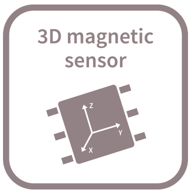
TLI493D-W2BW

Low power 3D Hall sensor with I²C interface and Wake-Up function

Features

SG-WFWLB-5-2



- 3D (X, Y, Z) magnetic flux density sensing up to ±160 mT
- Programmable sensitivity up to typ. 30.8 LSB_{12}/mT
- Extremely small form factor: typ. 1.13 mm * 0.93 mm * 0.59 mm
- Power down mode with 7 nA (typ.) power consumption
- 12-bit data resolution for each measurement direction plus 10-bit temperature sensor
- Variable update frequencies and power modes (configurable during operation)
- Temperature range T_j = -40°C…125°C, supply voltage range = 2.8 V…3.5 V
- Triggering by external microcontroller possible via I²C protocol
- X-Y angular measurement mode
- Interrupt signal to indicate a valid measurement to the microcontroller
- Pb-free (RoHS compliant) and halogen free package

Potential applications

The TLI493D-W2BW is designed for a wide range of magnetic sensing, including the following:
- Multi function knobs
- Joysticks and gimbals
- White good applications (washing, dryer machines, ...)
- Robotics position sensing
- Mobile camera lens position sensing for focus and zoom
- Angle measurement in end of shaft and out of shaft configurations

Benefits

- Component reduction due to 3D magnetic measurement principle
- Small sensor form factor allows for very compact system designs
- Wide application range addressable due to high flexibility
- Platform adaptability due to device configurability
- Very low system power consumption due to Wake-Up mode resulting in extended battery runtime
- Disturbance of smaller stray fields are neglectable compared to the high magnetic flux measurement range

Product validation

Qualified for industrial applications according to JEDEC JESD47.

Ordering information

Product type	Marking	Packing unit	Ordering code	Package	Default address write/read
TLI493D-W2BW A0	3DW0	4k on reel	SP005414809	SG-WFWLB-5-2	$6A_H$ / $6B_H$
		15k on reel	SP005409964		
TLI493D-W2BW A1	3DW1	4k on reel	SP005414807	SG-WFWLB-5-2	44_H / 45_H
		15k on reel	SP005409966		
TLI493D-W2BW A2	3DW2	4k on reel	SP005414805	SG-WFWLB-5-2	$F0_H$ / $F1_H$
		15k on reel	SP005409968		
TLI493D-W2BW A3	3DW3	4k on reel	SP005414803	SG-WFWLB-5-2	88_H / 89_H
		15k on reel	SP005409970		

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1 Functional description

This three dimensional Hall effect sensor can be configured by the microcontroller. The measurement data is provided in digital format to the microcontroller. The microcontroller is the master and the sensor is the slave. The sensor also provides the functionality to Wake-Up a sleeping system.

1.1 General

Description of the block diagram and its functions.

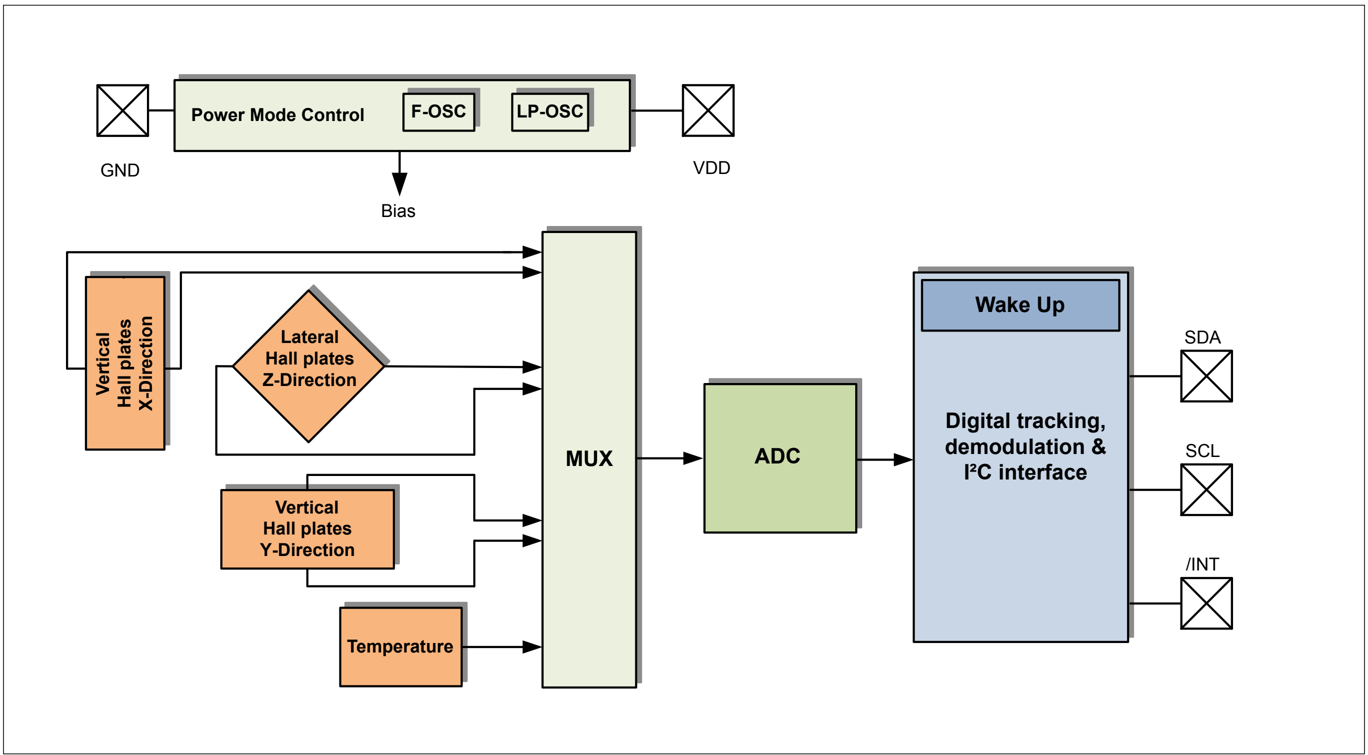


Figure 1 Block diagram

The IC consists of three main functional units containing the following building blocks:

- The power mode control system, containing a low-power oscillator, basic biasing, accurate restart, undervoltage detection and a fast oscillator.
- The sensing unit, which contains the HALL biasing, HALL probes with multiplexers and successive tracking ADC, as well as a temperature sensor is implemented.
- The I²C interface, containing the register files and I/O pads

1.1.1 Power mode control

The power mode control provides the power distribution in the IC, a power-on reset function and a specialized low-power oscillator as the clock source. It also manages the start-up behavior.

- On start-up, this unit:
  - activates the biasing, provides an accurate reset detector and fast oscillator
  - sensor enters low power mode and can be configured via I²C interface
- After re-configuration, a measurement cycle is performed, which consists of the following steps:
  - activating internal biasing, checking for the restart condition and providing the fast oscillator
  - HALL biasing

- measuring the three HALL probe channels sequentially (including the temperature). This is enabled by default
- reentering configured mode

In any case functions are only executed if the supply voltage is high enough, otherwise the restart circuit will halt the state machine until the required level is reached and restart afterwards. The functions are also restarted if a restart event occurs in between (see parameter ***ADC restart level***).

