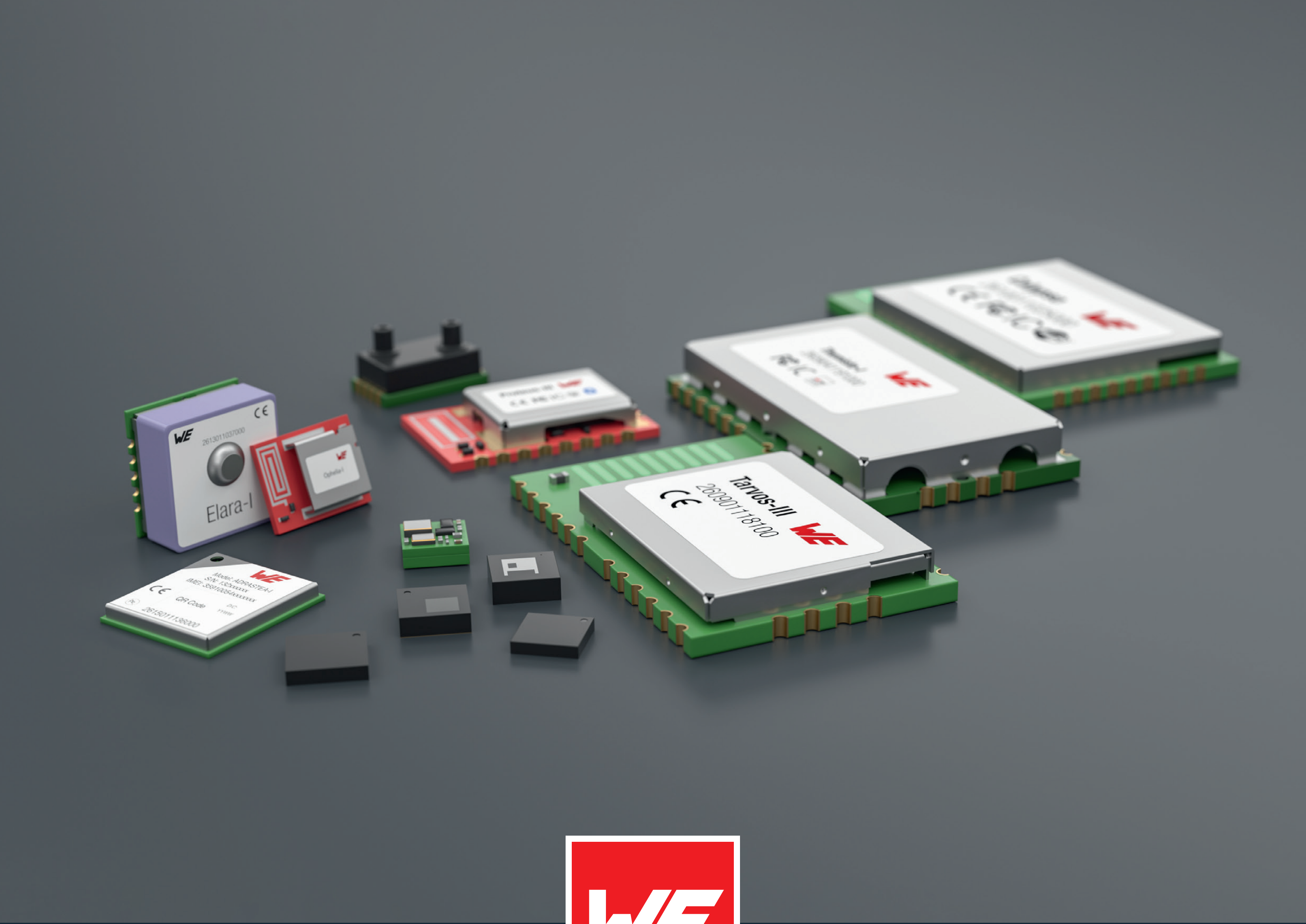


User manual

WSEN-TIDS

2521020222501

Version 1.2

October 10, 2024

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Revision history

Manual version	Notes	Date
1.0	• Initial release of the manual	December 2019
1.1	• Updated register type in section 10.2 & 10.3	February 2021
1.2	• Updated corporate design	October 2024

Abbreviations

Abbreviation	Description
ASIC	Application Specific Integrated Circuit
BDU	Block Data Update
ESD	Electrostatic Discharge
HBM	Human Body Model
I^2C	Inter Integrated Circuit
LSB	Least Significant Bit
MSB	Most Significant Bit
ODR	Output Data Rate
PCB	Printed Circuit Board
RH	Relative humidity
UDFN	Ultra-Dual Flat No Lead

Contents

Overview of helpful application notes

Application note ANM001 - MEMS Sensor PCB design and soldering guideline

http://www.we-online.com/ANM001
This technical document provides necessary information and general guidelines for soldering and PCB design for the Würth Elektronik eiSos MEMS sensor products with an LGA surface-mount package.

Application note ANR034 - How to use Zephyr sensor drivers

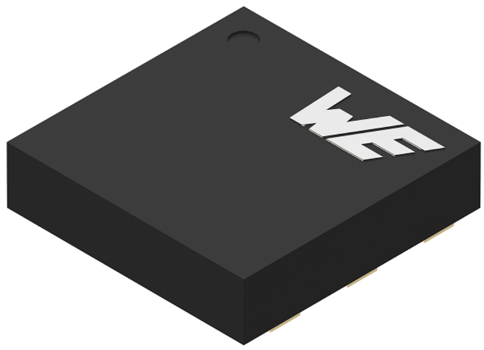
http://www.we-online.com/ANR034
The application note shows how to integrate the Zephyr drivers of Würth Elektronik eiSos sensors into the user's application source code to use Würth Elektronik eiSos sensors in the user's end device.

