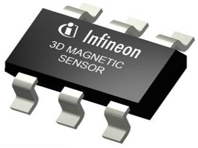
# TLE493D-W3B6-Bx

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

**Datasheet**

## Features

- Very good 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



RoHS

AEC Qualified

ISO 26262 compliant

## 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-W3B6 B0 | B0 | SP005952965 | $5D_H$ | $BA_H$ / $BB_H$ |
| TLE493D-W3B6 B1 | B1 | SP005952969 | $13_H$ | $26_H$ / $27_H$ |
| TLE493D-W3B6 B2 | B2 | SP005952973 | $29_H$ | $52_H$ / $53_H$ |
| TLE493D-W3B6 B3 | B3 | SP005952977 | $46_H$ | $8C_H$ / $8D_H$ |

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[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

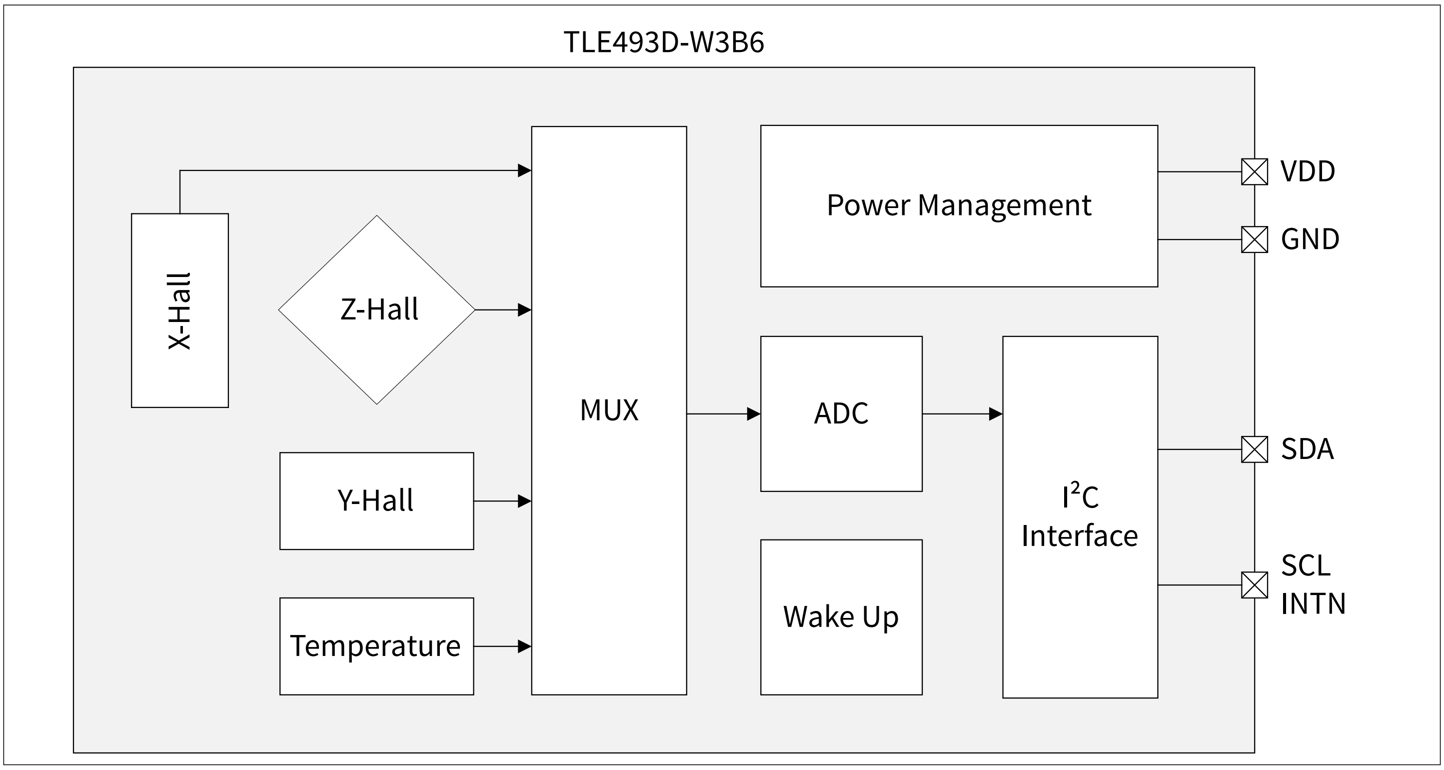

**Figure 1** **Block Diagram**

# 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:

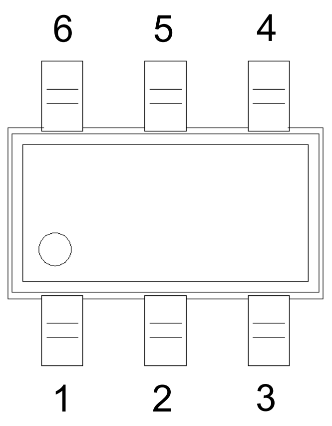

**Figure 2** **Sensor pinout**

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

| Pin number | Name | Description |
|---|---|---|
| 1 | SCL (INTN) | Interface serial clock pin (input)<br>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.

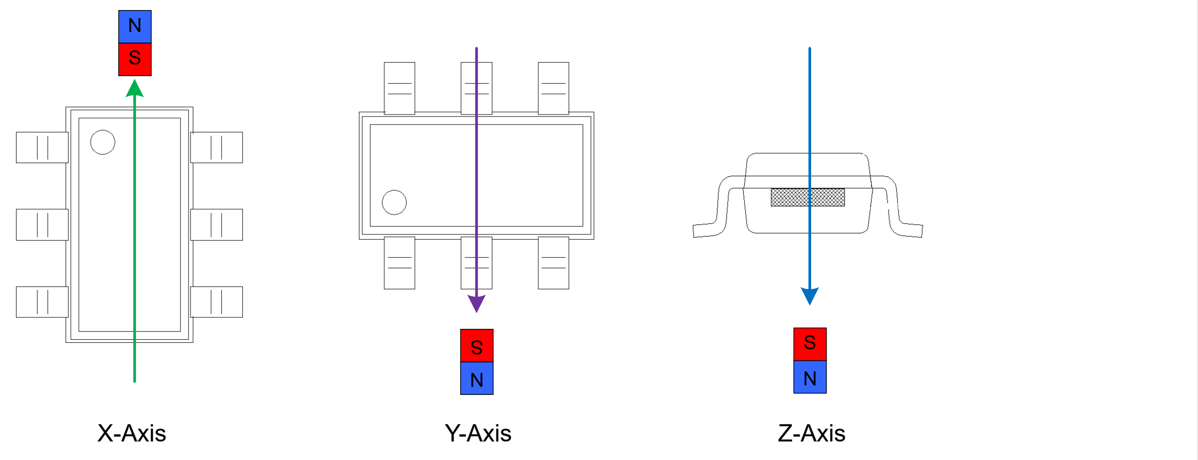

**Figure 3** **Definition of magnetic field direction**

## 2.3 Sensitive Area

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

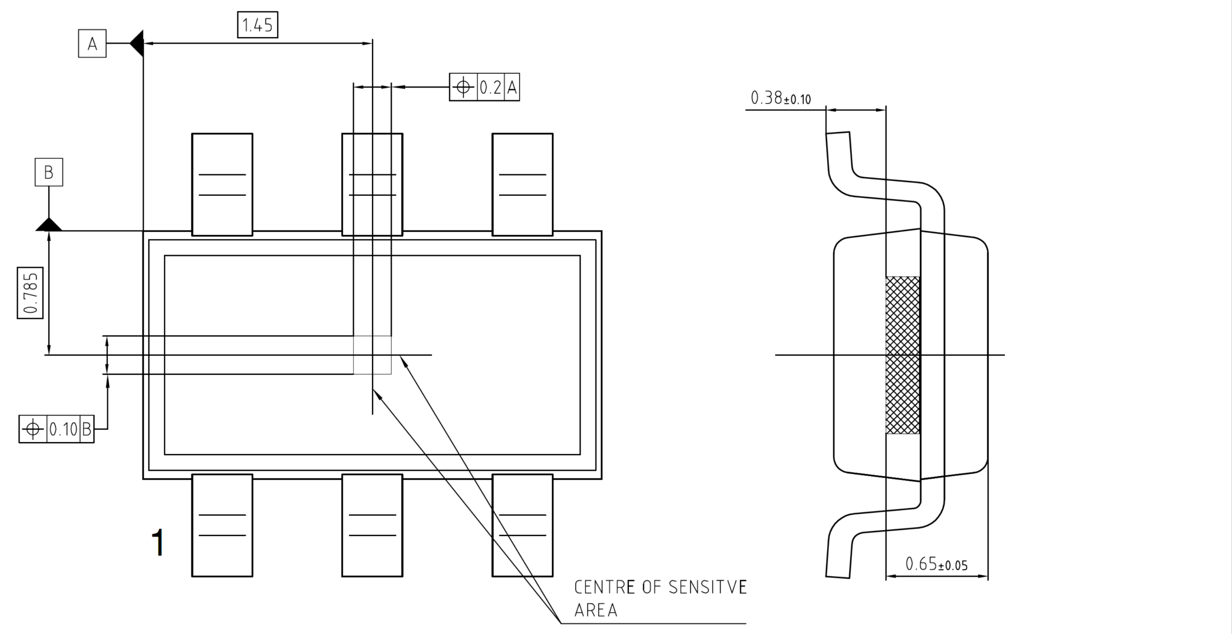

**Figure 4** **Center of sensitive Area (dimensions in mm)**

# 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...)**

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[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 | $0 V \leq V_{IO} \leq V_{DD}$ |
| 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.