1.1.2 Sensing

Measures the magnetic field in X, Y and Z direction. Each X-, Y- and Z-Hall probe is connected sequentially to a multiplexer, which is then connected to an analog to digital converter (ADC). Optional, the temperature (default = activated) can be determined as well after the three Hall channels.

1.1.3 Wake-Up

For each of the three magnetic channels (X/Y/Z), the Wake-Up function has an upper and lower comparison threshold. Each component of the applied field is compared to the lower and upper threshold. If one of the results is above or below these thresholds, an interrupt pulse /INT is generated. This is called a Wake-Up function. The sensor signals a certain field strength change to the microcontroller. As long as all components of the field stay within the envelope, no interrupt signal will be provided. Note however that the /INT can also be inhibited during I²C activities, by activated collision avoidance. A Wake-Up interrupt /INT is the logical OR among all Wake-Up interrupt envelopes of the three channels.

1.2 Pin configuration

Figure 2 shows the pinout of the TLI493D-W2BW.

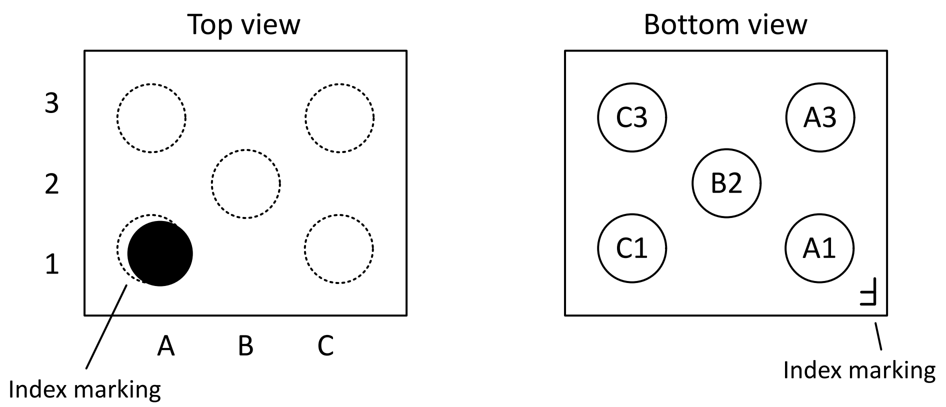


Figure 2 TLI493D-W2BW pinout (not to scale)

Table 1 SG-WFWLB-5-2 pin description and configuration (see *Figure 2*)

Pin no.	Name	Description
A1	/INT	Interrupt pin, signals a finished measurement cycle[1)] (output), open-drain
A3	SDA	Interface serial data pin (input/output), open-drain
B2	SCL	Interface serial clock pin (input)
C1	GND	Ground pin
C3	VDD	Supply pin

[1] The /INT pin can be used for I²C clock stretching. In this case the /INT pin must be connected to the SCL pin.

1.3 Definition of magnetic field

A positive field is considered as south-pole facing the corresponding Hall element.
Figure 3 shows the definition of the magnetic directions X, Y, Z of the TLI493D-W2BW.