1 Introduction

This user manual describes a silicon-based, high precision digital temperature sensor embedded with an analog and digital signal processing unit. The integrated ASIC with digital I^2C interface provides a factory calibrated 16-bit temperature data to the host controller. The operating voltage of the sensor from 1.5 V to 3.6 V and the typical current consumption of 1.75 µA makes it suitable for battery operated applications. Compact 6-lead UDFN package with a form factor of 2.0×2.0×0.5 mm provides a fast thermal response. The exposed pad at the bottom provides better temperature match with the surrounding environment.

1.1 Applications

- Power system monitoring
- PCB thermal monitoring
- HVAC
- Thermocouple cold junction compensation
- Industrial control
- Environmental monitoring
- Cold-chain industry (transport & storage)



1.2 Key features

- Temperature range: -40 to 125 ℃
- Output data rate: 25 Hz upto 200 Hz
- Temperature data: 16-bits
- Low current consumption: 1.75 µA in single conversion mode
- Digital interface: I^2C
- Interrupt pin functionality: programmable temperature threshold

1.3 Ordering information

WE order code	Temperature range	Dimensions	Description
2521020222501	-40 ℃ to +125 ℃	2.0 x 2.0 x 0.5 mm	Tape & reel packaging

Table 1: Ordering information

2 Sensor specifications

2.1 General information

Parameter	Value
Operating temperature	-40 ℃ up to 125 ℃
Storage conditions	<40 ℃; <75% RH
Communication interface	I^2C
Moisture sensitivity level (MSL)	1
Electrostatic discharge protection (HBM)	2 kV

Table 2: General information

2.2 Absolute maximum ratings

Absolute maximum ratings are the limits; the device can be exposed to without causing permanent damage. Exposure to absolute maximum conditions for extended periods may affect device reliability.

Parameter	Symbol	Value		Unit
		Min	Max	
Input voltage *VDD* pin	V_{DD_MAX}	-0.3	4.8	V
Input voltage *SDA*, *SCL* & *SAO* pins	V_{IN_MAX}	-0.3	V_{DD}+0.3	V

Table 3: Absolute maximum ratings

Supply voltage on any pin should never exceed 4.8 V.

The device is susceptible to be damaged by electrostatic discharge (ESD). Always use proper ESD precautions when handling. Improper handling of the device can cause performance degradation or permanent damage.

2.3 Temperature sensor specification

Unless otherwise stated, all specified values were measured under the following conditions: T = 25 °C, V_{DD} = 3.3 V.

Parameter	Symbol	Test conditions	Value			Unit
			Min	Typ	Max	
Measurement range	T_{RANGE}		-40		125	°C
Absolute accuracy	T_{ACC_ABS}	T= -10 to 60 °C	-0.5	±0.25	0.5	°C
Total accuracy	T_{ACC_TOT}	T= -40 to 125 °C	-1.0	±0.7	1.0	°C
Resolution	RES_T			16		bit
Sensitivity	SEN_T			0.01		°C/digit
Output data rate	ODR	Continuous mode	25		200	Hz
Noise (RMS)[1]	T_{NOISE}	ODR= 25 Hz		0.025		°C RMS
		ODR= 50 Hz		0.035		
		ODR= 100 Hz		0.050		
		ODR= 200 Hz		0.060		
Boot-on time	t_{BOOT}			12		ms

Table 4: Temperature sensor specifications

2.4 Electrical specifications

Unless otherwise stated, all specified values were measured under the following conditions: T = 25 °C, V_{DD} = 3.3 V.

Parameter	Symbol	Test conditions	Value			Unit
			Min	Typ	Max	
Operating supply voltage	V_{DD}		1.5	3.3	3.6	V
Current consumption in power down mode	I_{DD_PD}			0.6		µA
Current consumption in single conversion mode[2]	I_{DD_SC}			1.75		µA
Peak current consumption	I_{DD_PEAK}	During measurement		120	180	µA

Table 5: Electrical specifications

[1] Temperature noise RMS is measured in a controlled environment.
[2] Averaged supply current with one measurement per second.

3 Pinning information

3.1 Pin configuration

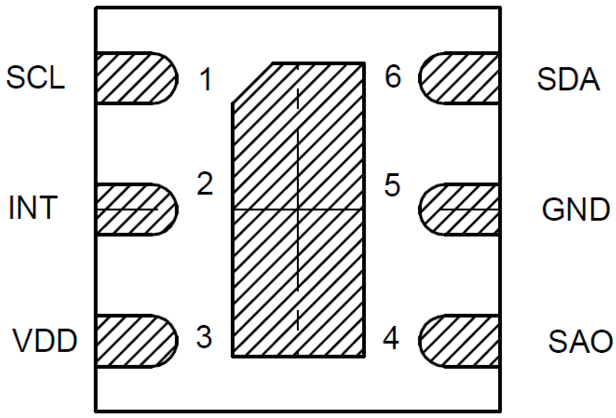


Figure 1: Pin specifications (top view)

3.2 Pin description

Pin No.	Name	Function	I/O	Comments
1	*SCL*	I^2C serial clock	Input	
2	*INT*	Interrupt	Output	Do not connect if not used
3	*VDD*	Positive supply voltage	Supply	
4	*SAO*	I^2C device address selection	Input	High: device address is 0111000b Low: device address is 0111111b
5	*GND*	Negative supply voltage	Supply	
6	*SDA*	I^2C serial data	Input/Output	

Table 6: Pin description

4 Digital interface

The sensor supports standard I^{2}C (Inter-IC) bus protocol. Further information about the I^{2}C interface can be found at *https://www.nxp.com/docs/en/user-guide/UM10204.pdf*. I^{2}C is a serial 8-bit protocol with two-wire interface that supports communication between different ICs, for example, between microcontrollers and other peripheral devices.