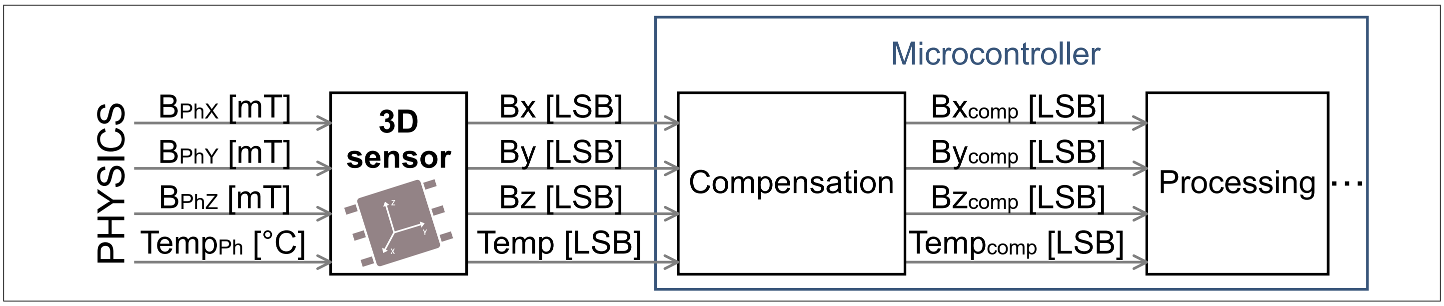


**Figure 5** **Measurement symbol definition**

**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 | $S_{X\_D\_comp}$,<br>$S_{Y\_D\_comp}$,<br>$S_{Z\_D\_comp}$ | -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 | $O_{X\_D\_comp}$,<br>$O_{Y\_D\_comp}$,<br>$O_{Z\_D\_comp}$ | -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 | $M_{XY\_D\_comp}$ | -1.9 | – | 1.9 | % | $Tj$ = -40...85°C |
| | | -1.9 | – | 1.9 | | $T_j$ = -40...105°C |
| | | -2.1 | – | 2.1 | | $Tj$ = -40...125°C |
| X/Y to Z magnetic matching drift | $M_{X/YZ\_D\_comp}$ | -9.5 | – | 9.5 | % | $Tj$ = -40...85°C |
| | | -10 | – | 10 | | $T_j$ = -40...105°C |
| | | -11 | – | 11 | | $Tj$ = -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 | $M_{XY\_D}$ | -1.9 | – | 1.9 | % | |
| X/Y to Z magnetic matching drift | $M_{X/YZ\_D}$ | -13.5 | – | 13.5 | % | |

**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.

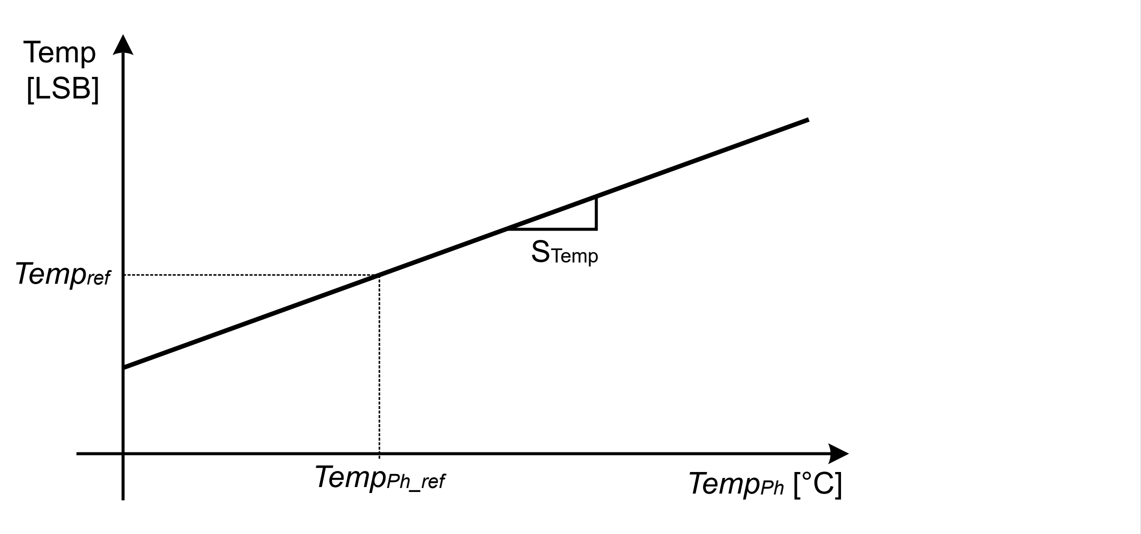


**Figure 6** **Temperature measurement**

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**

| **Mode** | **Measurement** | **Typ. $f_{\mathrm{Update}}$** | **Description** |
|---|---|---|---|
| Power Down | No measurements | - | Lowest possible supply current $I_{\mathrm{DD\_pd}}$. |
| Low Power Mode<br>(full range, short range and extra short range) | Bx, By, Bz, Temp | 16 Hz<br>31 Hz<br>125 Hz<br>1000 Hz | Self triggered cyclic measurements.<br>$f_{\mathrm{Update}}$ is valid with the second conversion after power up and/or register reset. |
| | Bx, By | | |
| | Bx, Temp | | |
| | Bz, Temp | | |
| Master Controlled Mode<br>(full range) | Bx, By, Bz, Temp | Up to 3.7 kHz | Measurements are triggered by the microcontroller. |
| | Bx, By | Up to 7 kHz | |
| | Bx, Temp | | |
| | Bz, Temp | | |
| Master Controlled Mode<br>(short range) | Bx, By, Bz, Temp | Up to 2.7 kHz | |
| | Bx, By | Up to 5.3 kHz | |
| | Bx, Temp | | |
| | Bz, Temp | | |
| Master Controlled Mode<br>(extra short range) | Bx, By, Bz, Temp | Up to 1.8 kHz | |
| | Bx, By | Up to 3.6 kHz | |
| | Bx, Temp | | |
| | Bz, Temp | | |

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

The timings of a measurement ($t_{\mathrm{Bx}}$, $t_{\mathrm{By}}$, $t_{\mathrm{Bz}}$, $t_{\mathrm{Temp}}$, $t_{\mathrm{trig\_d}}$, $t_{\mathrm{INTN\_d}}$, $t_{\mathrm{INTN}}$, $1/f_{\mathrm{Update}}$) 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.