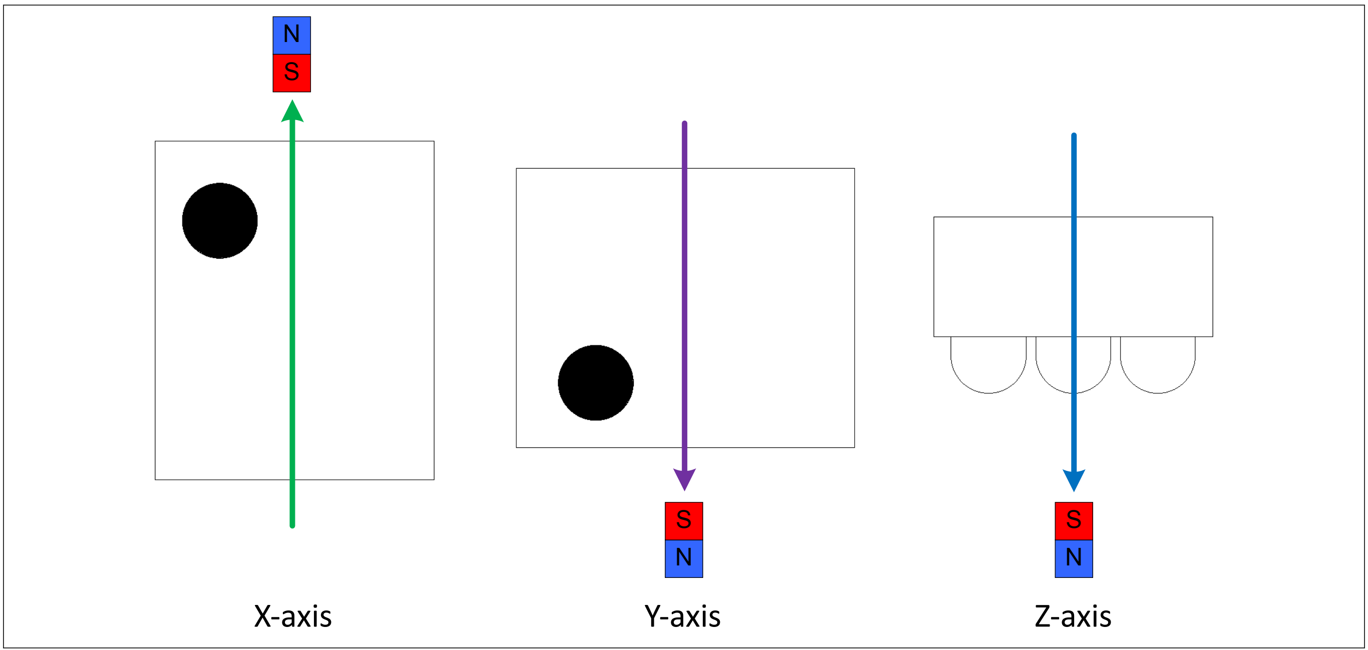


Figure 3 Definition of magnetic field direction

1.4 Sensitive area

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

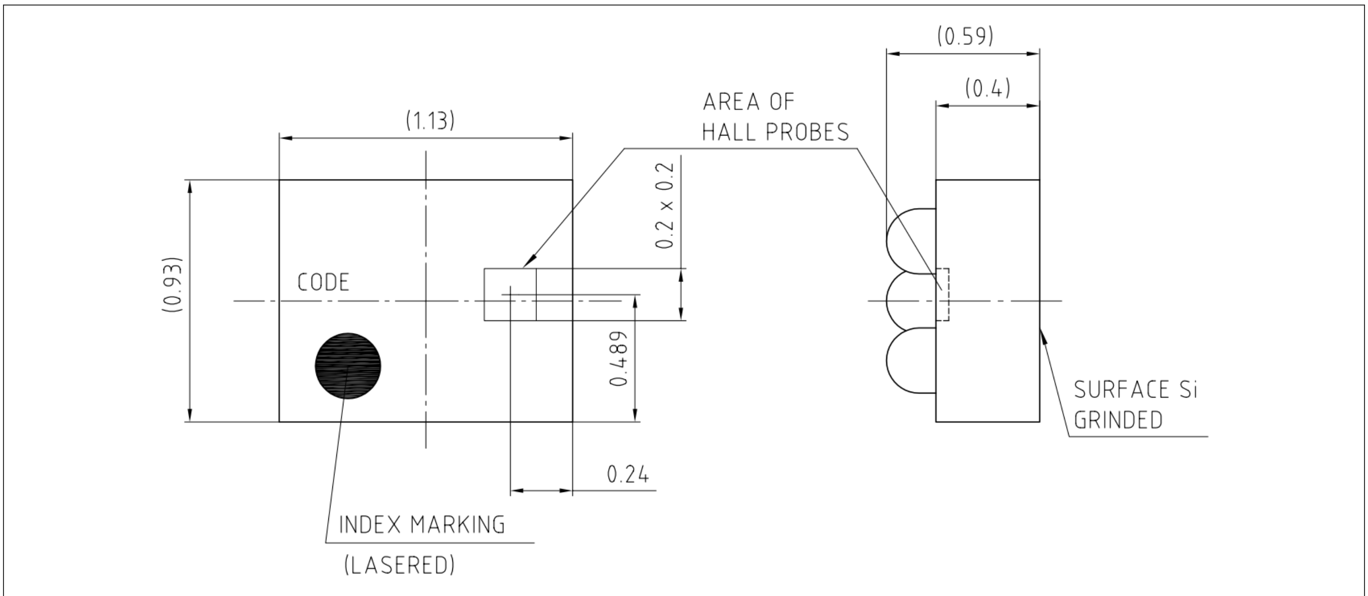


Figure 4 Center of sensitive area (dimensions in mm)

1.5 Application circuit

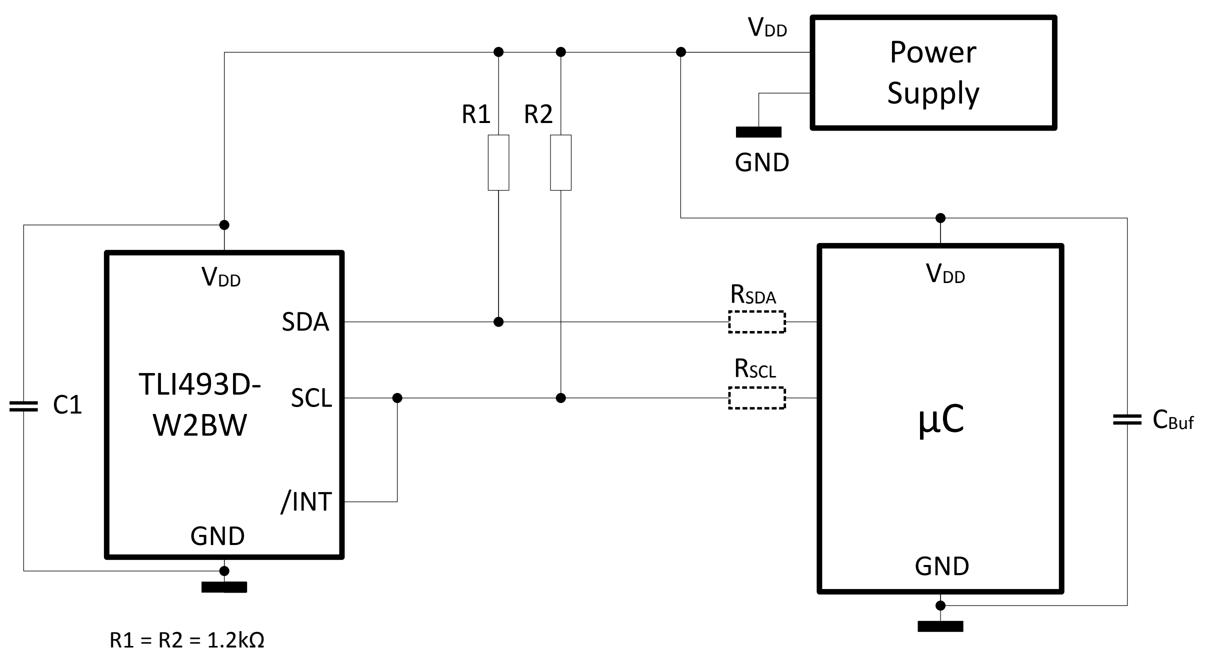
The default application circuit is shown in ***Figure 5***. In this configuration the interrupt pin (/INT) is combined with the I²C clock line (SCL) to achieve a minimum number of required microcontroller pins. I²C clock stretching is supported. The fast power up time t_{PUP}, see ***Table 5***, must be respected.

Alternatively, the interrupt pin can be connected to a dedicated microcontroller pin which is shown in ***Figure 6***. In this configuration any influence of the /INT signal on the I²C bus is avoided. The power up time t_{PUP} can be relaxed in case a I²C reset is issued after the power up, see ***Table 5***. I²C clock stretching is not supported.

The pull-up resistor values of the I²C bus have to be calculated in such a way as to fulfill the rise and fall time specification of the interface for the given worst case parasitic (capacitive) load of the actual application setup. Please note: Too small resistive R1/2 values have to be prevented to avoid unnecessary power consumption during interface transmissions, especially for low-power applications.

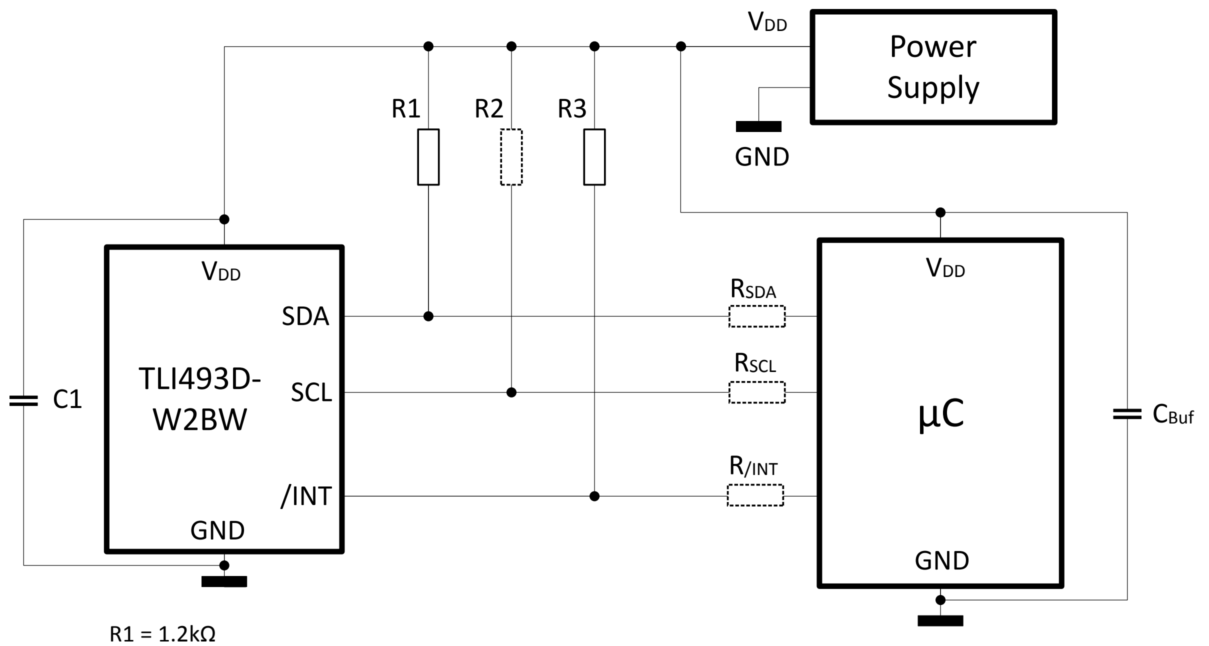
The efficiency of the capacitor C1 improves with an decreasing wire length to the sensor. In case of an ferromagnetic capacitor C1 the magnetic influence on the magnetic measurement increases with an closer position to the sensor. Both aspects must be balanced and evaluated carefully in the application.

