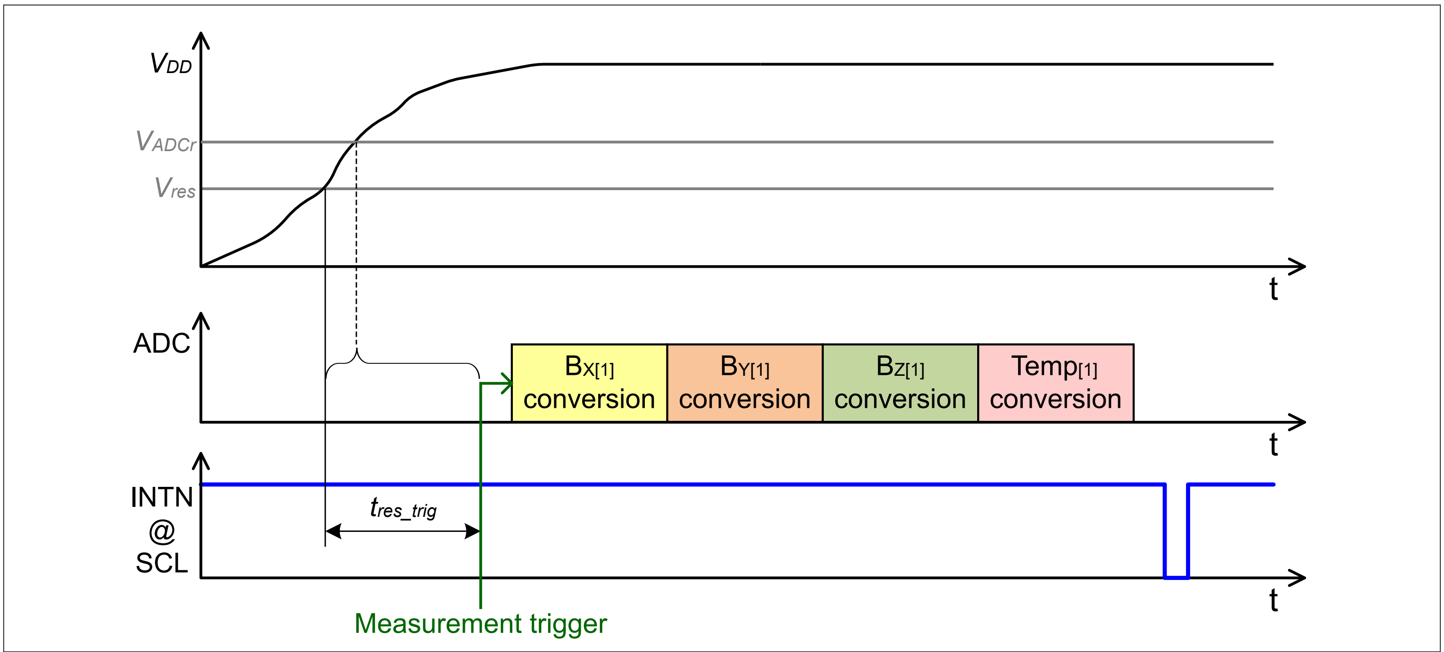


Figure 8 **1st measurement time after a register reset (V_{res}) and a ADC restart (V_{ADCr})**

Table 15 Measurement timing

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Oscillator period	t_{osc}	360	500	640	ns	
First measurement time	t_{res_trig}	–	–	75	µs	ADC restart (V_{ADCr}) within t_{res_trig}. See Figure 8
Trigger delay	t_{trig_d}	10	16	23	µs	

Measurement oscillator cycles

The sensor timings are derived from the sensors oscillator periode t_{OSC}.

Table 16 Measurement oscillator cycles

Parameter	Symbol	Values			Unit
		full range	short range	extra short range	
INTN pulse width	t_{INTN}	5	5	5	t_{OSC}
Bx, By, Bz conversion time	t_{Bx}. t_{By}, t_{Bz}	86	118	182	t_{OSC}
Temp conversion time	t_{Temp}	86	86	86	t_{OSC}
INTN delay	t_{INTN_d}	1	1	1	t_{OSC}

4.2 Wake Up

This Wake Up mode can be used to allow the sensor to continue performing magnetic field measurements while the microcontroller is in the power-down state, which means the power consumption of the application is significantly reduced and the microcontroller accesses the sensor only if relevant measurement data are available.

For each of the three magnetic channels (Bx, By, Bz), the Wake Up function has a lower and an upper threshold. The thresholds have a resolution of 10 bits, corresponding to the 10 MSB of the magnetic measurement results Bx, By and Bz.

The magnetic measurement results of Bx, By and Bz are compared to the corresponding lower and upper Wake Up thresholds. If one of the magnetic measurement results is above the upper or below the lower threshold, an interrupt pulse INTN is generated. If all magnetic measurement results are within the envelope of lower and upper Wake Up threshold, no interrupt pulse will be provided. See also Figure 9.

In the Wake Up mode the interrupt pulse INTN is always activated, independent of the interrupt configuration.

Each of the 3 Wake Up channels X, Y and Z can be disabled individually by configuring the upper Wake Up threshold to the maximum value and the lower Wake Up threshold to the minimum value. In this configuration no interrupt INTN is provided for the disabled channel.

The Wake Up mode is intended to be used together with the Low Power mode. Note that the collision avoidance also applies on the Wake Up interrupt pulse INTN.

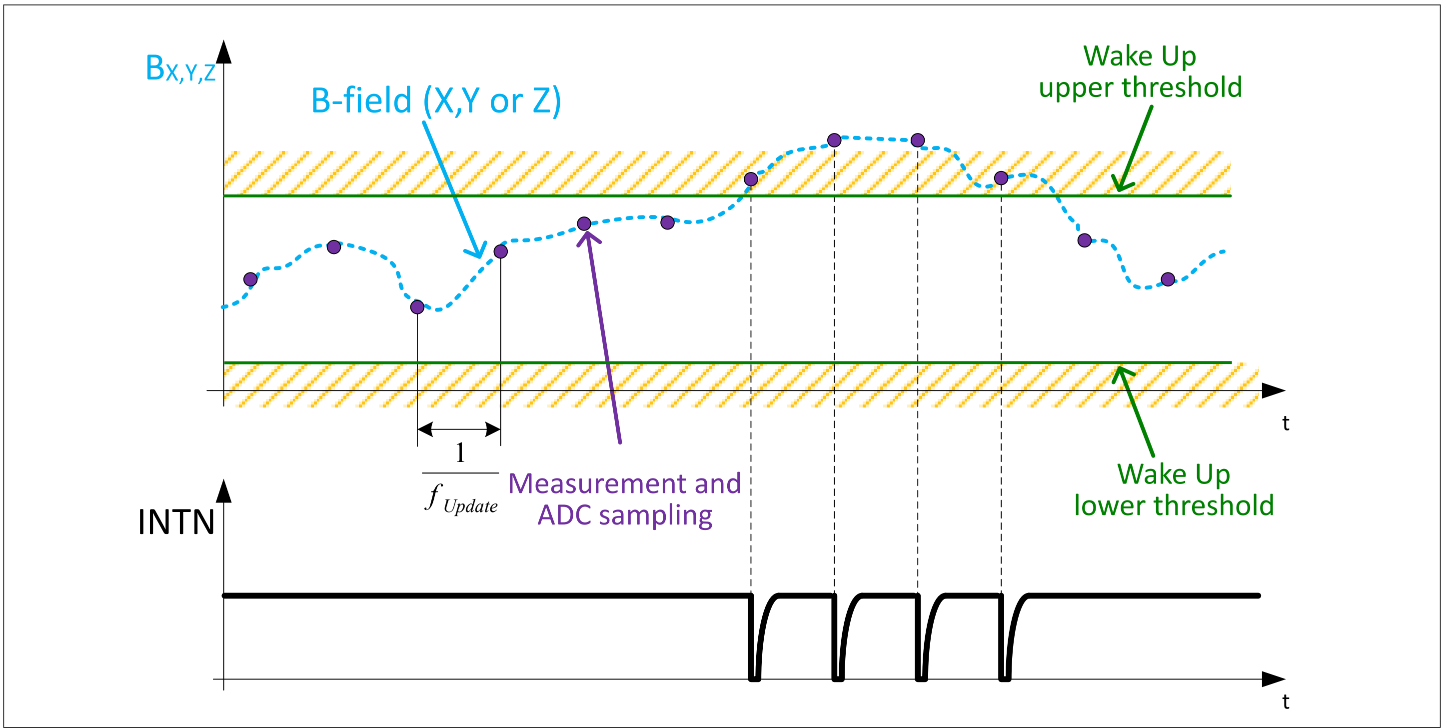


Figure 9 **Wake Up threshold operation**

The Wake Up function is activated when the following conditions are simultaneously met:

- Low Power mode must be activated
- wu_en or wu_en_cp must be set
- test functions must be disabled (channel_sel = 0000_B or 1100_B or 1101_B or 1110_B)
- Wake Up parity bit wu_par must be OK

4.3 Diagnosis

The sensor provides diagnostic functions. These functions are running in the background, providing results, which can be checked by the microcontroller for the verification of the measurement results.

The diagnosis flags are updated continuously.

Wake up parity bit and flag

A Wake Up parity check comprises all Wake Up registers of the sensor and the Wake Up parity bit (wu_par bit), which must be odd. The result of the parity check is indicated with a Wake Up parity flag wu_par_flg at the diagnosis readout. After a sensor reset or startup the Wake Up parity flag wu_par_flg is correct by default.