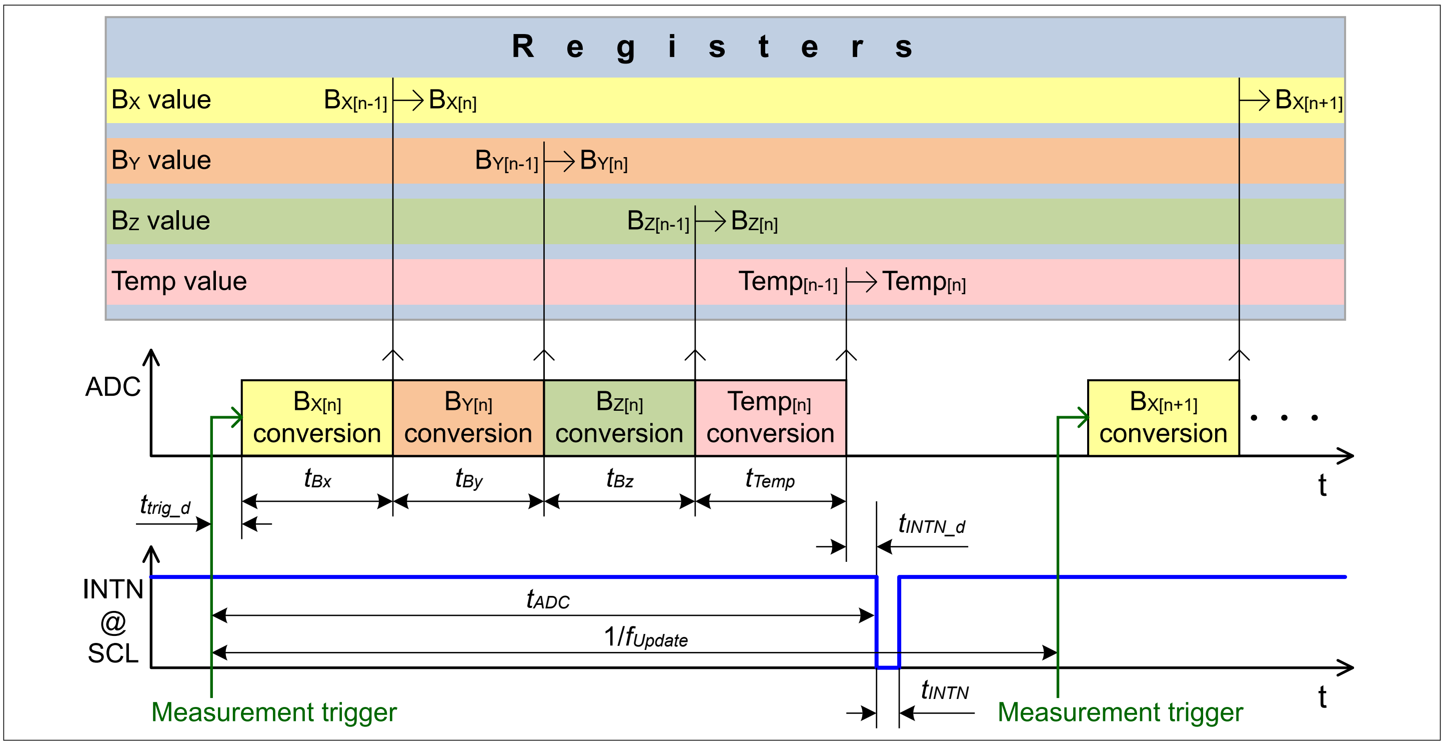


**Figure 7** **Measurement timing**

Measurement triggers are described in

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

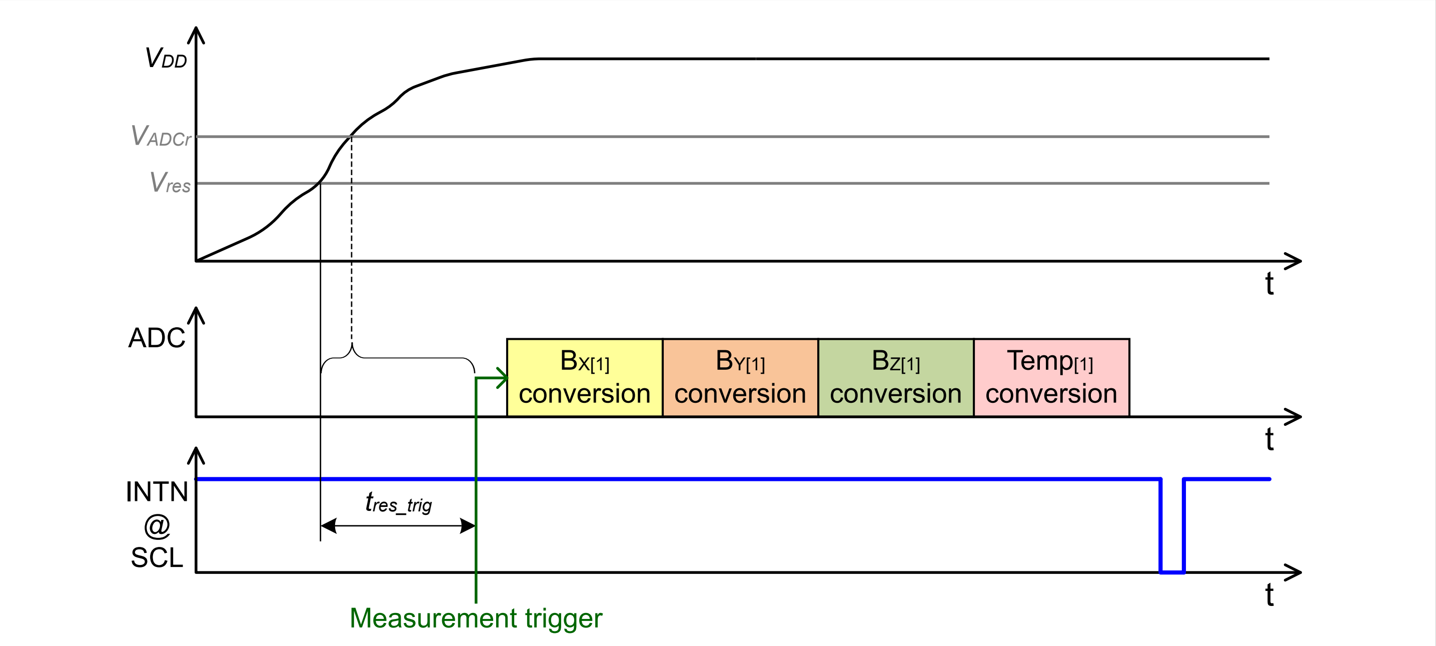


**Figure 8** **1st measurement time after a register reset ($V_{res}$) and a ADC restart ($V_{ADCr}$)**

**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.

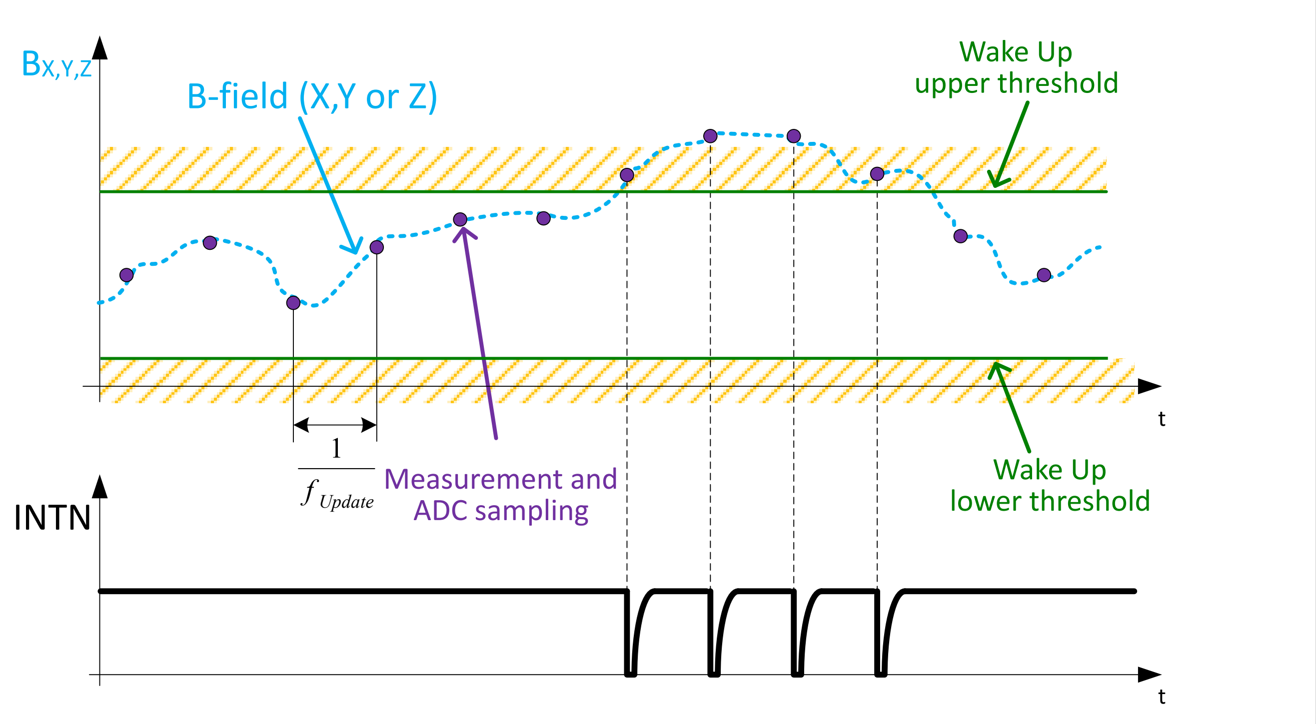


**Figure 9** **Wake Up threshold operation**

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.