For additional EMC precaution in harsh environments, C_1 may be implemented by two 100 nF capacitors in parallel, which should be already given by C_{Buf} near the µC and/or power supply.



R1 = R2 = 1.2kΩ
C1 = 100nF
Optional (recommended for wire harness): RSDA, RSCL
SDA, SCL capacitance < 200 pF each, including all stray capacitances

Figure 5 **Default application circuit with combined SCL and /INT pin**



R1 = 1.2kΩ
R2 = 1.2kΩ (defined by micrcontroller)
R3 = 10 kΩ
C1 = 100nF
Optional (recommended for wire harness): R_{SDA}, R_{SCL}, $R_{/INT}$
SDA, SCL capacitance < 200 pF each, including all stray capacitances

Figure 6 Alternative application circuit with separated SCL and /INT pin

2 Specification

This sensor is intended to be used in an industrial environment. This chapter describes the environmental conditions required by the device (magnetic, thermal and electrical).

2.1 Absolute maximum ratings

Stresses above those listed under "Absolute maximum ratings" 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. Furthermore, only single error cases are assumed. More than one stress/error case may also damage the device.

Exposure to absolute maximum rating conditions for extended periods may affect device reliability. During absolute maximum rating overload conditions the voltage on V_{DD} pin with respect to ground (GND) must not exceed the values defined by the absolute maximum ratings.

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Junction temperature	T_j	-40	–	125	°C	
Voltage on V_{DD}	V_{DD}	-0.3	–	3.5	V	
Magnetic field	B_{max}	–	–	±1	T	
Voltage range on any pin to GND	V_{max}	-0.1	–	3.5	V	open-drain outputs are not current limited.

Table 3 ESD protection[2)]

Ambient temperature T_A = 25°C

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
ESD voltage (HBM)[3)]	V_{ESD}	–	–	±2.0	kV	R = 1.5 kΩ, C = 100 pF
ESD voltage (CDM)[4)]		–	–	±0.75	kV	for corner pins, TC 750 (test condition)
		–	–	±0.5	kV	all pins, TC 500 (test condition)

2 Characterization of ESD is carried out on a sample basis, not subject to production test.
3 Human body model (HBM) tests according to ANSI/ESDA/JEDEC JS-001.
4 Charged device model (CDM), ESD susceptibility according to ANSI/ESDA/JEDEC JS-002.

2.2 Operating range

To achieve ultra low power consumption, the chip does not use a conventional, power-consuming restart procedure. The focus of the restart procedure implemented is to ensure a proper supply for the ADC operation only. So it inhibits the ADC until the sensor supply is high enough.

Table 4 Operating range

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Operating temperature	T_j	-40	–	125	°C	$T_j = T_a$ +3 K in fast mode
Supply voltage	V_{DD}	2.8	3.3	3.5	V	Supply voltage must be above restart level
ADC restart level	V_{res}	2.2	2.5	2.8	V	Min. ADC operating level
ADC restart hysteresis	$V_{res\text{-}hys}$	–	50	–	mV	
Register stable level	V_{reg}	–	–	2.5	V	Register values are stable above this voltage level

The sensor relies on a proper supply ramp defined with t_{PUP}, V_{OUS} and $I_{DD\text{-}PUP}$, see ***Figure 7***. The I²C reset feature of the sensor shall be used by the µC after power up. If supply monitoring is used in the system (e.g. brown-out detector etc.), it is also recommended to use the I²C reset of the sensor following events detected by this monitor.

In any case, an external supply switch (either provided by a system-basis-chip solution which includes a supply-enable feature, a Bias-resistor-transistor device, a capable µC GPIO pin, etc.) shall allow a power-cycle of the sensor as backup for high availability applications to cope with any form of V_{DD} ramps (including potential EMC influences), see ***Figure 7***.

At power up, *SDA* and *SCL* shall be pulled to V_{DD} using R1 and R2 of ***Application circuit*** and not be driven to low by any device or µC on *SDA* and *SCL*.

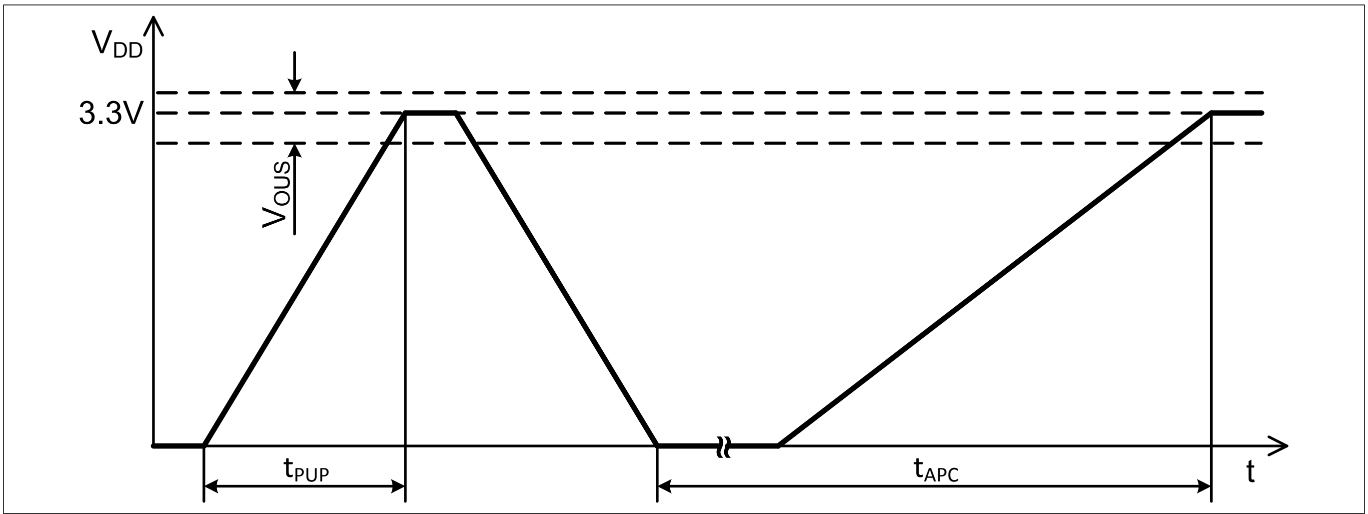


Figure 7 V_{DD} power up and power cycle for high availability

Table 5 **V_{DD} power up and power cycle**

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Power up ramp time	t_{PUP}	–	–	10	µs	Default application circuit, see *Figure 5*
		–	–	10	ms	Alternative application circuit with an I²C reset after power up, see *Figure 6*
Availability power cycle[5]	t_{APC}	–	150	400	µs	
Power up over- undershoot	V_{OUS}	3	3.3	3.5	V	Envelope which must not be exceeded at the end of a power up.
Power up current consumption	$I_{DD\text{-}PUP}$	–		10	mA	Current consumption during t_{PUP}

2.3 Electrical characteristics

This sensor provides different operating modes and a digital communication interface. The corresponding electrical parameters are listed in *Table 6*. Regarding current consumption more information are available in *Chapter 2.6*.