4.1 General characteristics

A serial data line (*SDA*) and a serial clock line (*SCL*) are required for the communication between the devices connected via I^{2}C bus. Both *SDA* and *SCL* lines are bidirectional. The output stages of devices connected to the bus must have an open-drain or open-collector. Hence, the *SDA* and *SCL* lines are connected to a positive supply voltage via pull-up resistors. In I^{2}C protocol, the communication is realized through master-slave principle. A master device generates the clock pulse, a start command and a stop command for the data transfer. Each connected device on the bus is addressable via a unique address. Master and slave can act as a transmitter or a receiver depending upon whether the data needs to be sent or received.

This sensor behaves like a slave device on the I^{2}C bus.

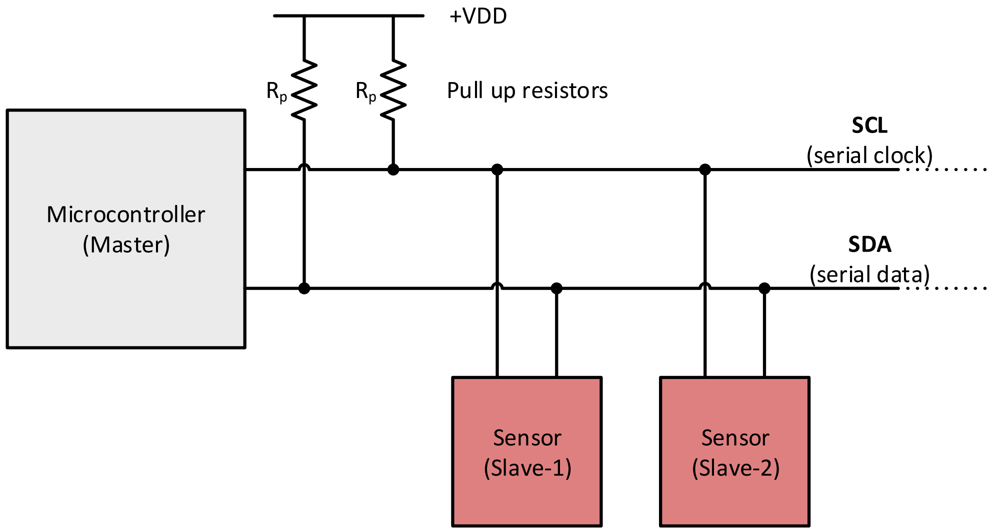


Figure 2: Master-slave concept

4.2 *SDA* and *SCL* logic levels

The positive supply voltage to which *SDA* and *SCL* lines are pulled up (through pull-up resistors), in turn determines the high level input for the slave devices. The logic high '1' and logic low '0' levels for the *SDA* and *SCL* lines then depend on the *VDD*. Input reference levels for this sensor are set as 0.8 * *VDD* (for logic high) and 0.2 * *VDD* (for logic low). Explained in the figure 3.

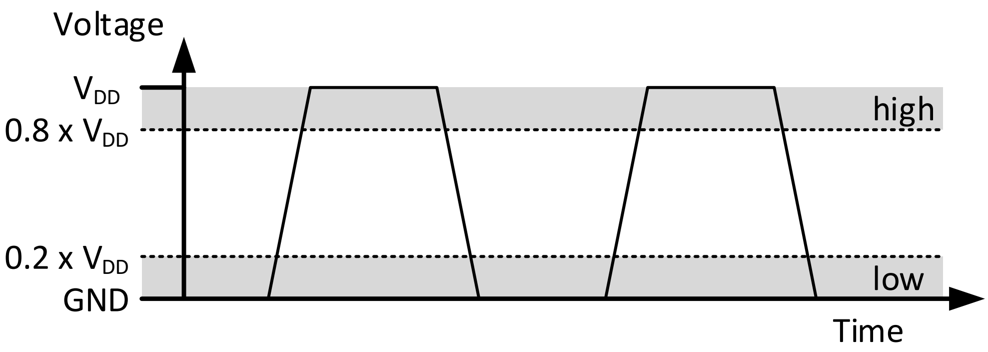


Figure 3: *SDA* and *SCL* logic levels

4.3 Communication phase

4.3.1 Idle state

During the idle state, the bus is free and both *SDA* and *SCL* lines are in logic high '1' state.

4.3.2 START (S) and STOP (P) condition

Data transfer on the bus starts with a START command, which is generated by the master. A start condition is defined as a high-to-low transition on the *SDA* line while the *SCL* line is held high. The bus is considered busy after the start condition.