Measurement success flag

The diagnosis meas_flg shows that all read out measurement values including the frame counter belong to the same measurement or test function cycle and that during the cycle no shift between measurement and test function occurred.

Test function flag

The test function test_flg indicates if the registers Bx, By, Bz and Temp contain measurement or test data.

Frame counter

A two bit frame counter frame_counter is incremented at every finished measurement, as configured by CHANNEL_SEL, once a complete ADC conversion cycle is finished and the new measurement results have been stored in the registers 00_H to 07_H.

CRC

Used CRC polynomial:

- 8 bit
- $2F_H = x^8+x^5+x^3+x^2+x+1$
- Start value = 00_H

Readout from the sensor to the microcontroller:

- The measurement data, diagnosis information and configuration are used to calculate the CRC-byte by the sensor.
- This function is always active.

The crc_wr_flg indicates if data with correct CRC has been received by the sensor when the CRC at write is enabled.

- Relevant for the CRC calculation are all bytes in the communication frame excluding the last byte which is the CRC computed by the microcontroller.
- By default this function is disabled. It can be enabled with the crc_wr_en configuration bit.
- If a write command disables the CRC at write, the CRC calculation for this and further write commands is not executed.
- Independent from the crc_wr_flg the transmitted data are executed immediately by the sensor.
- The CRC at write configuration bit is not CRC write protected. The CRC at write configuration can be checked by reading the crc_wr_flg.
- The structure of the write command differs, dependent on the CRC at write configuration bit. See the write command description.

Loss of VDD

If the SDA or SCL line is pulled “low” and the sensor is disconnected from the VDD supply line, the affected I²C line will most likely get a stuck in the Low state and will interfere with the communication on the bus.

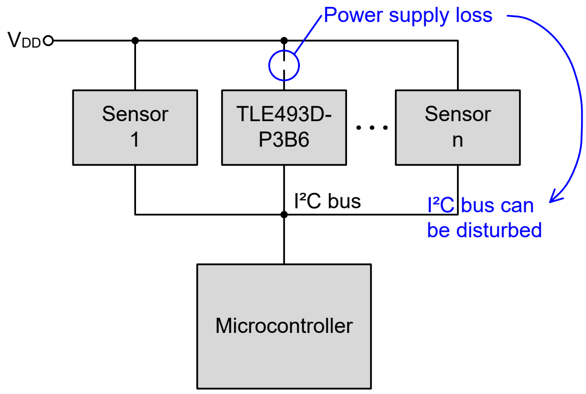


Figure 10 **Example of I²C bus and a sensor with disconnected VDD**

Loss of GND

This sensor has no capability to detect a loss of GND, neither any capability to handle this issue.

4.4 Test functions

Test functions are only executed by the sensor following a request by the microcontroller. The test functions provide test values instead of measurement values, which can be used to check if the sensor is working properly.

The test functions can be executed in the Master Controlled Mode and Low Power Mode. To activate a test function the channel_sel bits must be configured accordingly.

All reference values generated during module production test must be measured within $T_{\text{ref-ambient}}$.

Table 17 **Calibration temperature**

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Calibration temperature	$T_{\text{ref-ambient}}$	10	-	40	°C	E.g. module production test

4.4.1 Vhall bias/Vext test function

This test checks the signal path, the Hall devices bias voltage and the external supply voltage.

Instead of measuring the Hall voltages on the probe (which depend on the external magnetic field), the Hall probes bias voltage is measured. Instead of measuring the temperature the external supply voltage, applied via the VDD-pin, is measured.

As the Hall bias voltage and the external supply voltage are known, any unexpected result would detect a malfunctioning of the internal Hall biasing or the signal path.

This test should be executed in module production test first. The values generated in this first test should be compared, if inside the limits listed in Table 18 and stored on module level. During module life time this stored values should be compared with additional life time test results and the system must check, if the values are inside the limits listed in Table 18**.**

The test is performed as described below:

- Set the channel_sel field according to Vhall bias/Vext test.
- Trigger a new measurement.
- When the measurement is completed, read the value of the registers Bx, By, Bz and Temp.

Vhall bias test:

- Check that the registers Bx, By and Bz have values inside the limits of Table 18.
- Testing one voltage reference (V_{DD}) is sufficient to cover the Vhall bias test.

Vext test:

- Make the microcontroller aware of the VDD-pin voltage.
- Check that the Vext value corresponds to the values listed in Table 18.

After the test:

- Continue with another test or leave the test function by setting the channel_sel field accordingly.

Timing:

- t_{ADC} for this test is the full range timing (full-, short-, extra short range), independent from the range settings plus the communication timing.

Table 18 Vhall bias / Vext diagnostic limits

Diagnostic test	Module production test Checked and stored for product life time				Temperature and lifetime drift of stored product values		
	Unit	min.	typ.	max.	Unit	min.	max.
Vhall bias X, Y @ 2.8 V to 5.5 V	LSB_{14}	2950	–	3950	%	-12	12
Vhall bias Z @ 2.8 V to 5.5 V	LSB_{14}	2200	–	4650	%	-14	14
Vext @ 3.3 V	LSB_{14}	3100	–	3750	%	-9	9
Vext gain @ 2.8 V to 5.5 V	LSB_{14}/V	935	–	1160	%	-9	9

The test limits are different for production and life time. Both is shown in Table 18 and illustrated in Figure 11.

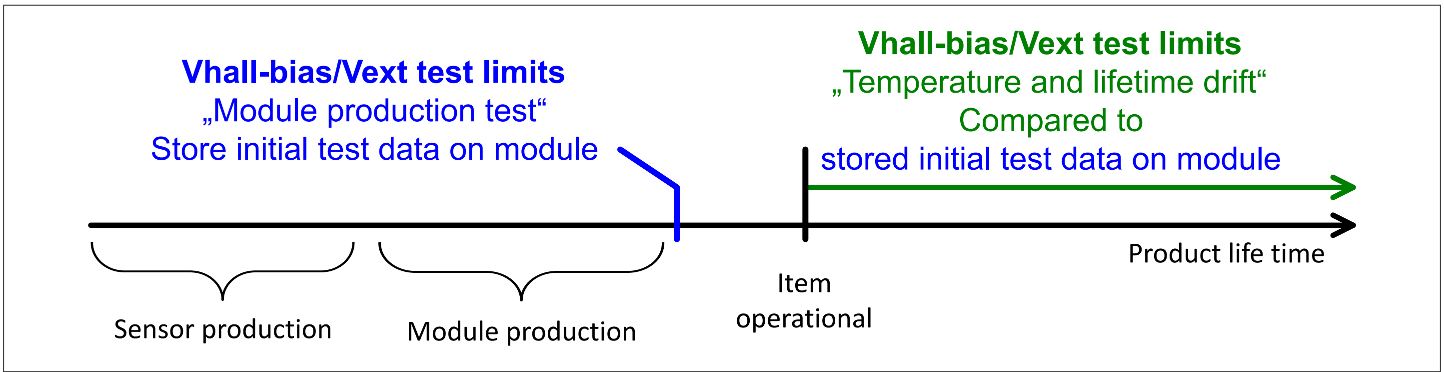


Figure 11 Vhall bias/Vext diagnostic limits vs. lifetime

4.4.2 Spintest/Vint test function

This test checks the correct spinning (also known as chopping) of all four phases of a Hall probe for the three channels Bx, By and Bz of the sensor and provides a measurement for the Hall probes and ADC offset. Instead of measuring the temperature the internal regulator supply (Vint) is measured.

In a magnetic measurement run, the result of the four spinning phases is:

$$(V_H + V_{Oh} + V_{Oa}) + (V_H - V_{Oh} - V_{Oa}) + (V_H - V_{Oh} - V_{Oa}) + (V_H + V_{Oh} + V_{Oa}) = 4 \cdot V_H$$

Equation 5

- V_H is the voltage at the Hall probes
- V_{Oh} is the voltage offset at the Hall probes
- V_{Oa} is the voltage offset at the ADC

By spinning the measurement four times at the Hall probes, the Hall offset and the ADC offset are eliminated in magnetic measurements. The Spintest can be used to measure the sum of the Hall probes offset and ADC offset. In a Spintest measurement run the result is:

$$(V_H + V_{Oh} + V_{Oa}) - (V_H - V_{Oh} - V_{Oa}) - (V_H - V_{Oh} - V_{Oa}) + (V_H + V_{Oh} + V_{Oa}) = 4 \cdot V_{Oh} + 4 \cdot V_{Oa} = 4 \cdot (V_{Oh} + V_{Oa})$$

Equation 6

The Spintest duration on one channel is the same as the duration of a full range measurement on that channel, independent if full-, short- or extra short range is configured.

The test is performed as described below:

- Set the channel_sel registers according to Spintest/Vint test.
- Trigger a new measurement.
- When the measurement is completed, read the value of the registers Bx, By, Bz and Temp.

Spintest:

- Check that Bx, By and Bz have values inside the limits of Table 19.

Vint test:

- Check that the Vint value read from Temp corresponds to the values listed in Table 19.

After the test:

- Continue with another test or leave the test mode by setting the channel_sel field accordingly.

Timing:

- t_{ADC} for this test is the full range timing (full-, short-, extra short range), independent from the range settings plus the communication timing.