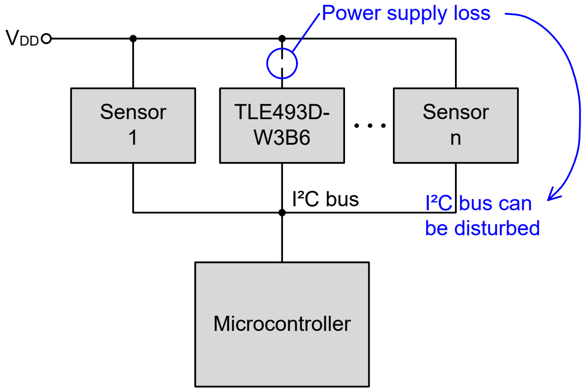


**Figure 10** **Example of I²C bus and a sensor with disconnected VDD**

### 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<br>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.

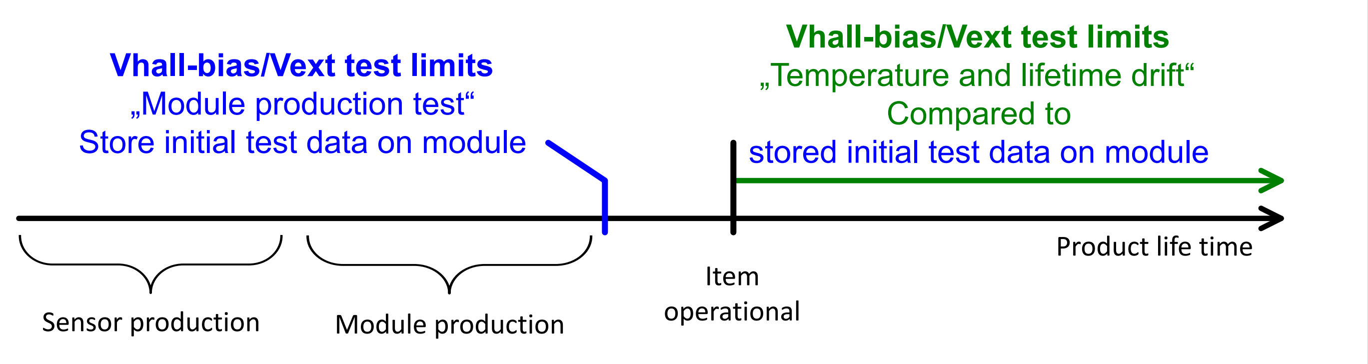


**Figure 11** **Vhall bias/Vext diagnostic limits vs. lifetime**

### 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<br>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 |

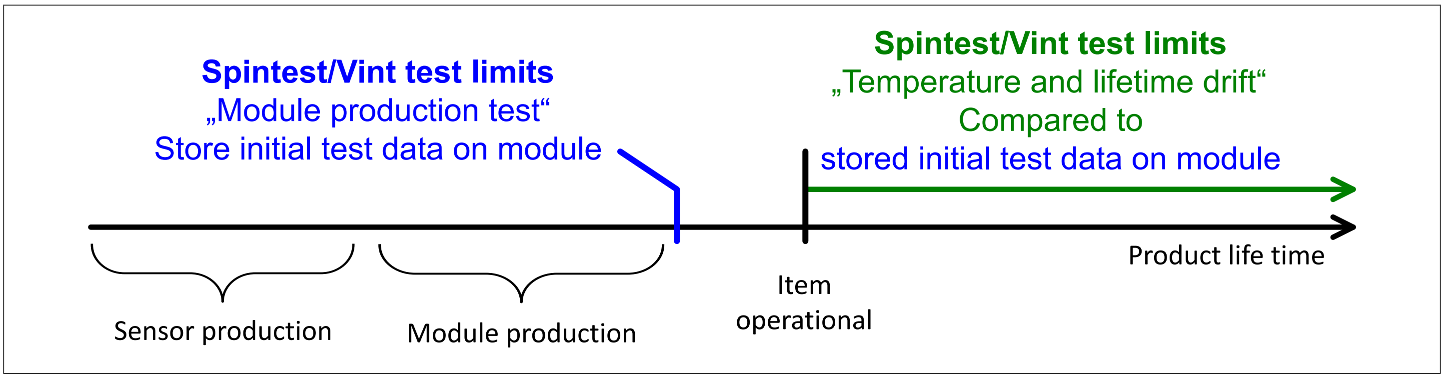


**Figure 12** **Spintest/Vint test diagnostic limits vs. lifetime**

### 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$^2$C stop condition, rising edge at SDA.
The trigger option $00_B$ disables the ADC trigger.

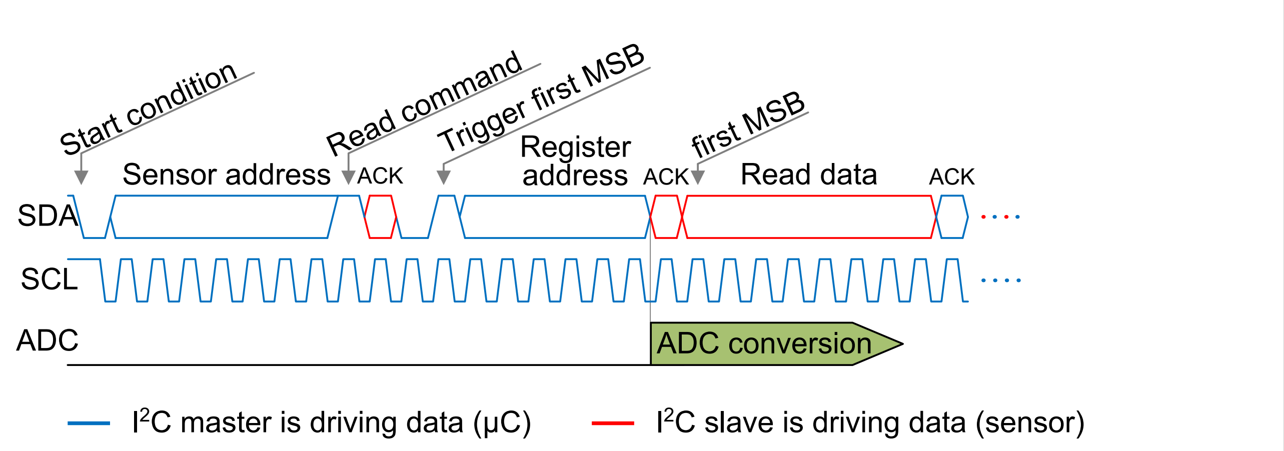


**Figure 13** **ADC trigger before reading data**

For the I$^2$C 1-byte read command the trigger bits are configurable in the configuration registers.
In the I$^2$C 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.

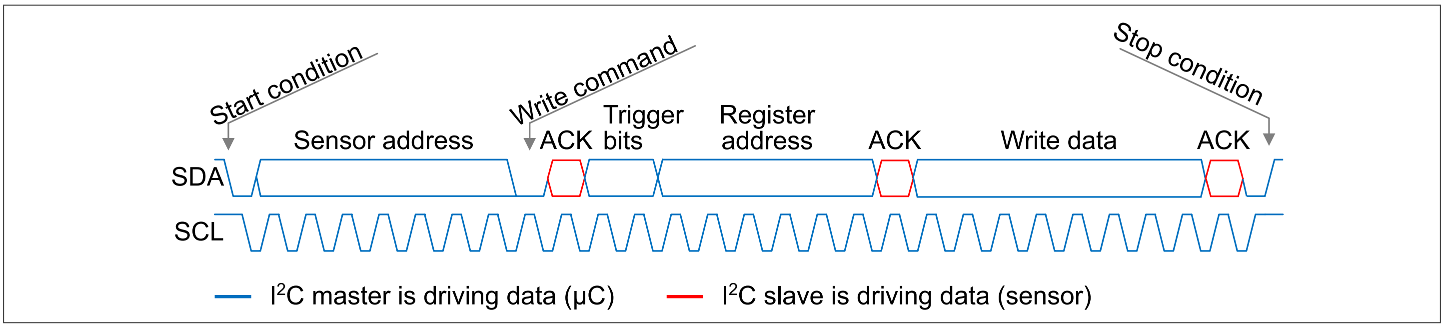


**Figure 14** General I$^2$C write frame format: Write data from microcontroller to sensor

### Write command without CRC

The I$^2$C 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.