Data transfer on the bus is terminated with a STOP command, which is also generated by the master. A low-to-high transition on the *SDA* line, while the *SCL* line being high is defined as a STOP condition. After the stop condition, the bus is again considered free and is in idle state. Figure 4 shows the I^2C bus START and STOP conditions.

Master can also send a REPEATED START (SR) command instead of STOP command. REPEATED START condition is the same as the START condition.

4.3.3 Data validity

After the start condition, one data bit is transferred with each clock pulse. The transmitted data is only valid when the *SDA* line data is stable (high or low) during the high period of the clock pulse. High or low state of the data line can only change when clock pulse is in low state.

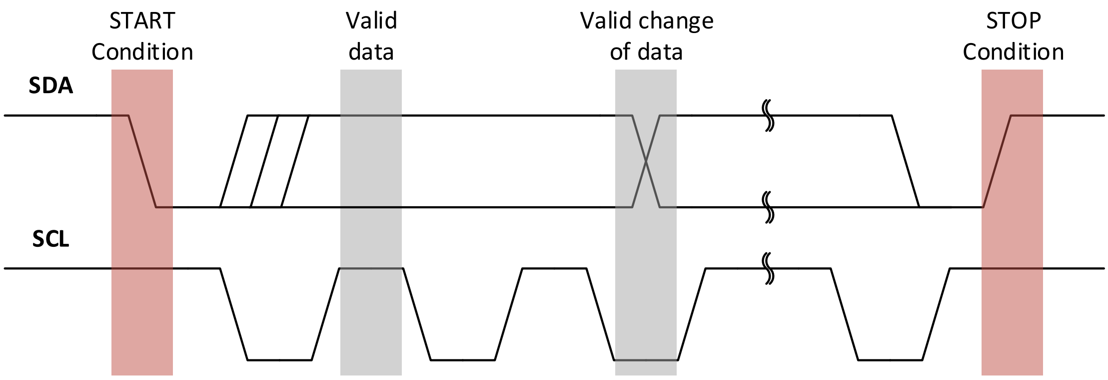


Figure 4: Data validity, START and STOP condition

4.3.4 Byte format

Data transmission on the *SDA* line is always done in bytes, with each byte being 8-bits long. Data is transferred with the most significant bit (MSB) followed by other bits.

If the slave cannot receive or transmit another complete byte of data, it can force the master into a wait state by holding *SCL* low. Data transfer continues when the slave is ready which is indicated by releasing the *SCL* line.

4.3.5 Acknowledge (ACK) and No-Acknowledge (NACK)

Each byte sent on the data line must be followed by an Acknowledge bit. The receiver (master or slave) generates an Acknowledge signal to indicate that the data byte was received successfully and another data byte could be sent.

After one byte is transmitted, the master generates an additional Acknowledge clock pulse to continue the data transfer. The transmitter releases the *SDA* line during this clock pulse so that the receiver can pull the *SDA* line to low state in such a way that the *SDA* line remains stable low during the entire high period of the clock pulse. This is considered as an Acknowledge signal.

In case the receiver does not want to receive any further byte, it does not pull down the *SDA* line and it remains in stable high state during the entire clock pulse. This is considered as a No-Acknowledge signal and the master can generate either a stop condition to terminate the data transfer or a repeated start condition to initiate a new data transfer.

4.3.6 Slave address for the sensor

The slave address is transmitted after the start condition. Each device on the I^2C bus has a unique address. Master selects the slave by sending corresponding address after the start condition. A slave address is 7 bits long followed by a Read/Write bit.

Depending on the connection of the *SAO* pin, the 7-bit slave address for this sensor can either be 0111000b or 0111111b. When *SAO* is connected to positive supply voltage, the 7-bit slave address is 0111000b (0x38). If *SAO* is connected to ground, 7-bit slave address is 0111111b (0x3F).

The R/W bit determines the data direction. A '0' indicates a write operation (transmission from master to slave) and a '1' indicates a read operation (data request from slave).

<table>
<tr><th>Slave address[6:3]</th><th>Slave address[2:0]</th><th>7-bit slave address</th><th>R/W</th><th>Slave address + R/W</th></tr>
<tr><td>0111</td><td rowspan="2">000</td><td rowspan="2">0111000b (0x38)</td><td>0</td><td>01110000b (0x70)</td></tr>
<tr><td>0111</td><td>1</td><td>01110001b (0x71)</td></tr>
<tr><td>0111</td><td rowspan="2">111</td><td rowspan="2">0111111b (0x3F)</td><td>0</td><td>01111110b (0x7E)</td></tr>
<tr><td>0111</td><td>1</td><td>01111111b (0x7F)</td></tr>
</table>

Table 7: Slave address and Read/Write commands

4.3.7 Read/Write operation

Once the slave-address and data direction bit is sent, the slave acknowledges the master. The next byte sent by the master must be a register-address of the sensor. This indicates the address of the register where data needs to be written to or read from.