Table 6 **Electrical setup**

Values for V_{DD} = 3.3 V ±5%, T_j = -40°C to 125°C (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Supply current [6]	I_{DD_pd}	–	7	130	nA	T_j = 25°C; power down mode
	I_{DD_fm}	1	3.4	5	mA	Fast mode
Input voltage low threshold[7]	V_{IL}	–	–	30	%V_{DD}	All input pads
Input voltage high threshold[7]	V_{IH}	70	–	–	%V_{DD}	All input pads
Input voltage hysteresis[7]	V_{IHYS}	5	–		%V_{DD}	All input pads
Output voltage low level @ 3 mA load	V_{OL}	–	–	0.4	V	All output pads, static load

5 Not subject to production test - verified by design.
6 Currents at pull up resistors (*Application circuit*) needs to be considered for power supply dimensioning.
7 Based on I²C standard 1995 for V_{DD} related input levels

2.4 Magnetic characteristics

The magnetic parameters are specified for an end of line production scenario and for an application life time scenario. The magnetic measurement values are provided in the two’s complement with 12 bit or 8 bit resolution in the registers with the symbols Bx, By and Bz. Two examples, how to calculate the magnetic flux density are shown in ***Table 11*** and ***Table 12***.

Table 7 Initial magnetic characteristics[8]

Values for V_{DD} = 3.3 V, T_j = 25°C (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Magnetic linear range[9] (full range)	B_{xyz_LIN}	-160	-	160	mT	-40°C < T_j < 125°C
Magnetic linear range[9] (short range)	B_{xyz_LINSR}	-100	-	100	mT	
Magnetic linear range[9] (extra short range)	B_{xyz_LINXSR}	-50	-	50	mT	
Sensitivity X, Y, Z (full range)	Sx, Sy, Sz	5.5	7.7	10.5	LSB_{12}/ mT	
Sensitivity X, Y, Z (short range)	Sx_{SR}, Sy_{SR}, Sz_{SR}	11	15.4	21		
Sensitivity X, Y, Z (extra short range)	Sx_{XSR}, Sy_{XSR}, Sz_{XSR}	22	30.8	42		
Z-Offset (all ranges)	B_{0z}	-1.8	±0.2	1.8	mT	@ 0 mT
XY-Offset (all ranges)	B_{0xy}	-0.75	±0.2	0.75	mT	@ 0 mT
X to Y magnetic matching[10]	M_{XY}	-15	±1	15	%	
X/Y to Z magnetic matching[10]	$M_{X/YZ}$	-25	0	25	%	
Magnetic hysteresis [9] (all ranges)	B_{HYS}	–	1	–	LSB_{12}	due to quantization effects

$$M_{XY} = 100 \cdot 2 \cdot \frac{S_x - S_y}{S_x + S_y}[\%]$$

Equation 1 Parameter “X to Y magnetic matching”

8 Magnetic test on wafer level. It is assumed that initial variations are stored and compensated in the external µC during module test and calibration.
9 Not subject to production test - verified by design/characterization.
10 See the magnetic matching definition in ***Equation 1*** and ***Equation 2***.

$$M_{X/YZ} = 100 \cdot 2 \cdot \frac{S_x + S_y - 2 \cdot S_z}{S_x + S_y + 2 \cdot S_z} [\%]$$

Equation 2 Parameter "X/Y to Z magnetic matching"

Table 8 Magnetic noise characteristics

Values for V_{DD} = 3.3 V, T_j = 25°C

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Magnetic noise X, Y (rms, full range)	B_{Neff_X}, B_{Neff_Y}	-	85	-	µT	rms = 1 sigma
Magnetic noise X, Y (rms, short range)	$B_{Neff\_X\_SR}$, $B_{Neff\_Y\_SR}$	-	60	-	µT	
Magnetic noise X, Y (rms, extra short range)	$B_{Neff\_X\_XSR}$, $B_{Neff\_Y\_XSR}$	-	50	-	µT	
Magnetic noise Z (rms, full range)	B_{Neff_Z}	-	75	-	µT	
Magnetic noise Z (rms, short range)	$B_{Neff\_Z\_SR}$	-	50	-	µT	
Magnetic noise Z (rms, extra short range)	$B_{Neff\_Z\_XSR}$	-	40	-	µT	

Table 9 Sensor drifts[11] valid for both full range and short range (unless indicated)

Values for V_{DD} = 3.3 V ±5%, T_j = -40°C to 125°C, static magnetic field within full magnetic linear range (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Sensitivity drift X, Y, Z	Sx_D, Sy_D, Sz_D	-15	±5	15	%	TC_0
Offset drift X, Y	B_{O_DXY}	-0.45	–	0.45	mT	@ 0 mT, TC_0
Offset drift Z	B_{O_DZ}	-1.6	–	1.6	mT	@ 0 mT, TC_0
X to Y magnetic matching drift[12]	M_{XY_D}	-3.5	±1	3.5	%	TC_0
X/Y to Z magnetic matching drift[12]	M_{X/YZ_D}	-15	±10	15	%	TC_0

11 Not subject to production test, verified by design/characterization. Drifts are changes from the initial characteristics *Table 7* due to external influences.

12 See the magnetic matching definition in *Equation 1* and *Equation 2*.

Table 10 **Temperature compensation and non-linearity**[13)]

Values for V_{DD} = 3.3 V ±5%, T_j = -40°C to 125°C (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Temperature compensation[14)] (all ranges)	TC_0	–	±0	–	ppm/K	Bx, By and Bz (default)
	TC_1	–	-750	–		Bx, By and Bz (option 1)
	TC_2	–	-1500	–		Bx, By and Bz (option 2)
	TC_3	–	+350	–		Bx, By and Bz (option 3)
Differential non linearity (full range)	DNL	–	±2	–	LSB_{12}	Bx, By and Bz
Differential non linearity (short range)	DNL_{SR}	–	±4	–		
Differential non linearity (extra short range)	DNL_{XSR}	-	±8	-		
Integral non linearity (full range)	INL	–	±2	–	LSB_{12}	Bx, By and Bz
Integral non linearity (short range)	INL_{SR}	–	±4	–	LSB_{12}	
Integral non linearity (extra short range)	INL_{XSR}	-	±8	-	LSB_{12}	

Conversion register value to magnetic field value:

Table 11 **Magnetic conversion table for 12 bit**

	MSB	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	LSB
[Dec]	-2048	1024	512	256	128	64	32	16	8	4	2	1
[Bin] e.g.	1	1	1	1	0	0	0	0	1	1	1	1

The conversion is realized by the two's complement. Please use following table for transformation:

Example for 12-bit read out: $1111\ 0000\ 1111_B$: -2048 + 1024 + 512 + 256 + 0 + 0 + 0 + 0 + 8 + 4 + 2 +1 = -241 LSB_{12}

Calculation of magnetic flux density (full range): -241 LSB_{12} / 7.7 LSB_{12}/mT = -31.3 mT

Table 12 **Magnetic conversion table for 8 bit**

	MSB	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	LSB
[Dec]	-128	64	32	16	8	4	2	1
[Bin] e.g.	0	0	1	1	1	1	0	1

Example for 8-bit read out: $0011\ 1101_B$: 0 + 0 +32 + 16 + 8 + 4 + 0 + 1 = 61 LSB_8

Calculation of magnetic flux density (full range): 61 LSB_8 x 16 / 7.7 LSB_8/mT = 127 mT

13 Not subject to production test, verified by design/characterization.

14 TC_X must be set before magnetic flux trimming and measurements with the same value.

2.5 Temperature measurement

By default, the temperature measurement is activated. The temperature measurement can be disabled if it is not needed and to increase the speed of repetition of the magnetic values.