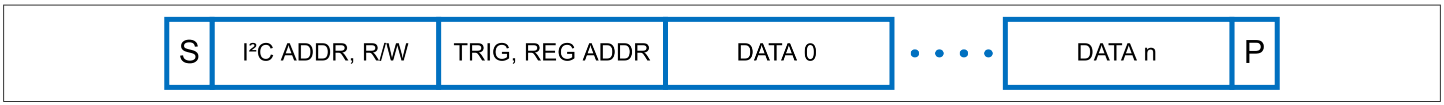


**Figure 15** General I$^2$C write command without CRC: Write data from microcontroller to sensor.

### Write command with CRC

The I$^2$C 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.

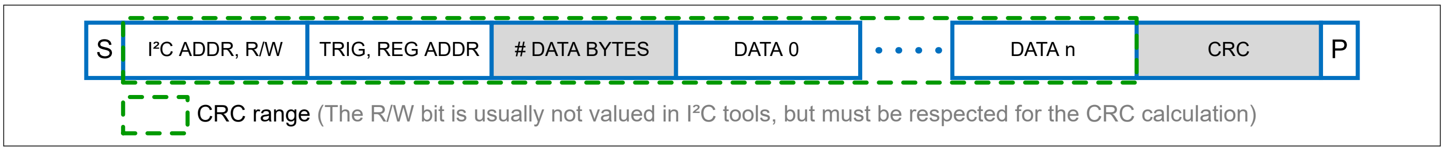


**Figure 16** **General I2C write command with CRC: Write data from microcontroller to sensor.**

### 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.

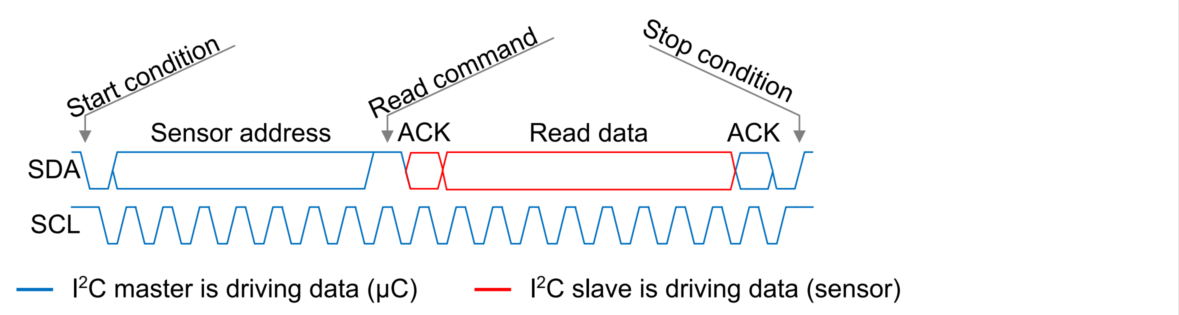


**Figure 17** **General I²C frame format 1-byte: Read data from sensor to microcontroller**

#### 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.

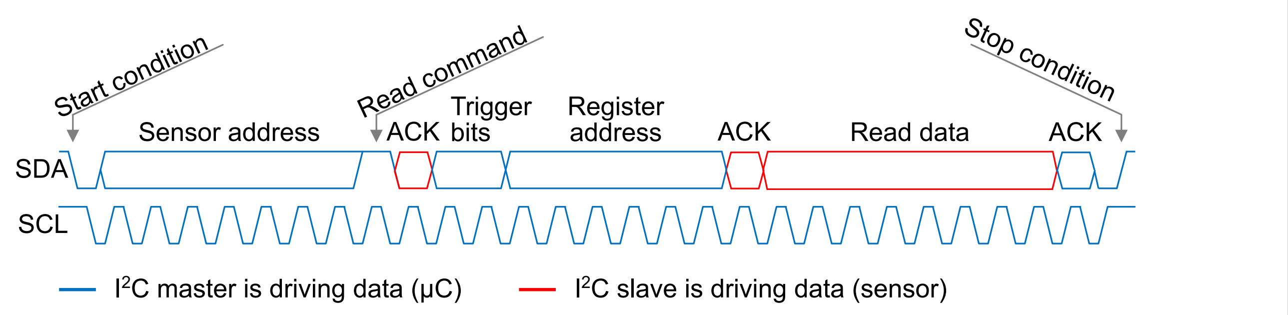


**Figure 18** General I²C frame format 2-byte: Read data from sensor to microcontroller

### 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.<br>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.<br>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 |

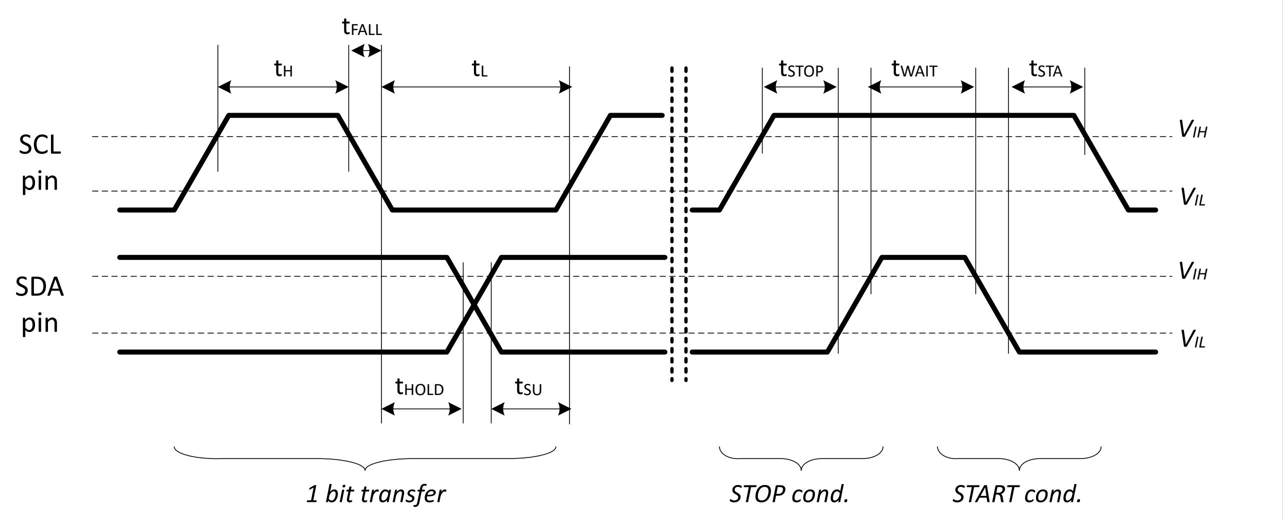


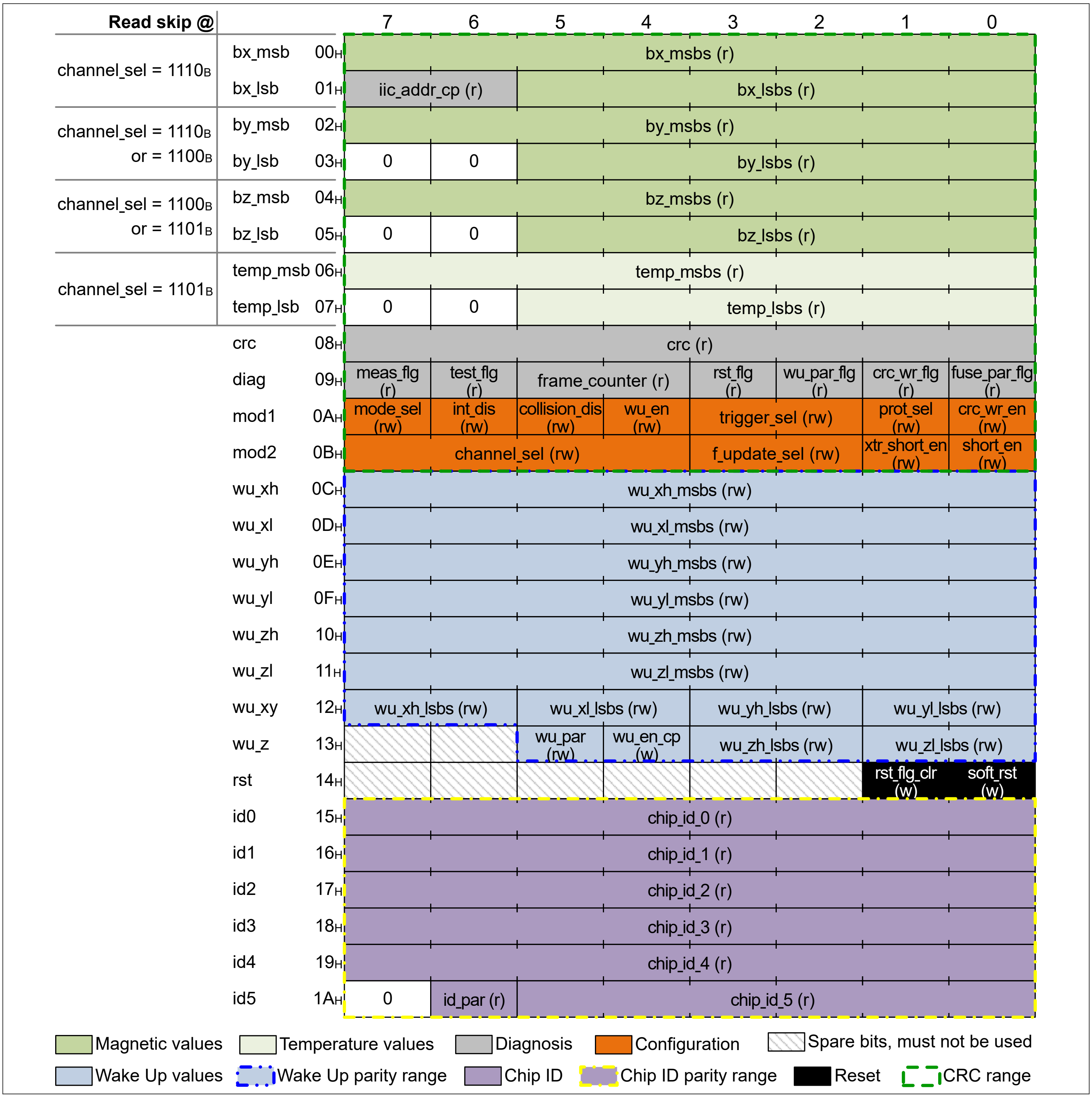
**Figure 19** **I²C timing specification**