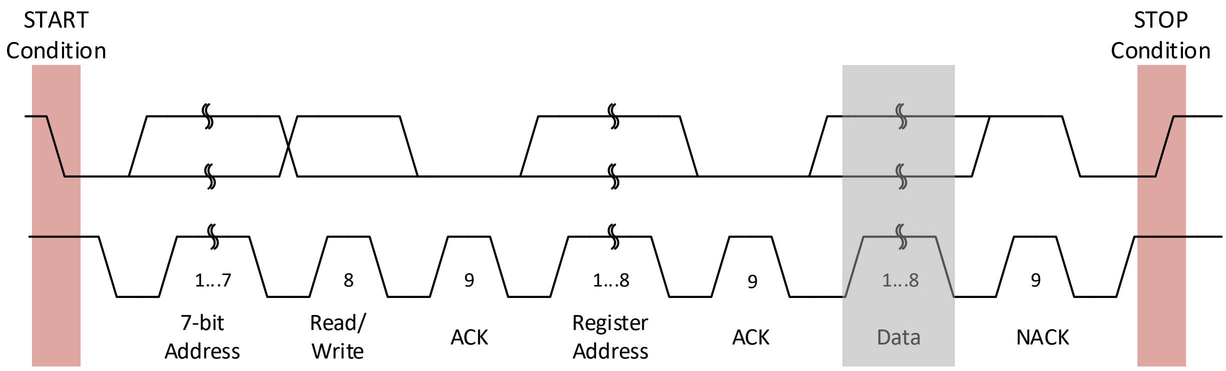


Figure 5: Complete data transfer

After receiving the register address, the slave sends an Acknowledgement (ACK). If the master is still writing to the slave (R/W bit = 0), it will transmit the data to slave in the same direction. If the master wants to read from the addressed register (R/W bit =1), a repeated start (SR) condition must be sent to the slave. Master acknowledges the slave after receiving each data byte. If the master no longer wants to receive further data from the slave, it would send No-Acknowledge (NACK). Afterwards, Master can send a STOP condition to terminate the data transfer. Figure 6 shows the writing and reading procedures between the master and the slave device (sensor).

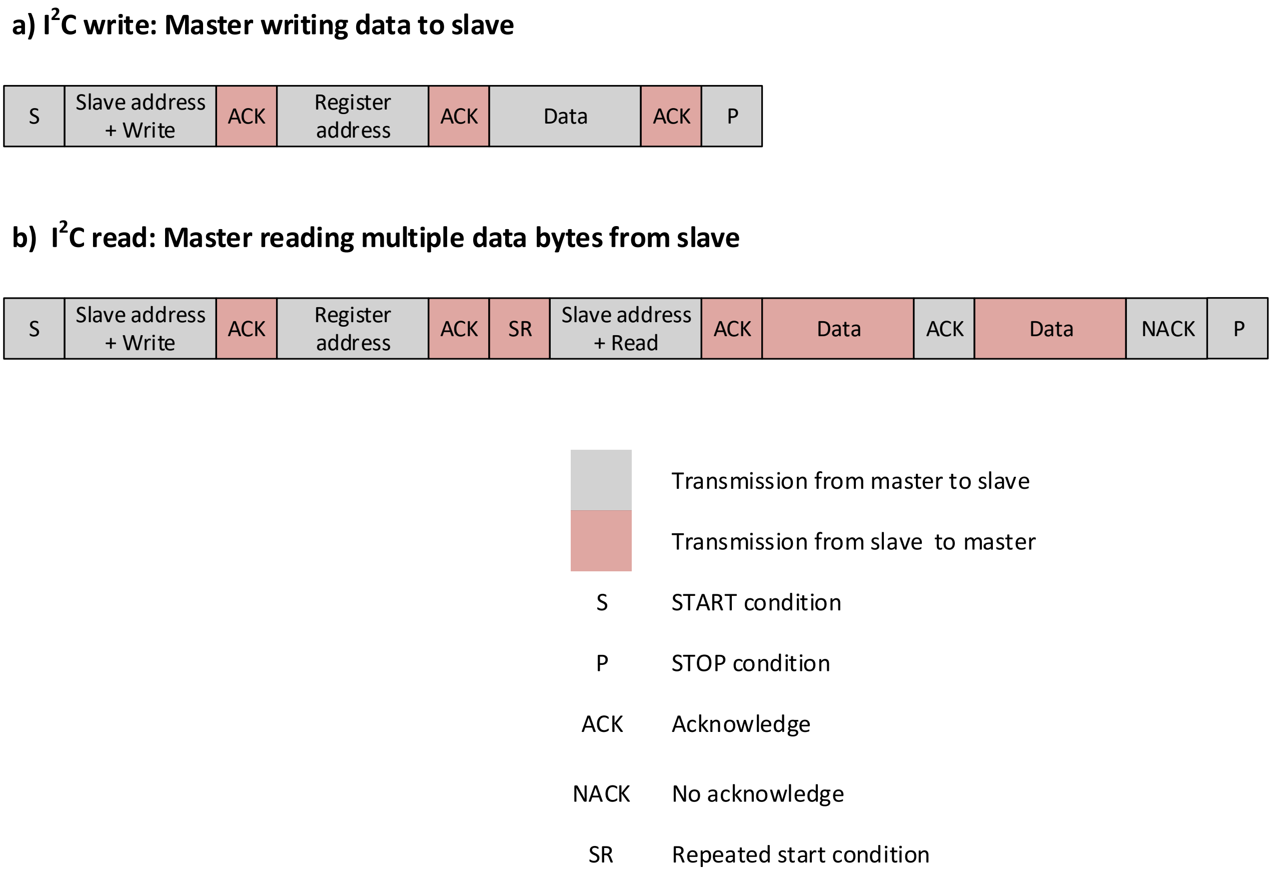


Figure 6: Write and read operations with the device

> 7-bit slave address of this device can be set to either 0x38 or 0x3F. 7-bit slave address depends on the *SAO* pin connection.