Table 13 Temperature measurement characteristics[15)]

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Digital value @ 25°C	T_{25}	1000	1180	1360	LSB_{12}	
Temperature resolution, 12 bit	T_{Res12}	0.21	0.24	0.27	K/LSB_{12}	referring to T_j
Temperature resolution, 8 bit	T_{Res8}	–	3.84	–	K/LSB_8	referring to T_j

Table 14 Temperature conversion table for 12 bit

The bits MSB to Bit2 are read out from the temperature value registers. Bit1 and LSB are added to get a 12-bit value for calculation.

	MSB	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2
[Dec]	-2048	1024	512	256	128	64	32	16	8	4
[Bin] e.g.	0	1	0	1	0	0	1	0	1	1

Example for 12-bit calculation: $0110\ 1010\ 11_B$: 0 + 1024 + 0 + 256 + 0 + 0 + 32 + 0 + 8 + 4 = 1324 LSB_{12}

Calculation to temperature: (1324 LSB_{12} - 1180 LSB_{12}) x 0.24 K/LSB_{12} + 25°C ≈ 60°C

15 The temperature measurement is not trimmed on the sensor. An external µC can measure the sensor during module production and implement external trimming to gain higher accuracies. Temperature values are based on 12 bit resolution. Please note: only bit 11 ... 2 are listed in the bitmap registers.

2.6 Overview of modes

For a good adaptation on application requirements this sensor is equipped with different modes. An overview is listed in *Table 15*.

Table 15 Overview of modes[16)]

Mode	Measurements	Typ. f_{Update}[17)]	Description
Power down	No measurements	–	Lowest possible supply current I_{DD}
Low power mode (full range and short range)	Bx, By, Bz, T	0.05 Hz - 770 Hz (8 steps)	Cyclic measurements and ADC-conversions with different update rates
	Bx, By, Bz		
	Bx, By		
Fast mode (full range)	Bx, By, Bz, T	5.8 kHz	Measurements and ADC conversions are running continuously. An I^2C clock speed up to 1 MHz and use of the interrupt /INT is required.
	Bx, By, Bz	7.8 kHz	
	Bx, By	11.6 kHz	
Fast mode (short range)	Bx, By, Bz, T	4.5 kHz	
	Bx, By, Bz	5.6 kHz	
	Bx, By	8.5 kHz	
Fast mode (extra short range)	Bx, By, Bz, T	3.2 kHz	
	Bx, By, Bz	3.7 kHz	
	Bx, By	5.5 kHz	
Master controlled mode (full range and short range)	Bx, By, Bz, T Bx, By, Bz Bx, By	Up to fast mode values	Measurements triggered by the microcontroller via I^2C

Typical I_{DD} current consumption estimation formula (e.g. full range and all channels):

$$I_{DD} \approx I_{DD\_fm} \cdot f_{Update} \cdot (t_{Bx} + t_{By} + t_{Bz} + t_{Temp})$$

Equation 3 ***I_{DD} estimation formula***

16 Not subject to production test - verified by design/characterization.
17 This is the frequency at which specified measurements are updated.

2.7 Interface and timing description

This chapter refers to how to set the boundary conditions in order to establish a proper interface communication.

Table 16 Interface and timing[18]

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Bx, By and Bz conversion time (full range)	t_{Bx}, t_{By}, t_{Bz}	32	43	54	µs	
Bx, By and Bz conversion time (short range)	t_{Bx_SR}, t_{By_SR}, t_{Bz_SR}	44	59	74	µs	
Bx, By and Bz conversion time (extra short range)	t_{Bx_XSR}, t_{By_XSR}, t_{Bz_XSR}	68	91	114	µs	
Temp conversion time (all ranges)	t_{Temp}	32	43	54	µs	
/INT pulse width	t_{INT}	1.8	2.5	3.2	µs	
/INT delay	t_{INT_d}	1.8	2.5	3.2	µs	
I²C timings						
Allowed I²C bit clock frequency[19]	f_{I2C_clk}	–	400	1000	kHz	
Low period of SCL clock	t_L	0.5	–	–	µs	1.3 µs for 400-kHz mode
High period of SCL clock	t_H	0.4	–	–	µs	0.6 µs for 400-kHz mode
SDA fall to SCL fall hold time (hold time start condition to clock)	t_{STA}	0.4	–	–	µs	0.6 µs for 400-kHz mode
SCL rise to SDA rise setup time (setup time clock to stop condition)	t_{STOP}	0.4	–	–	µs	0.6 µs for 400-kHz mode
SDA rise to SDA fall hold time (wait time from stop to start cond.)	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[20]	t_{FALL}	–	0.25	0.3	µs	
Rise time SDA/SCL signal[20]	t_{RISE}	–	0.5	–	µs	R = 1.2 kΩ

18 Not subject to production test - verified by design/characterization
19 Dependent on R-C-combination on SDA and SCL. Ensure reduced capacitive load for speeds above 400 kHz.
20 Dependent on used R-C-combination.

The fast mode, shown in ***Figure 8***, requires a very strict I²C behavior synchronized with the sensor conversions and high bit rates. In this mode, a fresh measurement cycle is started immediately after the previous cycle was completed.

Other modes are available for more relaxed timing and also for a synchronous microcontroller operation of sensor conversions. In these modes, a fresh measurement cycle is only started if it is triggered by an internal or external trigger source.

In the default measurement configuration (Bx, By, Bz and T), shown in ***Figure 8***, the measurement cycle ends after the temperature measurement.

In 3-channel measurement configuration (Bx, By and Bz), the temperature channel is not converted and updated. Thus, the measurement cycle ends after the Bz measurement.

In X/Y angular measurement configuration (Bx and By), the Bz and temperature channel are not converted and updated. Thus, the measurement cycle ends after the By measurement.