The test limits are different for production and life time. Both is shown in Table 19 and illustrated in Figure 12. The spintest should be executed during the module production test first. The offset values generated in the first test should be compared to make sure that they are inside the limits specified in Table 19, section "Module production test" and stored on module level. During module lifetime these stored values must be compared in an additional Spintest to check if the values are inside the limits listed in Table 19, section "Temperature and lifetime drift".

Table 19 Spintest/Vint test diagnostic limits

Diagnostic test	Module production test Check and store for product life time				Temperature and lifetime drift of stored product values		
	Unit	min.	typ.	max.	Unit	min.	max.
Spintest X, Y @ 2.8 V to 5.5 V	LSB_{14}	-4120	–	3240	LSB_{14}	-2605	2605
Spintest Z @ 2.8 V to 5.5 V	LSB_{14}	-2800	–	2650	LSB_{14}	-1260	1260
Vint @ 2.8 V to 5.5 V	LSB_{14}	4100	–	5400	%	-9	9

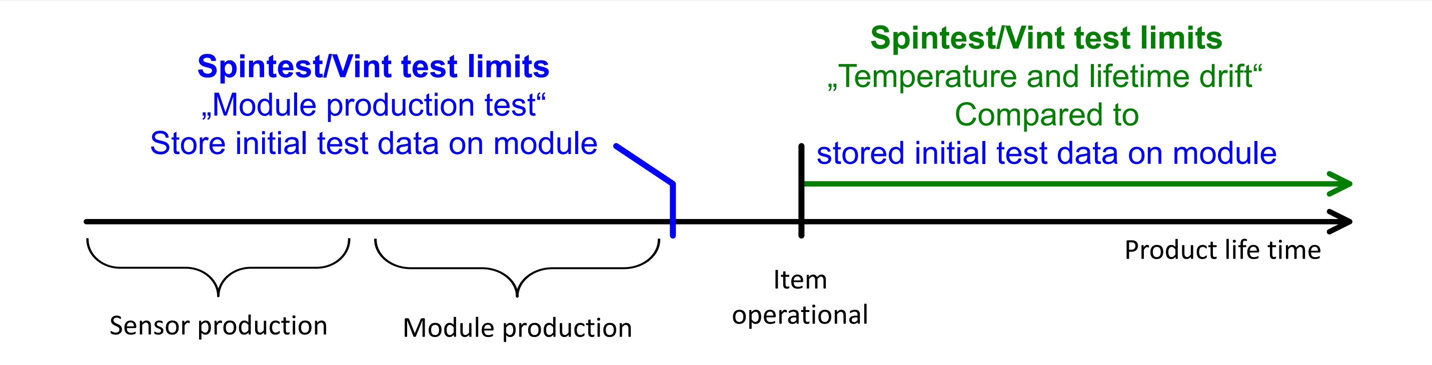


Figure 12 **Spintest/Vint test diagnostic limits vs. lifetime**

4.4.3 SAT test function

This test checks the whole digital signal path from sensor to microcontroller. This includes the ADC's digital core, the data register and the interface.

This test checks the Successive Approximation and Tracking (SAT) mechanism used for the four spin phases of each data channel (Hall probes and temperature sensor).

The test is performed as described below:

- Set the channel_sel field according to SAT test.
- Select one combination f_update_sel and short_en and xtr_short_en. Please note: One combination is sufficient for a valid SAT-test.
- Trigger a new measurement.
- Read the values of Bx, By, Bz and Temp and compare if they correspond with the values listed in Table 20.

After the test:

- Continue with another test or leave the test mode by setting the channel_sel field accordingly.

Timing:

- t_{ADC} for this test depends on the range timing (full-, short-, extra short range), dependent from the range settings plus the communication timing.

Table 20 **SAT test reference values**

f_update_sel	short_en	xtr_short_en	Bx[14b]	By[14b]	Bz[14b]	Temp[14b]
00_B	0_B	0_B	$1FE6_H$	$201A_H$	$1FFD_H$	2002_H
01_B	0_B	0_B	$201A_H$	$1FE6_H$	2002_H	$1FFD_H$
10_B	0_B	0_B	$1FFD_H$	2002_H	$1FE6_H$	$201A_H$
11_B	0_B	0_B	2002_H	$1FFD_H$	$201A_H$	$1FE6_H$
00_B	1_B	0_B	$1FFF_H$	2000_H	$1FFF_H$	2002_H
01_B	1_B	0_B	2000_H	$1FFF_H$	2000_H	$1FFD_H$
10_B	1_B	0_B	$1FFF_H$	2000_H	$1FFF_H$	$201A_H$
11_B	1_B	0_B	2000_H	$1FFF_H$	2000_H	$1FE6_H$
00_B	Don't care	1_B	$3ED8_H$	0128_H	$3FF7_H$	2002_H
01_B	Don't care	1_B	0128_H	$3ED8_H$	0008_H	$1FFD_H$
10_B	Don't care	1_B	$3FF7_H$	0008_H	$3ED8_H$	$201A_H$
11_B	Don't care	1_B	0008_H	$3FF7_H$	0128_H	$1FE6_H$

4.5 Trigger options in the Master Controlled Mode

The trigger option 01_B allows to trigger the ADC before reading the first data byte.
The trigger options 10_B or 11_B allow to trigger the ADC with the I^2C stop condition, rising edge at SDA.
The trigger option 00_B disables the ADC trigger.

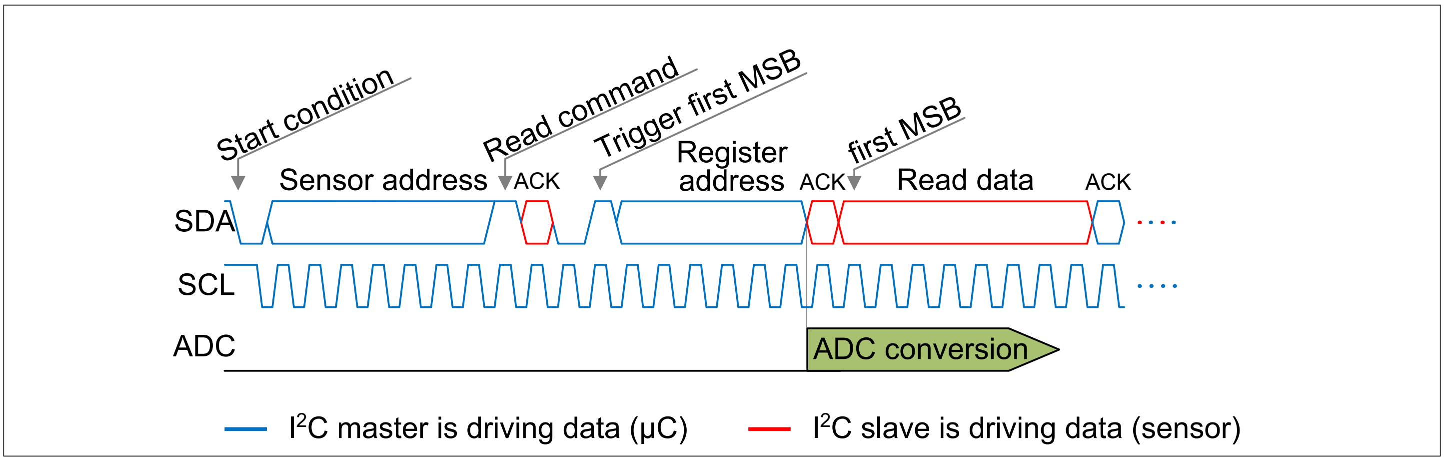


Figure 13 **ADC trigger before reading data**

For the I^2C 1-byte read command the trigger bits are configurable in the configuration registers.
In the I^2C 2-byte frame format the trigger bits are integrated as shown in the 2-byte read command and in the write command.

5 Functional Block Description

This sensor is a configurable sensor, intended for a very good adaptation to different applications. This requires a bidirectional communication interface.

5.1 I²C interface

The sensor uses inter-integrated circuit (I²C) as the communication interface with the microcontroller.

The I²C interface has the following main functions:

- Sensor configuration
- Transmit measurement data
- Diagnosis and test
- Interrupt handling

This sensor provides two I²C read protocols:

- 16 bit read frame (µC is driving data), so called 2-byte read command
- 8 bit read frame (µC is driving data), so called 1-byte read command

The I²C interface can be accessed in any power mode, after t_{res_trig} expired.

5.1.1 I²C protocol description

The sensor provides one I²C write protocol, which is based on 2 bytes, and two I²C read protocols. With a configuration bit it can be selected, if the 1-byte read protocol or the 2-byte read protocol is used. See also the default settings.

- The interface conforms to the I²C fast mode specification, but can be driven faster according to the "Allowed I²C bit clock frequency", see Table 21.
- The sensor does not support "repeated starts". Each addressing requires a start condition..
- The data transmission order is most significant bit (MSB) first, least significant bit (LSB) last.
- A I²C communication is always initiated with a start condition and concluded with a stop condition by the master (microcontroller). During a start or stop condition the SCL line must stay "high" and the SDA line must change its state: SDA line falling = start condition and SDA line rising = stop condition.
- Bit transfer occurs when the SCL line is "high".
- Each byte is followed by one ACK bit. The ACK bit is always generated by the recipient of each data byte.
  - If no error occurs during the data transfer, the ACK bit will be set to "low".
  - If an error occurs during the data transfer, the ACK bit will be set to "high".
  - If the communication is finished (before the stop condition), the ACK bit must be set to "high".