4.4 I²C timing parameters

Parameter	Symbol	V_{DD} < 3 V[1]		V_{DD} >3 V[1]		Unit
		Min	Max	Min	Max	
SCL clock frequency	f_{SCL}	10	400	0.01	1000	kHz
LOW period for *SCL* clock	t_{LOW_SCL}	1.3		0.6		µs
HIGH period for *SCL* clock	t_{HIGH_SCL}	0.6		0.16		µs
Hold time for START condition	t_{HD_S}	0.6		0.26		µs
Setup time for (repeated) START condition	f_{SCL}	0.6		0.26		µs
SDA setup time	t_{SU_SDA}	100		0.5		µs
SDA data hold time	t_{HD_SDA}	0		0		µs
Setup time for STOP condition	t_{SU_P}	0.6		0.26		µs
Bus free time between STOP and START condition	t_{BUF}	1.3		0.5		µs

Table 8: I²C timing parameters

1. Values measured at 25 °C with the SDA and SCL connected to *VDD* via pull up resistors

5 Application circuit

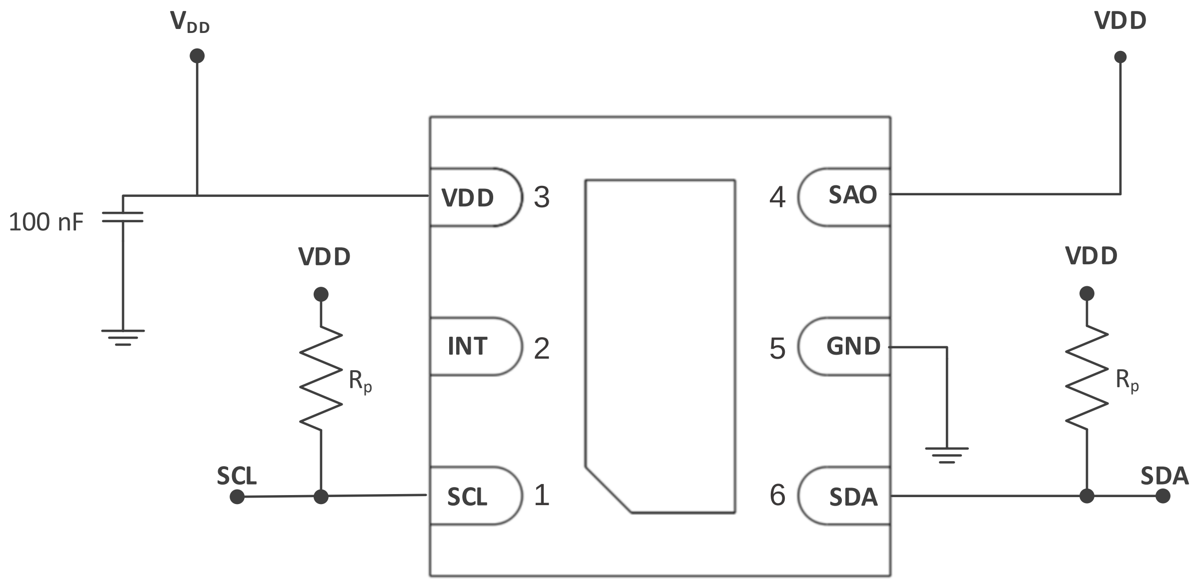


Figure 7: Application circuit with I^{2}C interface (sensor bottom view)

VDD pin is the central supply pin for the MEMS cell and internal circuits. In order to prevent ripple from the power supply, a decoupling capacitor of 100 nF must be placed as close to the *VDD* pad of the sensor as possible. An optional decoupling capacitor (4.7 µF) could be placed parallel to the 100 nF capacitor.

Figure 7 shows a typical application circuit for I^{2}C communication. Least significant bit of the 7-bit slave address can be modified based on the status of the *SAO* pin. When *SAO* is connected to *VDD*, the 7-bit slave address is 0x38 (0111000b). Refer to table 7 for more information. *SCL* and *SDA* must be connected to *VDD* through the pull-up resistors. Proper value of the pull-up resistors must be chosen depending on the I^{2}C bus speed and load.

INT pin is an open drain output and must be connected to *VDD* via pull-up resistors when used.

6 Quick start guide

6.1 Power-up sequence

The sensor is powered up when supply voltage is applied to *VDD*. During the power up sequence, it is recommended to keep the I²C interface pins in the high impedance state from the host controller side.

> **!** Wait at least 12 ms before accessing the internal registers after the device is powered on.

6.2 Communication with host controller

Communication with the host controller via I²C interface can be checked by reading the *DEVICE_ID* register (0x01). Device ID for this sensor is 0xA0.