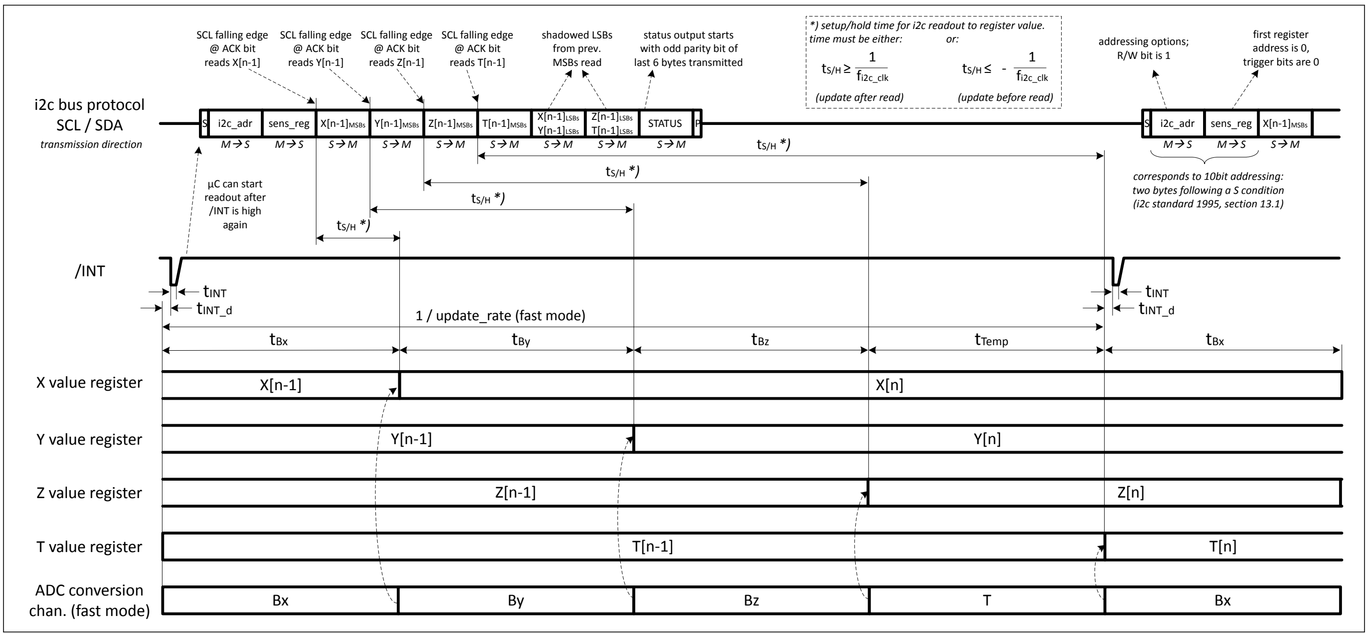


Figure 8 **I²C readout frame, ADC conversion and related timing**

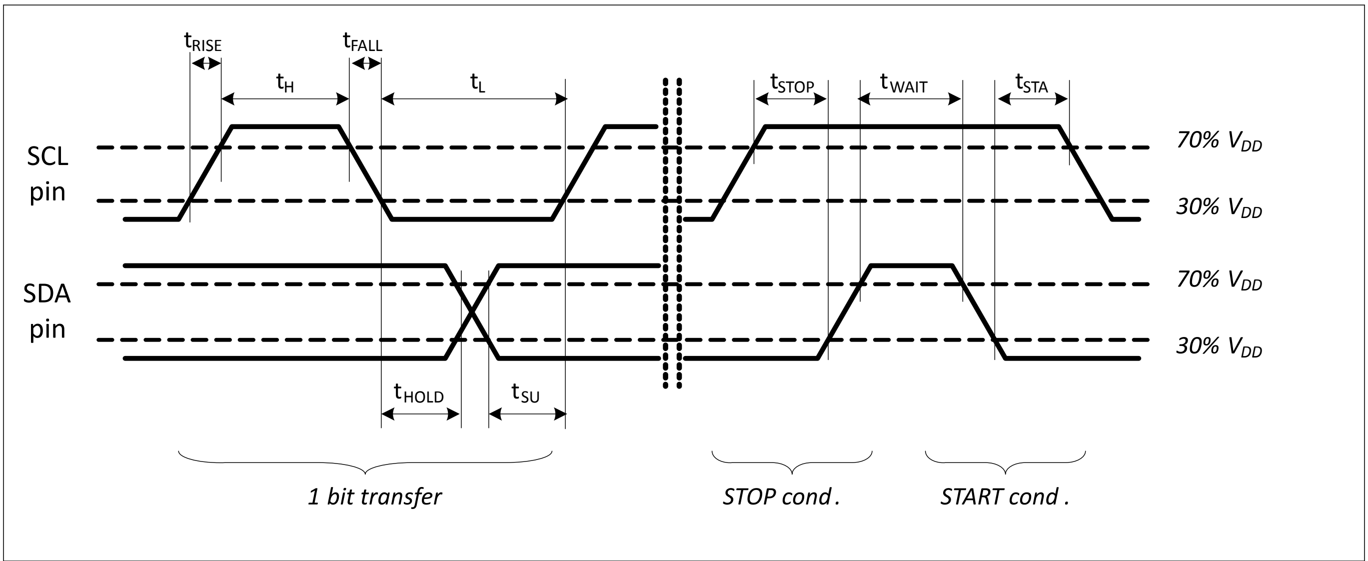


Figure 9 **I²C timing specification**

3 Package information

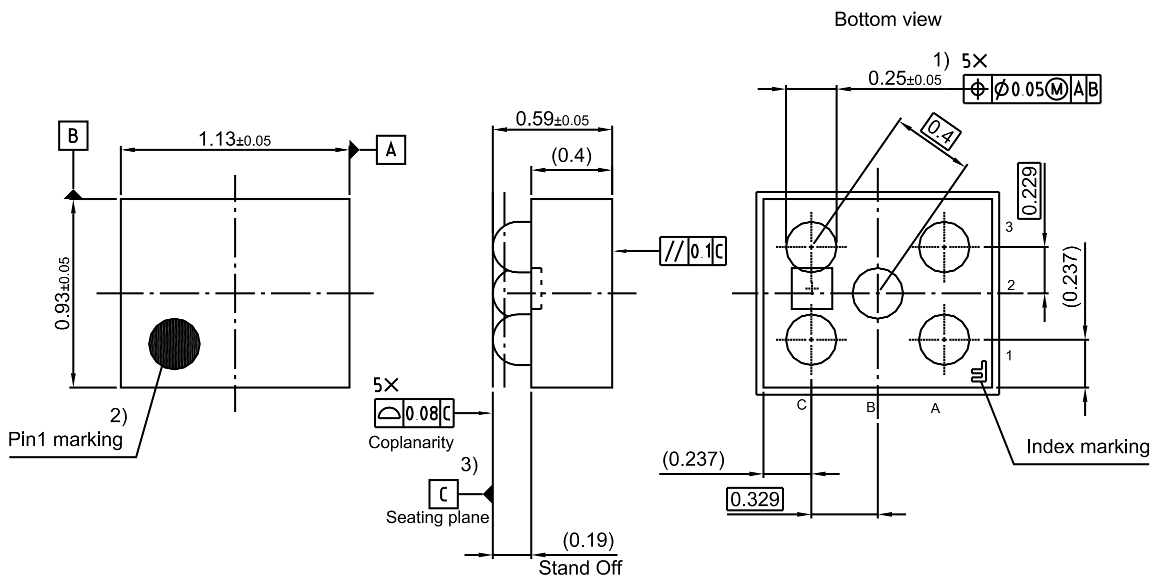
To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

3.1 Package parameters

Table 17 Package parameters

Parameter	Symbol	Values			Unit	Notes
		Min.	Typ.	Max.		
Thermal resistance[21] Junction ambient	R_{thJA}	–	220	-	K/W	Junction to ambient for SG-WFWLB-5-2
Soldering moisture level[22]	MSL 1					260°C

3.2 Package outlines



1) Dimension is measured at the maximum solder ball diameter, parallel to primary datum C
2) Ball A1 corner identified by marking
3) Primary datum C and seating plane are defined by the domed crowns of the balls
All dimensions are in units mm
The drawing is in compliance with ISO 128-30, Projection Method 1 [ ]