## 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.



<table>
<tr><th>Read skip @</th><th></th><th></th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td rowspan="2">channel_sel = $1110_B$</td><td>bx_msb</td><td>$00_H$</td><td colspan="8">bx_msbs (r)</td></tr>
<tr><td>bx_lsb</td><td>$01_H$</td><td colspan="2">iic_addr_cp (r)</td><td colspan="6">bx_lsbs (r)</td></tr>
<tr><td rowspan="2">channel_sel = $1110_B$<br>or = $1100_B$</td><td>by_msb</td><td>$02_H$</td><td colspan="8">by_msbs (r)</td></tr>
<tr><td>by_lsb</td><td>$03_H$</td><td>0</td><td>0</td><td colspan="6">by_lsbs (r)</td></tr>
<tr><td rowspan="2">channel_sel = $1100_B$<br>or = $1101_B$</td><td>bz_msb</td><td>$04_H$</td><td colspan="8">bz_msbs (r)</td></tr>
<tr><td>bz_lsb</td><td>$05_H$</td><td>0</td><td>0</td><td colspan="6">bz_lsbs (r)</td></tr>
<tr><td rowspan="2">channel_sel = $1101_B$</td><td>temp_msb</td><td>$06_H$</td><td colspan="8">temp_msbs (r)</td></tr>
<tr><td>temp_lsb</td><td>$07_H$</td><td>0</td><td>0</td><td colspan="6">temp_lsbs (r)</td></tr>
<tr><td></td><td>crc</td><td>$08_H$</td><td colspan="8">crc (r)</td></tr>
<tr><td></td><td>diag</td><td>$09_H$</td><td>meas_flg (r)</td><td>test_flg (r)</td><td colspan="2">frame_counter (r)</td><td>rst_flg (r)</td><td>wu_par_flg (r)</td><td>crc_wr_flg (r)</td><td>fuse_par_flg (r)</td></tr>
<tr><td></td><td>mod1</td><td>$0A_H$</td><td>mode_sel (rw)</td><td>int_dis (rw)</td><td>collision_dis (rw)</td><td>wu_en (rw)</td><td colspan="2">trigger_sel (rw)</td><td>prot_sel (rw)</td><td>crc_wr_en (rw)</td></tr>
<tr><td></td><td>mod2</td><td>$0B_H$</td><td colspan="4">channel_sel (rw)</td><td colspan="2">f_update_sel (rw)</td><td>xtr_short_en (rw)</td><td>short_en (rw)</td></tr>
<tr><td></td><td>wu_xh</td><td>$0C_H$</td><td colspan="8">wu_xh_msbs (rw)</td></tr>
<tr><td></td><td>wu_xl</td><td>$0D_H$</td><td colspan="8">wu_xl_msbs (rw)</td></tr>
<tr><td></td><td>wu_yh</td><td>$0E_H$</td><td colspan="8">wu_yh_msbs (rw)</td></tr>
<tr><td></td><td>wu_yl</td><td>$0F_H$</td><td colspan="8">wu_yl_msbs (rw)</td></tr>
<tr><td></td><td>wu_zh</td><td>$10_H$</td><td colspan="8">wu_zh_msbs (rw)</td></tr>
<tr><td></td><td>wu_zl</td><td>$11_H$</td><td colspan="8">wu_zl_msbs (rw)</td></tr>
<tr><td></td><td>wu_xy</td><td>$12_H$</td><td colspan="2">wu_xh_lsbs (rw)</td><td colspan="2">wu_xl_lsbs (rw)</td><td colspan="2">wu_yh_lsbs (rw)</td><td colspan="2">wu_yl_lsbs (rw)</td></tr>
<tr><td></td><td>wu_z</td><td>$13_H$</td><td>▨</td><td>▨</td><td>wu_par (rw)</td><td>wu_en_cp (w)</td><td colspan="2">wu_zh_lsbs (rw)</td><td colspan="2">wu_zl_lsbs (rw)</td></tr>
<tr><td></td><td>rst</td><td>$14_H$</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td><td>rst_flg_clr (w)</td><td>soft_rst (w)</td></tr>
<tr><td></td><td>id0</td><td>$15_H$</td><td colspan="8">chip_id_0 (r)</td></tr>
<tr><td></td><td>id1</td><td>$16_H$</td><td colspan="8">chip_id_1 (r)</td></tr>
<tr><td></td><td>id2</td><td>$17_H$</td><td colspan="8">chip_id_2 (r)</td></tr>
<tr><td></td><td>id3</td><td>$18_H$</td><td colspan="8">chip_id_3 (r)</td></tr>
<tr><td></td><td>id4</td><td>$19_H$</td><td colspan="8">chip_id_4 (r)</td></tr>
<tr><td></td><td>id5</td><td>$1A_H$</td><td>0</td><td>id_par (r)</td><td colspan="6">chip_id_5 (r)</td></tr>
</table>

🟩 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**<br>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**<br>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**<br>I2C address. (This is a read only copy of the field iic_addr from PROD_TYPE_R register)<br>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: $80_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8"><b>by_msbs</b></td></tr>
<tr><td colspan="8">r</td></tr>
</table>

| Field | Bits | Type | Description |
|---|---|---|---|
| by_msbs | 7:0 | r | **by_msbs**<br>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: $00_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="2"><b>Res</b></td><td colspan="6"><b>by_lsbs</b></td></tr>
<tr><td colspan="2">r</td><td colspan="6">r</td></tr>
</table>

| Field | Bits | Type | Description |
|---|---|---|---|
| by_lsbs | 5:0 | r | **by_lsbs**<br>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: $80_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8"><b>bz_msbs</b></td></tr>
<tr><td colspan="8">r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| bz_msbs | 7:0 | r | **bz_msbs**<br>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: $00_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="2"><b>Res</b></td><td colspan="6"><b>bz_lsbs</b></td></tr>
<tr><td colspan="2">r</td><td colspan="6">r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| bz_lsbs | 5:0 | r | **bz_lsbs**<br>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: $80_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8"><b>temp_msbs</b></td></tr>
<tr><td colspan="8">r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| temp_msbs | 7:0 | r | **temp_msbs**<br>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: $00_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="2"><b>Res</b></td><td colspan="6"><b>temp_lsbs</b></td></tr>
<tr><td colspan="2">r</td><td colspan="6">r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| temp_lsbs | 5:0 | r | **temp_lsbs**<br>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: $00_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8"><b>CRC</b></td></tr>
<tr><td colspan="8">r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| CRC | 7:0 | r | **Communication CRC**<br>Provided for all read communications.<br>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: $0C_H$