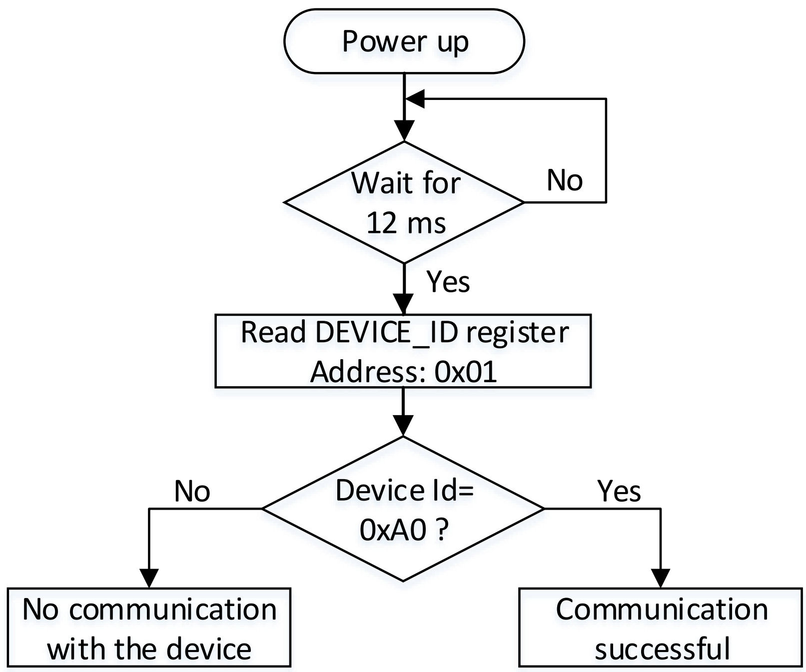


Figure 8: Communication check between host controller and the sensor

6.3 Sensor operation: single conversion mode

Flow chart shows sensor operation in the single conversion mode.

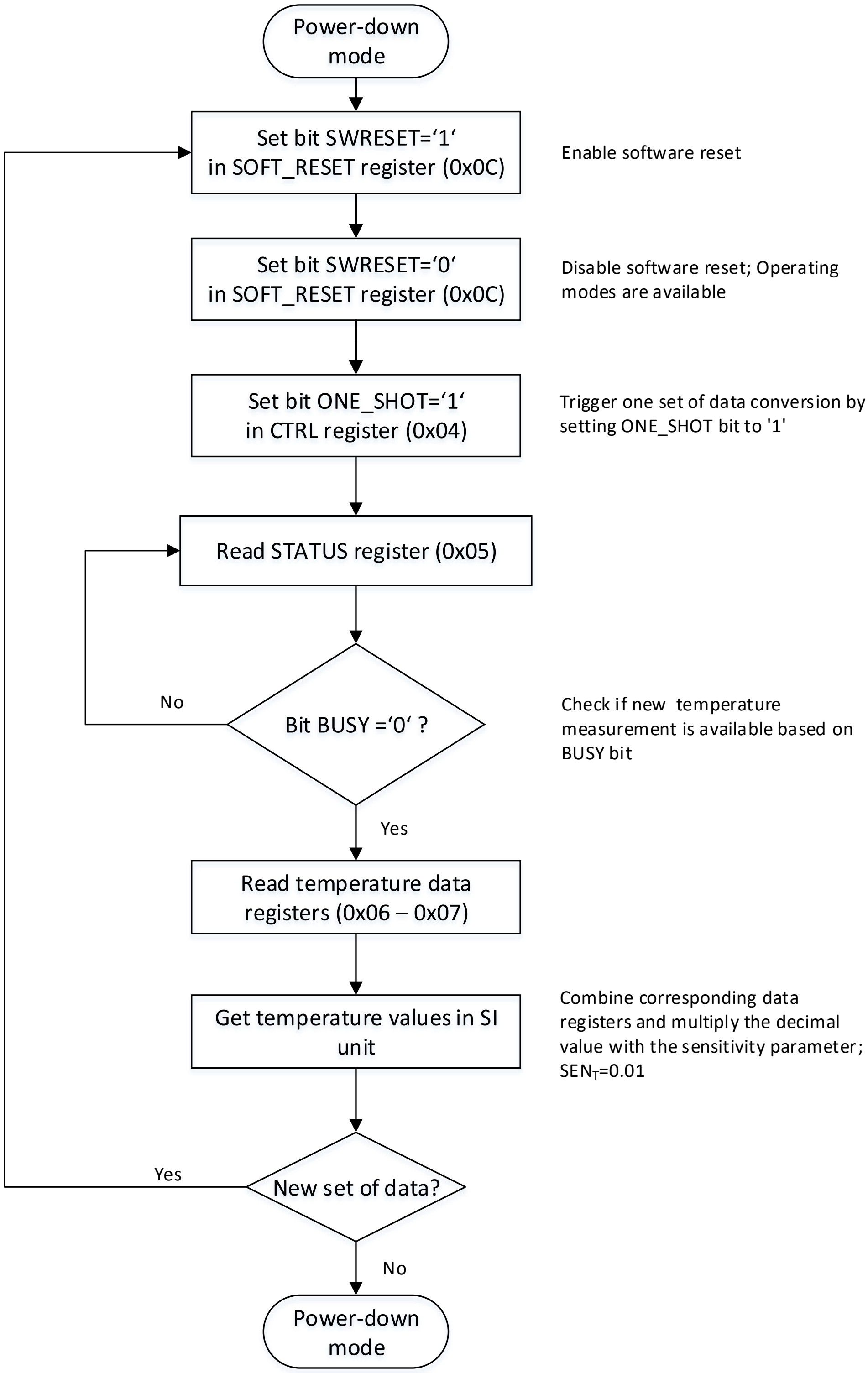


Figure 9: Sensor operation: single-conversion mode

6.4 Sensor operation: continuous mode

Flow chart shows sensor operation in continuous mode at ODR = 50 Hz with block data update enabled.