5.1.1.1 I²C write command

Write I²C communication description:

- The purpose of the sensor address is to identify the sensor with which communication should occur. The sensor address byte is required independently of the number of sensors connected to the microcontroller.
- The register address identifies the register in the bitmap with which the first data byte will be written.
- Data bytes are transmitted as long as the SCL line generates pulses. Each additional data byte increments the register address until the stop condition occurs.
- Bytes transmitted beyond the addressable register range are ignored and the corresponding ACK bit is sent "high", indicating an error.
- Any written configuration takes effect immediately or latest at the end of a first completed measurement cycle.

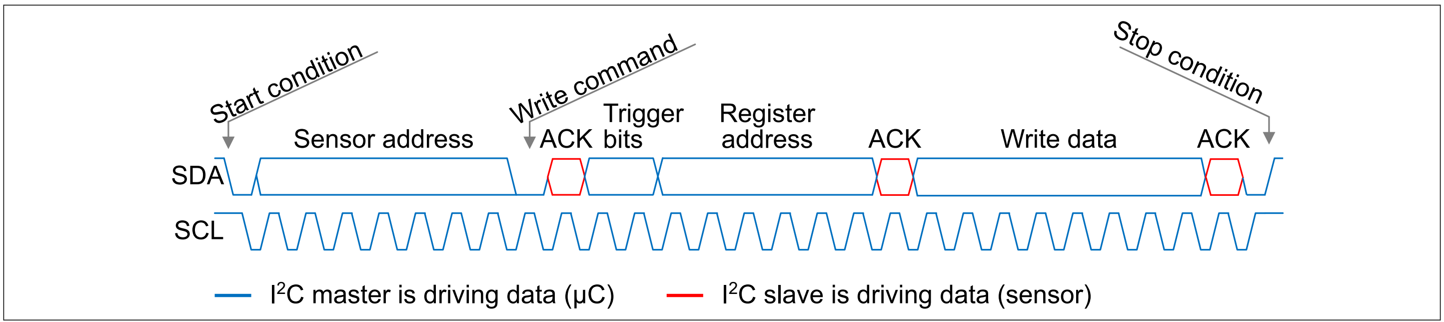


Figure 14 General I²C write frame format: Write data from microcontroller to sensor

Write command without CRC

The I²C write communication frame with disabled CRC consists of:

- The start condition
- The sensor address
- Write command bit = "low" (read = "high")
- Acknowledge ACK generated by the sensor
- Trigger bits
- The register address
- Acknowledge ACK generated by the sensor
- Write of one or several bytes to the sensor. Each byte is followed by an acknowledge ACK generated by the sensor
- The stop condition

See Figure 15.

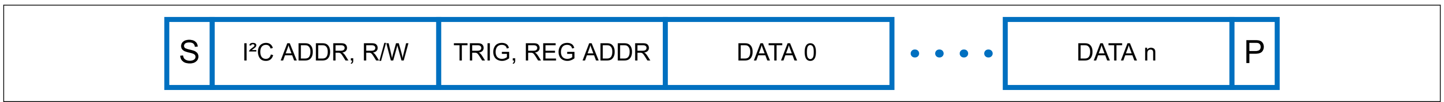


Figure 15 General I²C write command without CRC: Write data from microcontroller to sensor.

Write command with CRC

The I²C write communication frame with enabled CRC consists of:

- The start condition
- The sensor address
- Write command bit = "low" (read = "high")
- Acknowledge ACK generated by the sensor
- Trigger bits
- The register address
- Acknowledge ACK generated by the sensor
- Number of data bytes to be transmitted in this frame
- Acknowledge ACK generated by the sensor
- Write of one or several bytes to the sensor. Each byte is followed by an acknowledge ACK generated by the sensor
- The CRC
- Acknowledge ACK generated by the sensor
- The stop condition

See Figure 16.

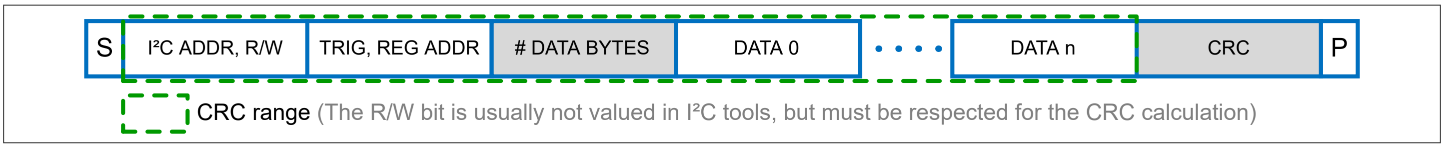


Figure 16 General I2C write command with CRC: Write data from microcontroller to sensor.

5.1.1.2 I²C read commands

Read I²C communication description:

- The purpose of the sensor address is to identify the sensor with which communication should occur. The sensor address byte is required independently of the number of sensors connected to the microcontroller.
- Only available in the 2-byte read command: The register address identifies the register in the bitmap from which the first data byte will be read.
  In the 1-byte read command the read out always starts at the register address 00_H.
- As many data bytes will be transferred as long as pulses are generated by the SCL line. Each additional data byte increments the register address, until the stop condition occurs.
- If bytes are read beyond the addressable register range the sensor keeps the SDA = 1_B.
- If the microcontroller reads data and does not acknowledge the sensor data (ACK = 1_B) the sensor keeps the SDA = 1_B until the next stop condition.

1-byte read command

The I²C communication frame consists of:

- The start condition
- The sensor address
- Read command bit = "high" (write = "low")
- Acknowledge ACK generated by the sensor
- Reading of one or several bytes from the sensor. Each byte is followed by an acknowledge ACK generated by the master
  - The ACK has to be set to "low" if further bytes will be read
  - The ACK has to be set to "high" if the data readout is finished
- The stop condition

See Figure 17.

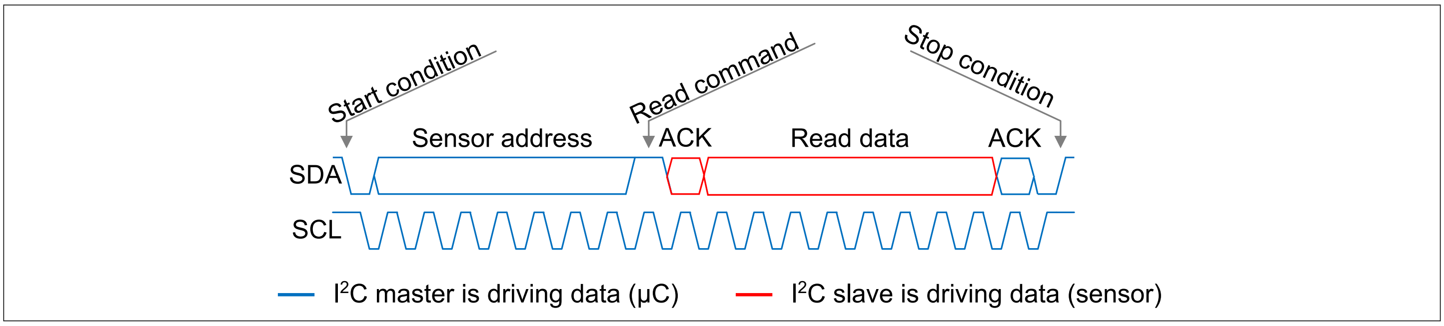


Figure 17 General I²C frame format 1-byte: Read data from sensor to microcontroller

2-byte read command

The I²C read communication frame consists of:

- The start condition
- The sensor address

- Read command bit = "high" (write = "low")
- Acknowledge ACK generated by the sensor
- Trigger bits
- The register address
- Acknowledge ACK generated by the sensor
- Reading of one or several bytes from the sensor. Each byte is followed by an acknowledge ACK generated by the master
  - The ACK has to be set to "low" if further bytes will be read
  - The ACK has to be set to "high" if the data readout is finished
- The stop condition

See Figure 18.

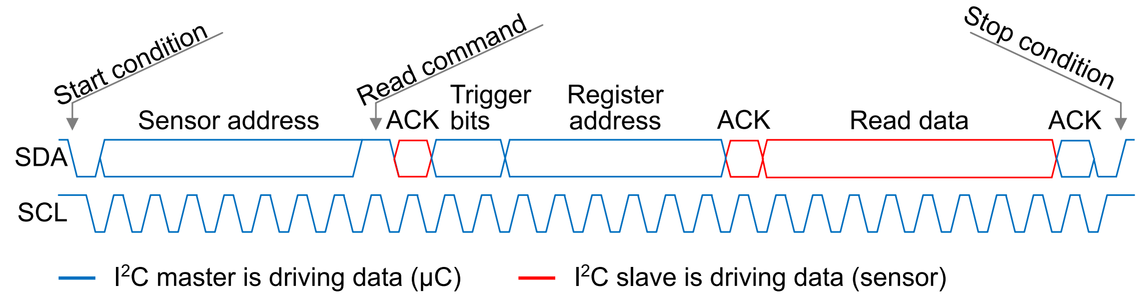


Figure 18 General I²C frame format 2-byte: Read data from sensor to microcontroller

5.1.1.3 Collision avoidance

With a configuration the collision avoidance function can be enabled or disabled:

Especially in a bus configuration, the interrupt signal INTN has the potential to interfere with ongoing communication. Activated collision avoidance prevents the sensor from generating interrupt signals INTN between a valid I²C start and stop condition.

It is strongly recommended to use the collision avoidance feature whenever the interrupt signal INTN is used.