Figure 10 Package outlines

21 According to Jedec JESD51-7
22 Suitable for reflow soldering with soldering profiles according to JEDEC J-STD-020D.1 (March 2008)

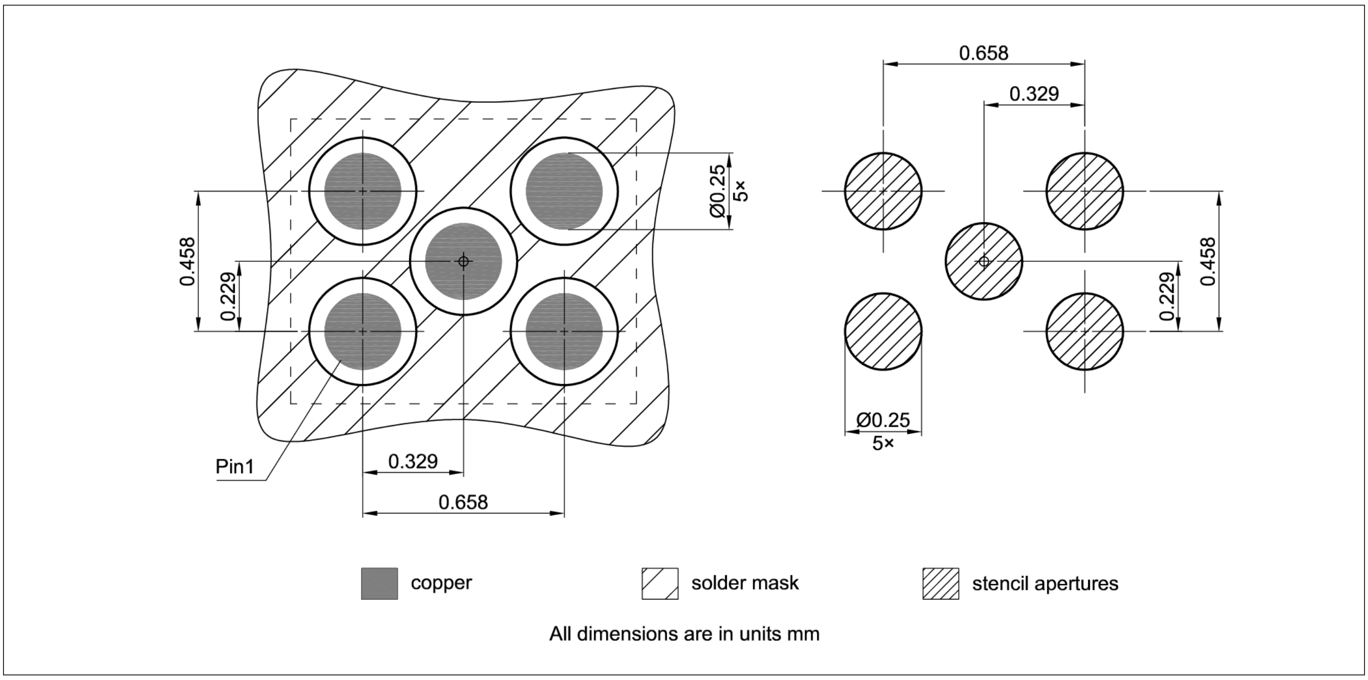


Figure 11 **Footprint SG-WFWLB-5-2**

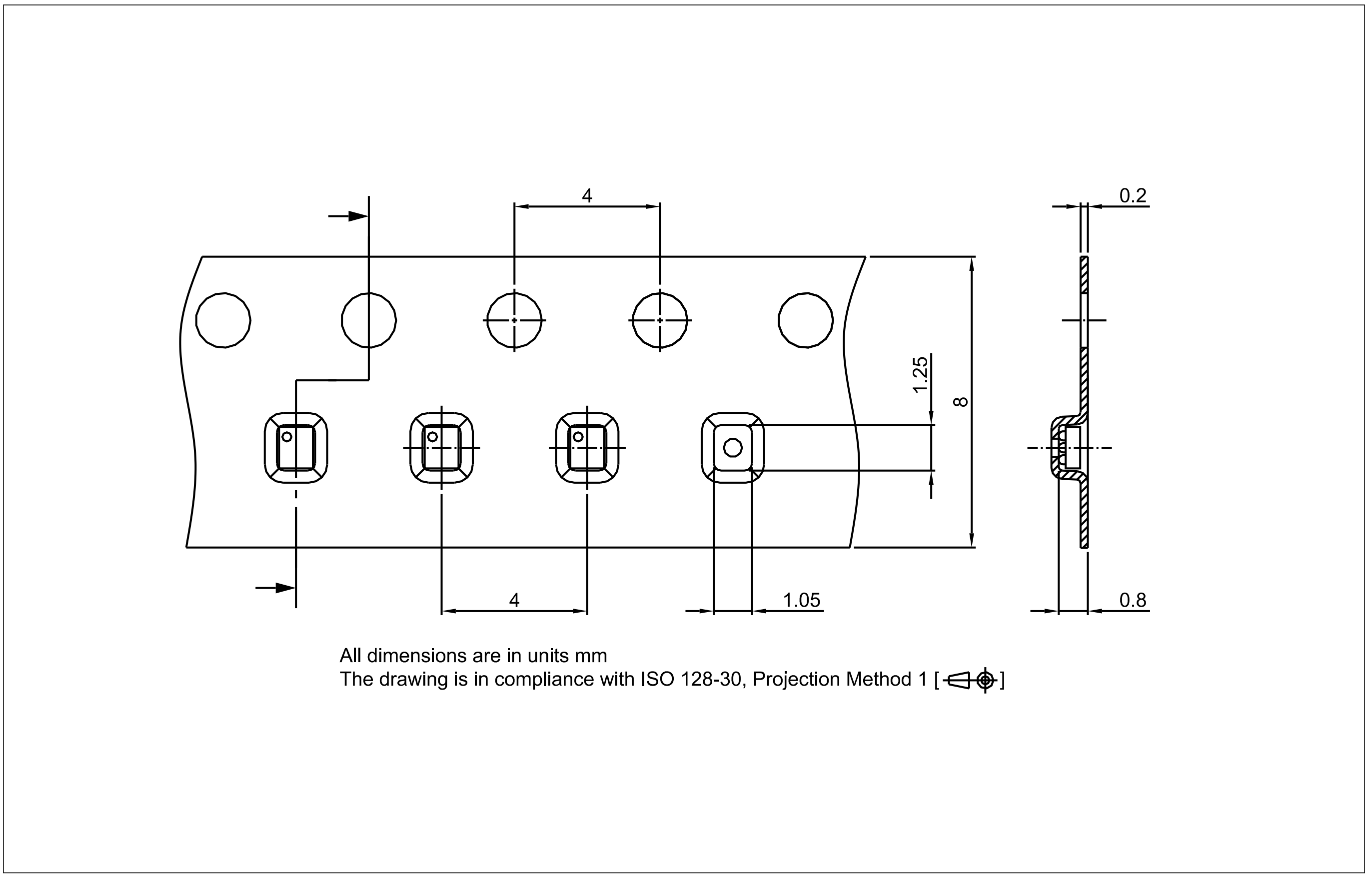


Figure 12 **Packing**

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

Revision history

Document version	Date of release	Description of changes
V1.0	2020-07-21	Initial release