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td><b>meas_flg</b></td><td><b>test_flg</b></td><td colspan="2"><b>frame_counter</b></td><td><b>rst_flg</b></td><td><b>wu_par_flg</b></td><td><b>crc_wr_flg</b></td><td><b>fuse_par_flg</b></td></tr>
<tr><td>r</td><td>r</td><td colspan="2">r</td><td>r</td><td>r</td><td>r</td><td>r</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| fuse_par_flg | 0 | r | **Fuse Parity Flag**<br>Flag reflecting the result of fuse parity check for fuses related to internal trimming.<br>$0_B$: 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.<br>$1_B$: Fuse parity check is correct |
| crc_wr_flg | 1 | r | **CRC Write OK Flag**<br>crc_wr_flg is cleared with the next write command.<br>$0_B$: The CRC at write is enabled and incorrect CRC has been transmitted or the CRC at write is disabled.<br>$1_B$: 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**<br>$0_B$: Wake Up parity check is not correct. The sensor does not enter Wake Up mode.<br>$1_B$: Wake Up parity check is correct. The sensor can enter Wake Up mode. |
| rst_flg | 3 | r | **Reset Flag**<br>Indicates a sensor reset. The field is cleared when $1_B$ is written to the rst_flg_clr field.<br>$0_B$: No sensor reset event.<br>$1_B$: Sensor reset event occurred. |
| frame_counter | 5:4 | r | **Frame Counter**<br>Increments at every ADC conversion cycle. |
| test_flg | 6 | r | **Test Function Flag**<br>$0_B$: The registers contain measurement data.<br>$1_B$: The registers contain test function data. |
| meas_flg | 7 | r | **Measure Success Flag**<br>$1_B$: All read out measurement values belong to the same ADC conversion cycle and were performed with the same channel_sel setting.<br>$0_B$: 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.**<br>$0_B$: CRC for write operations is disabled.<br>$1_B$: CRC for write operations is enabled. |
| prot_sel | 1 | rw | **I²C protocol selection**<br>$0_B$: 2 byte read protocol enabled.<br>$1_B$: 1 byte read protocol enabled. |

**(table continues...)**

**(continued)**

| Field | Bits | Type | Description |
|---|---|---|---|
| trigger_sel | 3:2 | rw | **Trigger options**<br>For I$^2$C 1 byte read protocol (prot_sel = $1_B$) the following trigger modes are available:<br>$00_B$: no trigger<br>$01_B$: trigger on read<br>$1x_B$: trigger on stop condition<br>Trigger bits in the I$^2$C command frame (write or 2 byte read command) overwrites the configuration bits in the mod1 register. |
| wu_en | 4 | rw | **Wake Up**<br>$0_B$: the Wake Up functionality is disabled.<br>$1_B$: the Wake Up functionality is enabled.<br>If enabled, the Wake Up functionality is only active if:<br>- Wake Up parity flag is OK.<br>- test functions are disabled. |
| collision_dis | 5 | rw | **Collision avoidance and clock stretching**<br>$0_B$ and (int_dis = $0_B$ or wu_en = wu_en_cp = $1_B$): collision avoidance is active (INTN will not be transmitted between I$^2$C start and stop condition).<br>$0_B$ 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).<br>$1_B$: Collision avoidance and clock stretching disabled. If int_dis = $0_B$, it may collide with clock from microcontroller. |
| int_dis | 6 | rw | **Interrupt disable**<br>The int_dis bit interacts with the collision_dis bit.<br>When Wake Up is enabled, the interrupt functionality is always activated, independent of the int_dis configuration.<br>$0_B$: Interrupt enabled: After a completed measurement and ADC conversion cycle, an interrupt pulse will be generated (see also collision_dis and Wake Up functionality).<br>$1_B$: Interrupt disabled |
| mode_sel | 7 | rw | **Operating modes**<br>$0_B$: Low Power Mode: Cyclic measurements and ADC-conversions with an update rate defined in the f_update_sel register. The trigger configuration is ignored.<br>$1_B$: Master Controlled Mode: Measurements are triggered by microcontroller. The trigger is configured via the trigger_sel bits or via I$^2$C 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**<br>$0_B$: The Bx, By and Bz ADC-conversion is set according the full range specification.<br>$1_B$: The Bx, By and Bz ADC-conversion is set according the short range specification.<br>short_en = $1_B$ and xtr_short_en = $1_B$ must not be used. |
| xtr_short_en | 1 | rw | **Magnetic extra short-range measurement**<br>$0_B$: The Bx, By and Bz ADC-conversion is set according the short_en setting.<br>$1_B$: The Bx, By and Bz ADC-conversion is set according the extra short range specification and short_en is ignorred.<br>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**<br>$00_B$: 1000 Hz<br>$01_B$: 125 Hz<br>$10_B$: 31 Hz<br>$11_B$: 16 Hz |
| channel_sel | 7:4 | rw | **Channel selection**<br>Selection of measurement channels and test function.<br>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.<br>When one channel is disabled, for all new measurements the register value for that channel will be set to reset value.<br>$0000_B$: Bx, By, Bz, Temp<br>$0001_B$: Vhall bias (X, Y, Z) / Vext test function.<br>$0010_B$: Spintest (X, Y, Z) / Vint test function.<br>$1000_B$: SAT test function (X, Y, Z, Temp).<br>$1100_B$: Bx, Temp<br>$1101_B$: Bx, By<br>$1110_B$: 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: | $7F_H$ |

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8"><b>wu_xh_msbs</b></td></tr>
<tr><td colspan="8">rw</td></tr>
</table>

| Field | Bits | Type | Description |
|---|---|---|---|
| wu_xh_msbs | 7:0 | rw | **Wake Up X-high MSBs**<br>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**<br>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**<br>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**<br>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: $7F_H$

<table>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="8"><b>wu_zh_msbs</b></td></tr>
<tr><td colspan="8">rw</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| wu_zh_msbs | 7:0 | rw | **Wake Up Z-high MSBs**<br>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: $80_H$

<table>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="8"><b>wu_zl_msbs</b></td></tr>
<tr><td colspan="8">rw</td></tr>
</table>

| **Field** | **Bits** | **Type** | **Description** |
|---|---|---|---|
| wu_zl_msbs | 7:0 | rw | **Wake Up Z-low MSBs**<br>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: $CC_H$

<table>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="2"><b>wu_xh_lsbs</b></td><td colspan="2"><b>wu_xl_lsbs</b></td><td colspan="2"><b>wu_yh_lsbs</b></td><td colspan="2"><b>wu_yl_lsbs</b></td></tr>
<tr><td colspan="2">rw</td><td colspan="2">rw</td><td colspan="2">rw</td><td colspan="2">rw</td></tr>
</table>

| Field | Bits | Type | Description |
|---|---|---|---|
| wu_yl_lsbs | 1:0 | rw | **Wake Up Y-low LSBs**<br>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**<br>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**<br>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**<br>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**<br>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**<br>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**<br>Alternative enable/disable bit for Wake Up functionality.<br>A read from this location always returns $0_B$.<br>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.<br>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**<br>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.<br>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 value: $00_H$

Reset register

| 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**<br>A soft reset is triggered when writing $1_B$ to this field.<br>A read operation will always return $0_B$ for this field. |
| rst_flg_clr | 1 | w | **Sensor reset clear**<br>Write $1_B$ to clear the rst_flg status bit from the diag register.<br>A read operation will always return $0_B$ for this field. |

## 5.2.2.22 Unique chip identifier register 0

**id0** Offset address: $15_H$
Reset value: $XX_H$

Unique chip identifier register 0

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| **chip_id_0** | | | | | | | |
| r | | | | | | | |

| Field | Bits | Type | Description |
|---|---|---|---|
| chip_id_0 | 7:0 | r | **Chip identifier**<br>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: $16_H$
Reset value: $XX_H$

Unique chip identifier register 1

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| **chip_id_1** | | | | | | | |
| r | | | | | | | |

| Field | Bits | Type | Description |
|---|---|---|---|
| chip_id_1 | 7:0 | r | **Chip identifier**<br>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**<br>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**<br>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**<br>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