Please note: In case the I²C start condition occurs at approximately the same time as the start of an INTN-pulse, it is possible that the INTN-pulse is not suppressed and is generated short after the I²C start condition. In case the INTN-pulse would start by at least t_{INTN} after the I²C start condition, the INTN-pulse is surely suppressed. To avoid this race condition between INTN-pulse and I²C start condition, it is recommended to start an I²C communication between the end of an INTN-pulse and the configured minimum t_{ADC}.

5.1.1.4 Clock stretching

In the master controlled mode (MCM) the clock stretching function can be enabled or disabled with a configuration:

With the clock stretching feature, data read out is delayed during an ongoing ADC conversion. Thus it can be avoided that during an ADC conversion old or corrupted measurement results are read out, which may occur when the ADC is writing to a register while it is being read out by the microcontroller.

In the low power mode (LPM) clock stretching must not be used.

The sensor pulls the SCL line to low during the following situation:

- An ADC conversion is in progress.
- The sensor is addressed for register read (writes are never affected by clock stretching).
- The sensor is about to transmit the valid ACK in response to the I²C addressing of the microcontroller.

5.1.1.5 I²C timing characteristics

Table 21 I²C timing characteristics

All timings correspond to a 1.2 kΩ pull up resistor with an open-drain output

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Allowed I²C bit clock frequency	f_{I2C_SCL}	100	400	1000	kHz	See Application Circuit
Low period of SCL clock	t_L	0.5	–	5	µs	1.3 µs for 400-kHz mode. Maximum value except clock stretching or between communication bytes.
High period of SCL clock	t_H	0.4	–	5	µs	0.6 µs for 400-kHz mode. Maximum value except clock stretching or between communication bytes.
SDA fall to SCL fall hold time	t_{STA}	0.4	–	–	µs	0.6 µs for 400-kHz mode
SCL rise to SDA rise time	t_{STOP}	0.4	–	–	µs	0.6 µs for 400-kHz mode
SDA rise to SDA fall hold time	t_{WAIT}	0.4	–	–	µs	0.6 µs for 400-kHz mode
SDA setup before SCL rising	t_{SU}	0.1	–	–	µs	
SDA hold after SCL falling	t_{HOLD}	0	–	–	µs	
Fall time SDA/SCL signal	t_{FALL}	–	0.25	0.3	µs	See Application Circuit

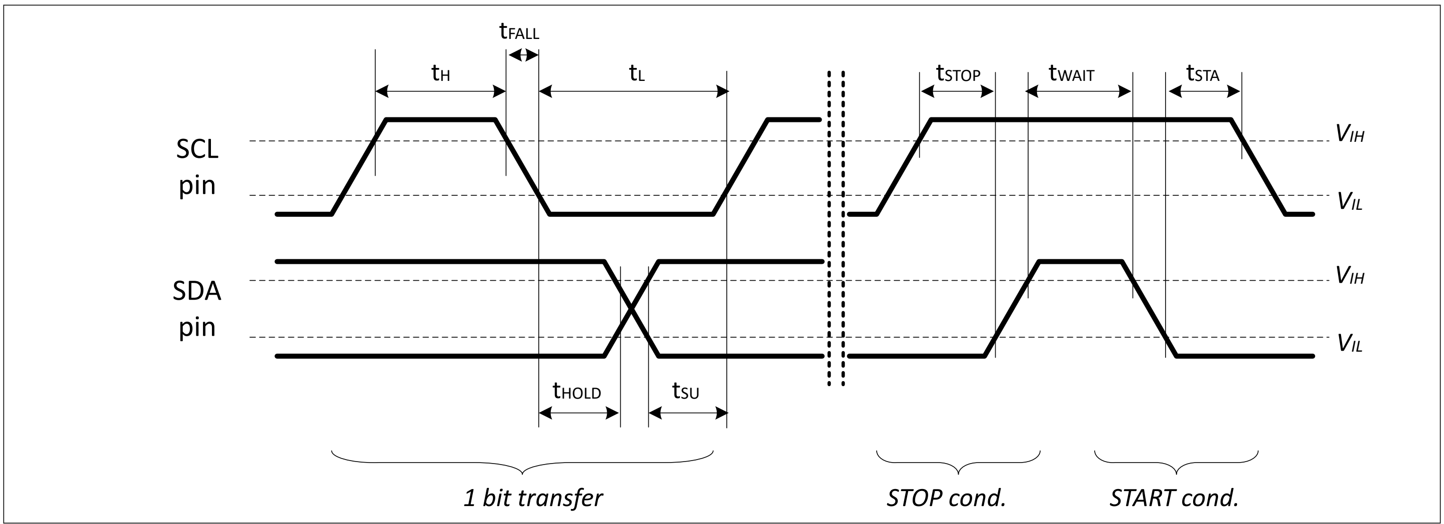


Figure 19 I²C timing specification

5.2 Registers

The sensor includes several registers that can be accessed via the interface to read data as well as to write and configure settings.

5.2.1 Registers overview

The bitmap illustrates the registers and bits with the corresponding addresses.

Read skip @	Register	Address	7	6	5	4	3	2	1	0
channel_sel = 1110_B	bx_msb	00_H	bx_msbs (r)							
	bx_lsb	01_H	iic_addr_cp (r)		bx_lsbs (r)					
channel_sel = 1110_B or = 1100_B	by_msb	02_H	by_msbs (r)							
	by_lsb	03_H	0	0	by_lsbs (r)					
channel_sel = 1100_B or = 1101_B	bz_msb	04_H	bz_msbs (r)							
	bz_lsb	05_H	0	0	bz_lsbs (r)					
channel_sel = 1101_B	temp_msb	06_H	temp_msbs (r)							
	temp_lsb	07_H	0	0	temp_lsbs (r)					
	crc	08_H	crc (r)							
	diag	09_H	meas_flg (r)	test_flg (r)	frame_counter (r)		rst_flg (r)	wu_par_flg (r)	crc_wr_flg (r)	fuse_par_flg (r)
	mod1	$0A_H$	mode_sel (rw)	int_dis (rw)	collision_dis (rw)	wu_en (rw)	trigger_sel (rw)		prot_sel (rw)	crc_wr_en (rw)
	mod2	$0B_H$	channel_sel (rw)				f_update_sel (rw)		xtr_short_en (rw)	short_en (rw)
	wu_xh	$0C_H$	wu_xh_msbs (rw)							
	wu_xl	$0D_H$	wu_xl_msbs (rw)							
	wu_yh	$0E_H$	wu_yh_msbs (rw)							
	wu_yl	$0F_H$	wu_yl_msbs (rw)							
	wu_zh	10_H	wu_zh_msbs (rw)							
	wu_zl	11_H	wu_zl_msbs (rw)							
	wu_xy	12_H	wu_xh_lsbs (rw)		wu_xl_lsbs (rw)		wu_yh_lsbs (rw)		wu_yl_lsbs (rw)	
	wu_z	13_H			wu_par (rw)	wu_en_cp (w)	wu_zh_lsbs (rw)		wu_zl_lsbs (rw)	
	rst	14_H							rst_flg_clr (w)	soft_rst (w)
	id0	15_H	chip_id_0 (r)							
	id1	16_H	chip_id_1 (r)							
	id2	17_H	chip_id_2 (r)							
	id3	18_H	chip_id_3 (r)							
	id4	19_H	chip_id_4 (r)							
	id5	$1A_H$	0	id_par (r)	chip_id_5 (r)					

Magnetic values | Temperature values | Diagnosis | Configuration | Spare bits, must not be used
Wake Up values | Wake Up parity range | Chip ID | Chip ID parity range | Reset | CRC range

Figure 20 Bitmap

5.2.2 Register descriptions

The registers can be read or written at any time.

It is recommended to read measurement data in a synchronized fashion, i.e. after an interrupt pulse (INTN). This avoids reading inconsistent sensor or diagnostic data. Additionally, several flags can be used for a plausibility check of the read out data.

Bit types

The sensor contains read bits and write bits.

Table 22 Bit Types

Abbreviation	Function	Description
r	Read	Read-only bits
w	Write	Write-only bits
rw	Read Write	Readable and writable bit

5.2.2.1 Magnetic X-value MSBs register

bx_msb Offset address: 0_H

Magnetic X-value MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
bx_msbs							
r							

Field	Bits	Type	Description
bx_msbs	7:0	r	**bx_msbs** Raw magnetic measurement result in the X direction (signed two's complement notation). Contains the 8 Most Signficant Bits out of the 14b value. If Bx is deactivated, bx_msbs value is set to reset value.

5.2.2.2 Magnetic X-value LSBs register

bx_lsb Offset address: 1_H

Magnetic X-value LSBs register Reset value: 00_H

7	6	5	4	3	2	1	0
iic_addr_cp		bx_lsbs					
r		r					

Field	Bits	Type	Description
bx_lsbs	5:0	r	**bx_lsbs** Raw magnetic measurement result in the X direction (signed two's complement notation). Contains the 6 Least Signficant Bits out of the 14b value. If Bx is deactivated, bx_lsbs value is set to reset value.

(table continues...)

(continued)

Field	Bits	Type	Description
iic_addr_cp	7:6	r	**iic_addr_copy** I2C address. (This is a read only copy of the field iic_addr from PROD_TYPE_R register) Four possible values available to define the slave address in bus configuration.

5.2.2.3 Magnetic Y-value MSBs register

by_msb Offset address: 2_H

Magnetic Y-value MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
by_msbs							
r							

Field	Bits	Type	Description
by_msbs	7:0	r	**by_msbs** Raw magnetic measurement result in the Y direction (signed two's complement notation). Contains the 8 Most Signficant Bits out of the 14b value. If By is deactivated, by_msbs value is set to reset value.

5.2.2.4 Magnetic Y-value LSBs register

by_lsb Offset address: 3_H

Magnetic Y-value LSBs register Reset value: 00_H

7	6	5	4	3	2	1	0
Res		**by_lsbs**					
r		r					

Field	Bits	Type	Description
by_lsbs	5:0	r	**by_lsbs** Raw magnetic measurement result in the Y direction (signed two's complement notation). Contains the 6 Least Signficant Bits out of the 14b value. If By is deactivated, by_lsbs value is set to reset value.

5.2.2.5 Magnetic Z-value MSBs register

bz_msb Offset address: 4_H

Magnetic Z-value MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
bz_msbs							
r							

Field	Bits	Type	Description
bz_msbs	7:0	r	**bz_msbs** Raw magnetic measurement result in the Z direction (signed two's complement notation). Contains the 8 Most Signficant Bits out of the 14b value. If Bz is deactivated, bz_msbs value is set to reset value.

5.2.2.6 Magnetic Z-value LSBs register

bz_lsb Offset address: 5_H
Magnetic Z-value LSBs register Reset value: 00_H

7	6	5	4	3	2	1	0
Res		**bz_lsbs**					
r		r					

Field	Bits	Type	Description
bz_lsbs	5:0	r	**bz_lsbs** Raw magnetic measurement result in the Z direction (signed two's complement notation). Contains the 6 Least Signficant Bits out of the 14b value. If Bz is deactivated, bz_lsbs value is set to reset value.

5.2.2.7 Temperature value MSBs register

temp_msb Offset address: 6_H
Temperature value MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
temp_msbs							
r							

Field	Bits	Type	Description
temp_msbs	7:0	r	**temp_msbs** Raw temperature measurement result (signed two's complement notation). Contains the 8 Most Significant Bits out of the 14b value. If the temperature measurement is deactivated, temp_msbs value is set to reset value.

5.2.2.8 Temperature value LSBs register

temp_lsb Offset address: 7_H
Temperature value LSBs register Reset value: 00_H

7	6	5	4	3	2	1	0
Res		**temp_lsbs**					
r		r					

Field	Bits	Type	Description
temp_lsbs	5:0	r	**temp_lsbs** Raw temperature measurement result (signed two's complement notation). Contains the 6 Least Significant Bits out of the 14b value. If the temperature measurement is deactivated, temp_lsbs value is set to reset value.

5.2.2.9 Communication CRC

CRC Offset address: 8_H

Communication CRC Reset value: 00_H

7	6	5	4	3	2	1	0
CRC							
r							

Field	Bits	Type	Description
CRC	7:0	r	**Communication CRC** Provided for all read communications. Included registers are defined in the bitmap, without the registers excluded according to channel_sel.

5.2.2.10 Diagnosis register

diag Offset address: 9_H

Diagnosis register Reset value: $0C_H$

7	6	5	4	3	2	1	0
meas_flg	**test_flg**	**frame_counter**		**rst_flg**	**wu_par_flg**	**crc_wr_flg**	**fuse_par_flg**
r	r	r		r	r	r	r

Field	Bits	Type	Description
fuse_par_flg	0	r	**Fuse Parity Flag** Flag reflecting the result of fuse parity check for fuses related to internal trimming. 0_B: Fuse parity check is not correct for trimming bits. When fuse parity check is not correct, the output of the sensor must be considered corrupted. The external user can attempt to see if this error disappears after a soft reset. If the error persists, the device can no longer be used. 1_B: Fuse parity check is correct
crc_wr_flg	1	r	**CRC Write OK Flag** crc_wr_flg is cleared with the next write command. 0_B: The CRC at write is enabled and incorrect CRC has been transmitted or the CRC at write is disabled. 1_B: The CRC at write is enabled and correct CRC has been transmitted.

(table continues...)

(continued)

Field	Bits	Type	Description
wu_par_flg	2	r	**Wake Up Parity Flag** 0_B: Wake Up parity check is not correct. The sensor does not enter Wake Up mode. 1_B: Wake Up parity check is correct. The sensor can enter Wake Up mode.
rst_flg	3	r	**Reset Flag** Indicates a sensor reset. The field is cleared when 1_B is written to the rst_flg_clr field. 0_B: No sensor reset event. 1_B: Sensor reset event occurred.
frame_counter	5:4	r	**Frame Counter** Increments at every ADC conversion cycle.
test_flg	6	r	**Test Function Flag** 0_B: The registers contain measurement data. 1_B: The registers contain test function data.
meas_flg	7	r	**Measure Success Flag** 1_B: All read out measurement values belong to the same ADC conversion cycle and were performed with the same channel_sel setting. 0_B: The read out measurement values either belong to different ADC conversion cycle or to different channel_sel settings.

5.2.2.11 Sensor mode register 1

mod1 Offset address: $0A_H$

Sensor mode register 1 Reset value: 62_H

7	6	5	4	3 2	1	0
mode_sel	**int_dis**	**collision_dis**	**wu_en**	**trigger_sel**	**prot_sel**	**crc_wr_en**
rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
crc_wr_en	0	rw	**CRC enable for write operations.** 0_B: CRC for write operations is disabled. 1_B: CRC for write operations is enabled.
prot_sel	1	rw	**I²C protocol selection** 0_B: 2 byte read protocol enabled. 1_B: 1 byte read protocol enabled.

(table continues...)

(continued)

Field	Bits	Type	Description
trigger_sel	3:2	rw	**Trigger options** For I²C 1 byte read protocol (prot_sel = 1_B) the following trigger modes are available: 00_B: no trigger 01_B: trigger on read $1x_B$: trigger on stop condition Trigger bits in the I²C command frame (write or 2 byte read command) overwrites the configuration bits in the mod1 register.
wu_en	4	rw	**Wake Up** 0_B: the Wake Up functionality is disabled. 1_B: the Wake Up functionality is enabled. If enabled, the Wake Up functionality is only active if: - Wake Up parity flag is OK. - test functions are disabled.
collision_dis	5	rw	**Collision avoidance and clock stretching** 0_B and (int_dis = 0_B or wu_en = wu_en_cp = 1_B): collision avoidance is active (INTN will not be transmitted between I²C start and stop condition). 0_B and (int_dis = 1_B and wu_en = wu_en_cp = 0_B): clock stretching is active (sensor delays read out during ongoing ADC conversion by pulling SCL low). 1_B: Collision avoidance and clock stretching disabled. If int_dis = 0_B, it may collide with clock from microcontroller.
int_dis	6	rw	**Interrupt disable** The int_dis bit interacts with the collision_dis bit. When Wake Up is enabled, the interrupt functionality is always activated, independent of the int_dis configuration. 0_B: Interrupt enabled: After a completed measurement and ADC conversion cycle, an interrupt pulse will be generated (see also collision_dis and Wake Up functionality). 1_B: Interrupt disabled
mode_sel	7	rw	**Operating modes** 0_B: Low Power Mode: Cyclic measurements and ADC-conversions with an update rate defined in the f_update_sel register. The trigger configuration is ignored. 1_B: Master Controlled Mode: Measurements are triggered by microcontroller. The trigger is configured via the trigger_sel bits or via I²C command.

5.2.2.12 Sensor mode register 2

mod2 Offset address: $0B_H$

Sensor mode register 2 Reset value: 00_H

7	6	5	4	3	2	1	0
channel_sel				**f_update_sel**		**xtr_short_en**	**short_en**
rw				rw		rw	rw

Field	Bits	Type	Description
short_en	0	rw	**Magnetic short-range measurement** 0_B: The Bx, By and Bz ADC-conversion is set according the full range specification. 1_B: The Bx, By and Bz ADC-conversion is set according the short range specification. short_en = 1_B and xtr_short_en = 1_B must not be used.
xtr_short_en	1	rw	**Magnetic extra short-range measurement** 0_B: The Bx, By and Bz ADC-conversion is set according the short_en setting. 1_B: The Bx, By and Bz ADC-conversion is set according the extra short range specification and short_en is ignorred. short_en = 1_B and xtr_short_en = 1_B must not be used.
f_update_sel	3:2	rw	**Update frequency for low power mode** 00_B: 1000 Hz 01_B: 125 Hz 10_B: 31 Hz 11_B: 16 Hz
channel_sel	7:4	rw	**Channel selection** Selection of measurement channels and test function. When a readout is performed, the addresses corresponding to measurement registers for which a measurement is not performed are skipped. Register addresses, not included in the measurement are not covered by CRC at read. When one channel is disabled, for all new measurements the register value for that channel will be set to reset value. 0000_B: Bx, By, Bz, Temp 0001_B: Vhall bias (X, Y, Z) / Vext test function. 0010_B: Spintest (X, Y, Z) / Vint test function. 1000_B: SAT test function (X, Y, Z, Temp). 1100_B: Bx, Temp 1101_B: Bx, By 1110_B: Bz, Temp

5.2.2.13 Wake Up X-high threshold MSBs register

wu_xh Offset address: $0C_H$

Wake Up X-high threshold MSBs register Reset value: $7F_H$

7	6	5	4	3	2	1	0
wu_xh_msbs							
rw							

Field	Bits	Type	Description
wu_xh_msbs	7:0	rw	**Wake Up X-high MSBs** Defines the Wake Up upper threshold for the Bx magnetic channel above which the sensor enables INTN.