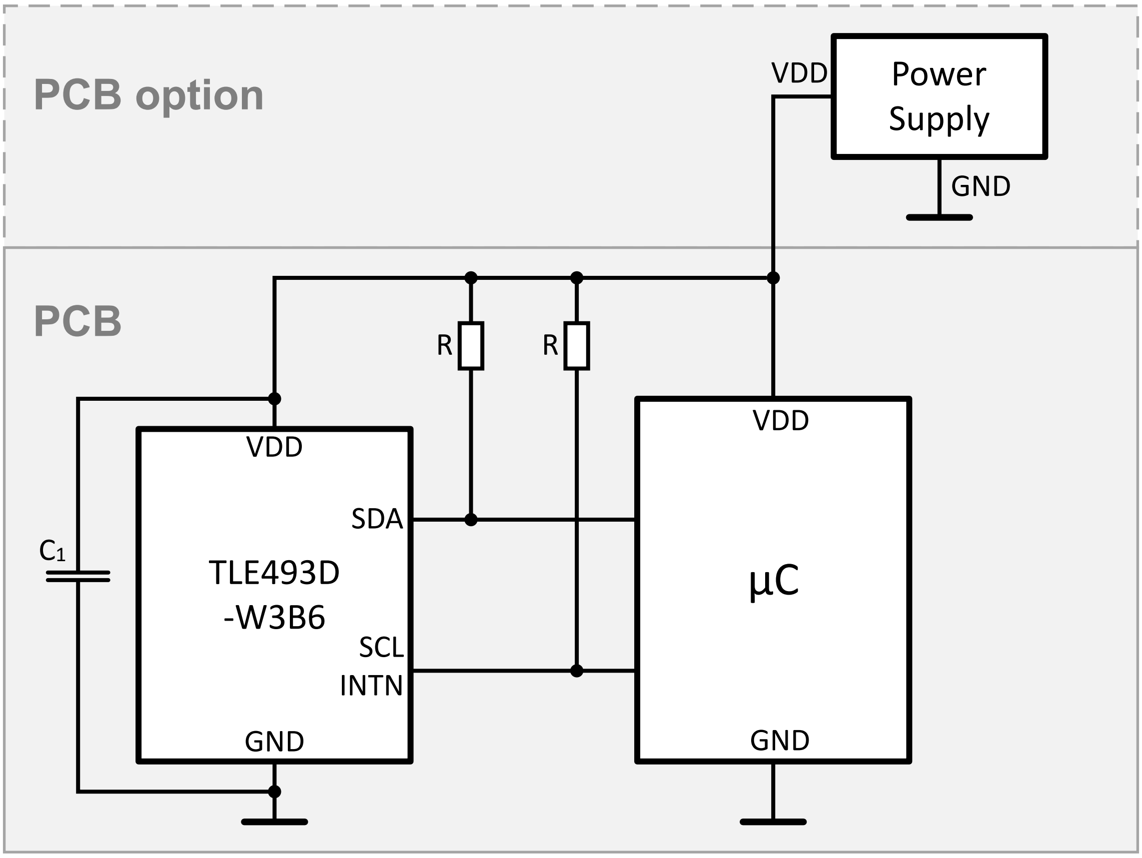
**id5** Offset address: $1A_H$

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**<br>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**<br>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 |

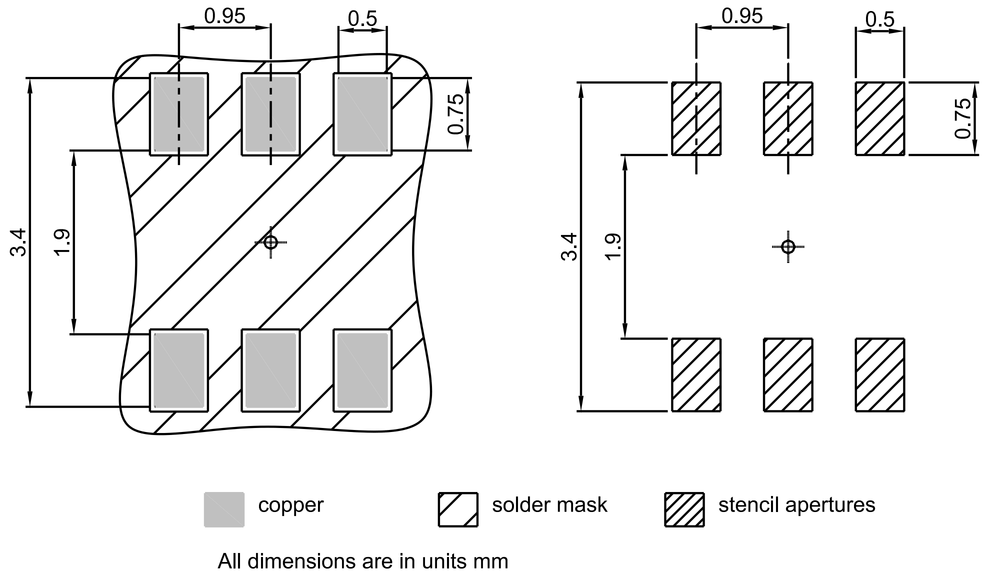


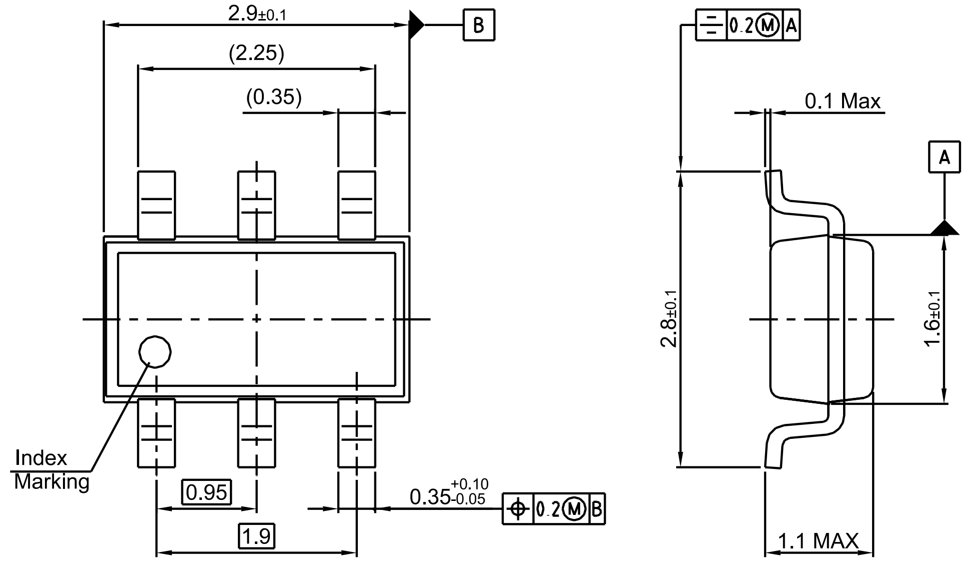
**Figure 22 Footprint of the PG-TSOP6-6-8**

---

[4] Reflow soldering according to JEDEC J-STD-020

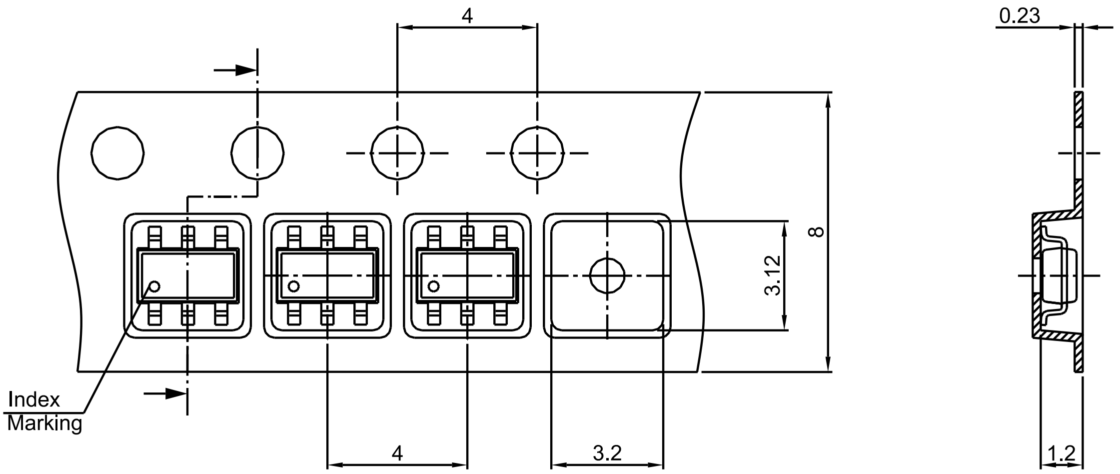
[5] According to Jedec JESD51-7

## 7.2 Package Outlines



All dimensions are in units mm
The drawing is in compliance with ISO 128-30, Projection Method 1 [⌖]

**Figure 23** Package outlines



All dimensions are in units mm
The drawing is in compliance with ISO 128-30, Projection Method 1 [⌖]

**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-W3B6 product |
| sensor module | refers to the TLE493D-W3B6 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 |

# 9 Revision history

| Revision | Date | Changes |
|---|---|---|
| 1.0 | 2024-08-26 | Initial release |

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