5.2.2.14 Wake Up X-low threshold MSBs register

wu_xl Offset address: $0D_H$

Wake Up X-low threshold MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
wu_xl_msbs							
rw							

Field	Bits	Type	Description
wu_xl_msbs	7:0	rw	**Wake Up X-low MSBs** Defines the Wake Up lower threshold for the Bx magnetic channel below which the sensor enables INTN.

5.2.2.15 Wake Up Y-high threshold MSBs register

wu_yh Offset address: $0E_H$

Wake Up Y-high threshold MSBs register Reset value: $7F_H$

7	6	5	4	3	2	1	0
wu_yh_msbs							
rw							

Field	Bits	Type	Description
wu_yh_msbs	7:0	rw	**Wake Up Y-high MSBs** Defines the Wake Up upper threshold for the By magnetic channel above which the sensor enables INTN.

5.2.2.16 Wake Up Y-low threshold MSBs register

wu_yl Offset address: $0F_H$

Wake Up Y-low threshold MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
wu_yl_msbs							
rw							

Field	Bits	Type	Description
wu_yl_msbs	7:0	rw	**Wake Up Y-low MSBs** Defines the Wake Up lower threshold for the By magnetic channel below which the sensor enables INTN.

5.2.2.17 Wake Up Z-high threshold MSBs register

wu_zh Offset address: 10_H
Wake Up Z-high threshold MSBs register Reset value: $7F_H$

7	6	5	4	3	2	1	0
wu_zh_msbs							
rw							

Field	Bits	Type	Description
wu_zh_msbs	7:0	rw	**Wake Up Z-high MSBs** Defines the Wake Up upper threshold for the Bz magnetic channel above which the sensor enables INTN.

5.2.2.18 Wake Up Z-low threshold MSBs register

wu_zl Offset address: 11_H
Wake Up Z-low threshold MSBs register Reset value: 80_H

7	6	5	4	3	2	1	0
wu_zl_msbs							
rw							

Field	Bits	Type	Description
wu_zl_msbs	7:0	rw	**Wake Up Z-low MSBs** Defines the Wake Up lower threshold for the Bz magnetic channel below which the sensor enables INTN.

5.2.2.19 Wake Up XY thresholds LSBs register

wu_xy Offset address: 12_H
Wake Up XY thresholds LSBs register Reset value: CC_H

7	6	5	4	3	2	1	0
wu_xh_lsbs		**wu_xl_lsbs**		**wu_yh_lsbs**		**wu_yl_lsbs**	
rw		rw		rw		rw	

Field	Bits	Type	Description
wu_yl_lsbs	1:0	rw	**Wake Up Y-low LSBs** Defines the Wake Up lower threshold for the By magnetic channel below which the sensor enables INTN.
wu_yh_lsbs	3:2	rw	**Wake Up Y-high LSBs** Defines the Wake Up upper threshold for the By magnetic channel above which the sensor enables INTN.
wu_xl_lsbs	5:4	rw	**Wake Up X-low LSBs** Defines the Wake Up lower threshold for the Bx magnetic channel below which the sensor enables INTN.
wu_xh_lsbs	7:6	rw	**Wake Up X-high LSBs** Defines the Wake Up upper threshold for the Bx magnetic channel above which the sensor enables INTN.

5.2.2.20 Wake Up Z thresholds LSBs register

wu_z Offset address: 13_H

Wake Up Z thresholds LSBs register Reset value: $2C_H$

7	6	5	4	3	2	1	0
Res		**wu_par**	**wu_en_cp**	**wu_zh_lsbs**		**wu_zl_lsbs**	
r		rw	w	rw		rw	

Field	Bits	Type	Description
wu_zl_lsbs	1:0	rw	**Wake Up Z-low LSBs** Defines the Wake Up lower threshold for the Bz magnetic channel below which the sensor enables INTN.
wu_zh_lsbs	3:2	rw	**Wake Up Z-high LSBs** Defines the Wake Up upper threshold for the Bz magnetic channel above which the sensor enables INTN.
wu_en_cp	4	w	**Wake Up enable copy** Alternative enable/disable bit for Wake Up functionality. A read from this location always returns 0_B. Any write operation at this address takes effect in the wu_en bit. This is an alternative address for changing the state of wu_en configuration bit. This allows the user to have a single write stream with automatically incremented address that disables Wake Up functionality, updates the Wake Up thresholds and enables the Wake Up functionality. This is the recommended sequence when the user wants to dynamically change the Wake Up threshold in a safer manner while the feature was already enabled.
wu_par	5	rw	**Wake Up parity bit** Odd parity bit for Wake Up thresholds and wu_en configuration bits. This field is written by the user in accordance with configured Wake Up settings. This field will be compared with the sensor computed parity in order to generate the wu_par_flg flag.

5.2.2.21 Reset register

rst Offset address: 14_H
Reset register Reset value: 00_H

7	6	5	4	3	2	1	0
Res						**rst_flg_clr**	**soft_rst**
r						w	w

Field	Bits	Type	Description
soft_rst	0	w	**Soft Reset trigger bit** A soft reset is triggered when writing 1_B to this field. A read operation will always return 0_B for this field.
rst_flg_clr	1	w	**Sensor reset clear** Write 1_B to clear the rst_flg status bit from the diag register. A read operation will always return 0_B for this field.

5.2.2.22 Unique chip identifier register 0

id0 Offset address: 15_H
Unique chip identifier register 0 Reset value: XX_H

7	6	5	4	3	2	1	0
chip_id_0							
r							

Field	Bits	Type	Description
chip_id_0	7:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.

5.2.2.23 Unique chip identifier register 1

id1 Offset address: 16_H
Unique chip identifier register 1 Reset value: XX_H

7	6	5	4	3	2	1	0
chip_id_1							
r							

Field	Bits	Type	Description
chip_id_1	7:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.

5.2.2.24 Unique chip identifier register 2

id2	Offset address:	17_H
Unique chip identifier register 2	Reset value:	XX_H

7	6	5	4	3	2	1	0
chip_id_2							
r							

Field	Bits	Type	Description
chip_id_2	7:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.

5.2.2.25 Unique chip identifier register 3

id3	Offset address:	18_H
Unique chip identifier register 3	Reset value:	XX_H

7	6	5	4	3	2	1	0
chip_id_3							
r							

Field	Bits	Type	Description
chip_id_3	7:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.

5.2.2.26 Unique chip identifier register 4

id4	Offset address:	19_H
Unique chip identifier register 4	Reset value:	XX_H

7	6	5	4	3	2	1	0
chip_id_4							
r							

Field	Bits	Type	Description
chip_id_4	7:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.

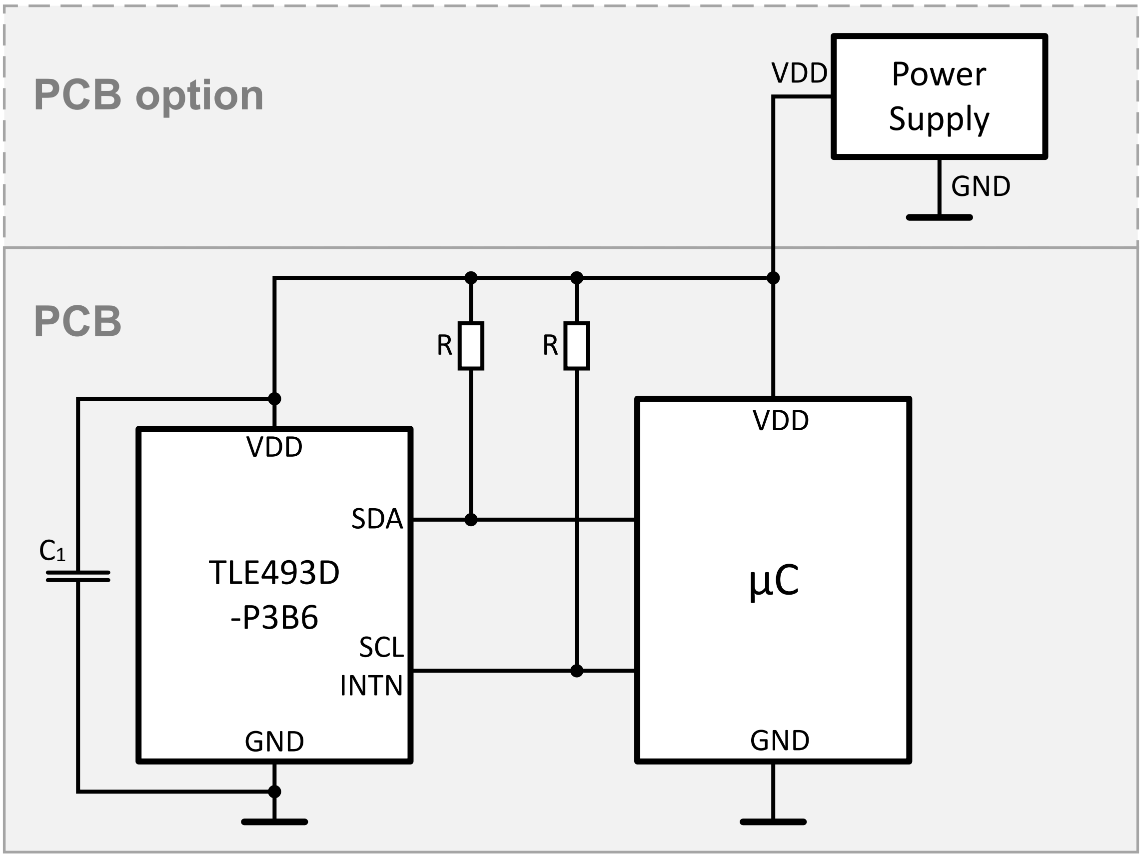
5.2.2.27 Unique chip identifier register 5

id5	Offset address:	$1A_H$
Unique chip identifier register 5	Reset value:	XX_H

7	6	5	4	3	2	1	0
Res	**id_par**	**chip_id_5**					
r	r	r					

Field	Bits	Type	Description
chip_id_5	5:0	r	**Chip identifier** Each individual chip is equipped with a unique chip identifier, comprising the register fields chip_id_0 to chip_id_5.
id_par	6	r	**Chip identifier fuse parity bit** Fuse bit storing odd parity for chip ID.

6 Application Information



R = 1.2 kΩ
C1 = 100 nF
Wires SDA and SCL capacitance < 200 pF each, including all stray capacitances.

Figure 21 Application Circuit with external power supply and microcontroller

The efficiency of the capacitor C_1 improves with a decreasing wire length to the sensor. In case of a ferromagnetic capacitor C_1 the magnetic influence on the magnetic measurement increases with a closer position to the sensor. Both aspects must be balanced and evaluated carefully in the application.

7 Package Information

This sensor is housed in a space saving, non magnetic SMD package.

7.1 Package Parameters

Table 23 Package Parameters PG-TSOP-6-6-8

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Soldering moisture level	*MSL1*	–	–	–	–	260°C, [4]
Thermal resistance Junction ambient	R_{thJA}	–	–	200	K/W	Junction to air, [5]
Thermal resistance Junction lead	R_{thJL}	–	–	100	K/W	Junction to lead

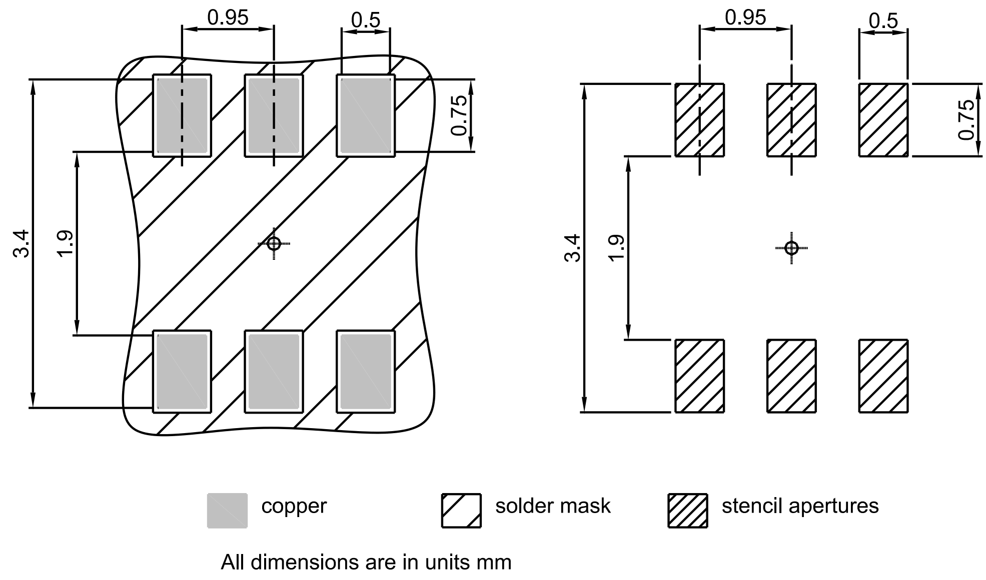


Figure 22 Footprint of the PG-TSOP6-6-8

4 Reflow soldering according to JEDEC J-STD-020
5 According to Jedec JESD51-7

7.2 Package Outlines

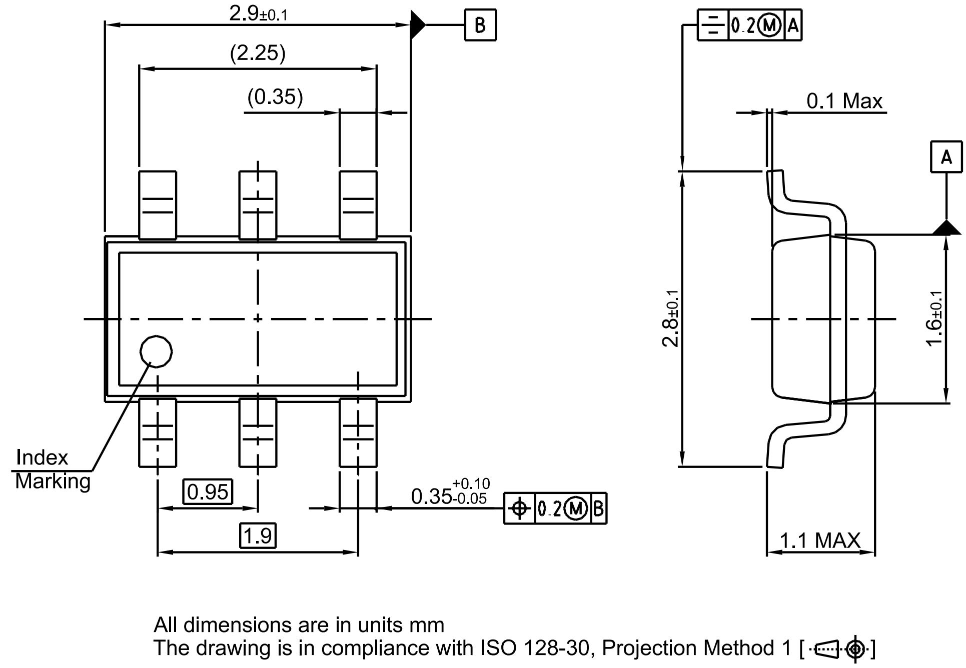


Figure 23 **Package outlines**

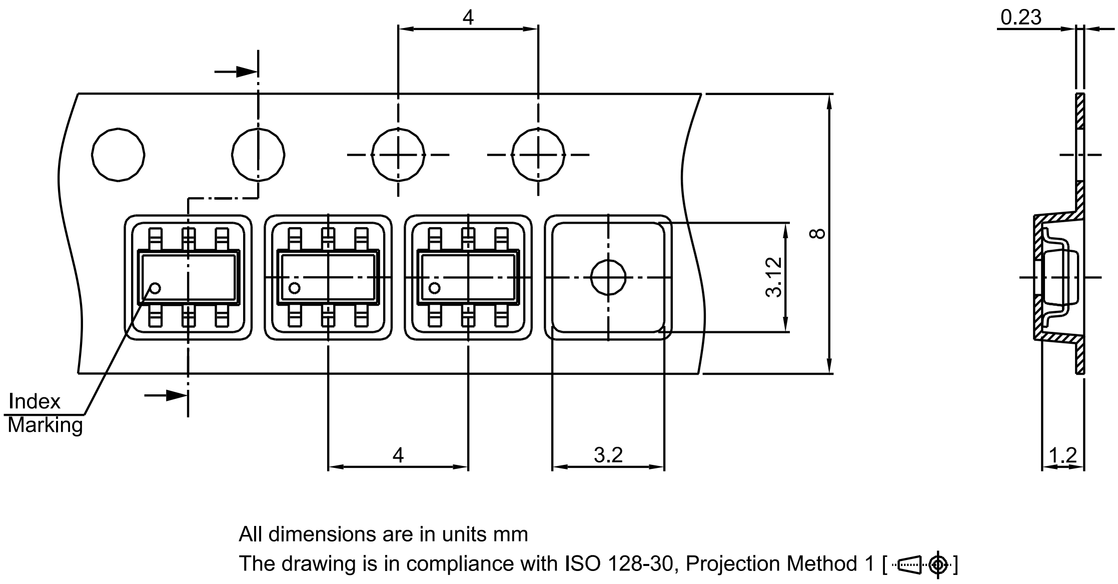


Figure 24 PG-TSOP6-6-8 carrier tape packaging

Further information about the package can be found here:
https://www.infineon.com/cms/en/product/packages/

8 Terminology

1D	one dimensional
3D	three dimensional
ACK	acknowledge
ADC	analog digital converter
ADDR	address
AEC	automotive electronics council
ASIL	automotive safety integrity level
CRC	cyclic redundancy check
e.g.	exempli gratia (for example)
EMC	electromagnetic compatibility
I^2C	inter-integrated circuit
IC	integrated circuit
INTN	interrupt pin, interrupt signal (low active)
ISO	international organization for standardization
LSB	least significant bit
magnetic field	magnetic flux density that the sensor measures
max	maximum
min	minimum
MSB	most significant bit
MSL	moisture sensitivity level
MUX	multiplexer
PCB	printed circuit board
reg	register
rms	root mean square
RoHS	restriction of hazardous substances
SCL	clock pin
SDA	data pin
sensor	refers to the TLE493D-P3B6 product
sensor module	refers to the TLE493D-P3B6 product and all the passive elements in the customer's module
SEooC	safety element out of context
SIL	safety integrity level
SMD	surface mounted device
supply	refers to the sensor supply pins VDD and GND
WU	wake up
µC	microcontroller

Revision history

Revision	Date	Changes
1.0	2024-08-26	Initial release

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