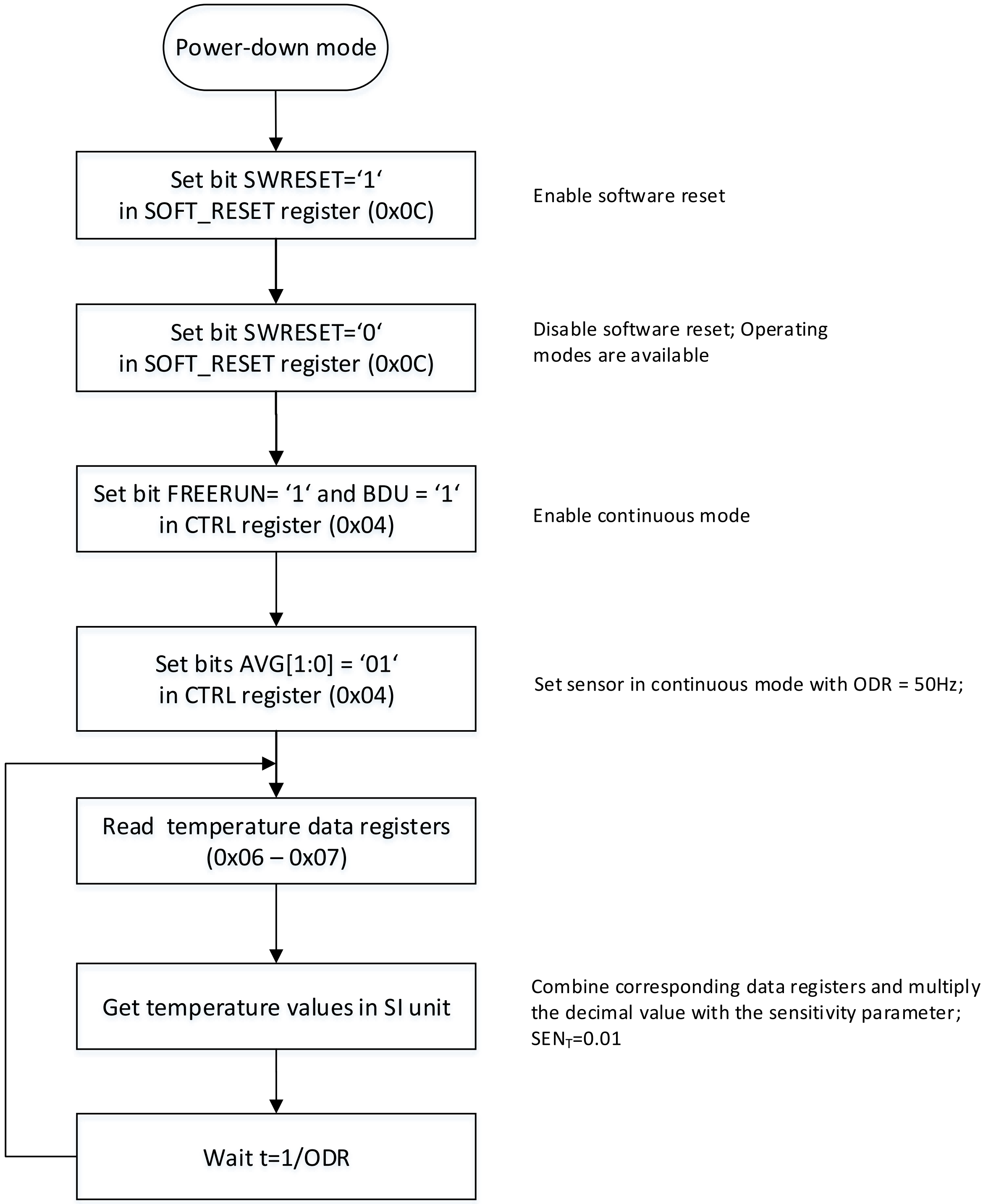


Figure 10: Sensor operation: continuous mode

6.5 Modes of operation

The sensor can be configured in the following three different modes

1. Power down mode
2. Single conversion mode
3. Continuous mode

6.6 Power-down mode

The power-down mode can be configured by setting the bit FREERUN in *CTRL* register (0x04) to '0'.

In power-down mode, the digital chain that samples the temperature data is turned off. New measurement is not performed during this mode. Hence, the temperature data registers are not updated. The temperature data registers contain the last sampled temperature value before going into power-down mode. Current consumption is at the minimum during this mode.

However, serial communication with the host controller via I²C bus is still possible. This allows the user to configure the device by accessing the control registers and temperature threshold registers.

Sensor is in power-down mode by default after the power-up sequence.

Before changing the operating mode or the ODR, the device must be first configured into power down mode.

6.7 Single conversion mode

In this mode, a single measurement of temperature is performed according to the request of the host controller. This mode can be activated when the sensor is in the power-down mode. When ONE_SHOT bit of *CTRL* register (0x04) is set to '1', the digital chain is turned on, data conversion starts and a single measurement of temperature is acquired. This measurement data is written to the temperature data registers. Afterwards, the digital chain is turned off again and the sensor enters the power-down mode. Bit BUSY in *STATUS* register stays '1' during the measurement is in progress. Temperature data registers are not updated until the host controller requests another data acquisition. This mode is useful when the application demands reduced power consumption.

Before requesting a new temperature data through ONE_SHOT bit, a software reset procedure must be performed each time.

During this mode the output data rate (ODR) of the sensor depends on the new measurement request from the host controller (frequency at which the ONE_SHOT bit is set to '1').

Single conversion mode can be used for measurement frequencies up to 1 Hz.

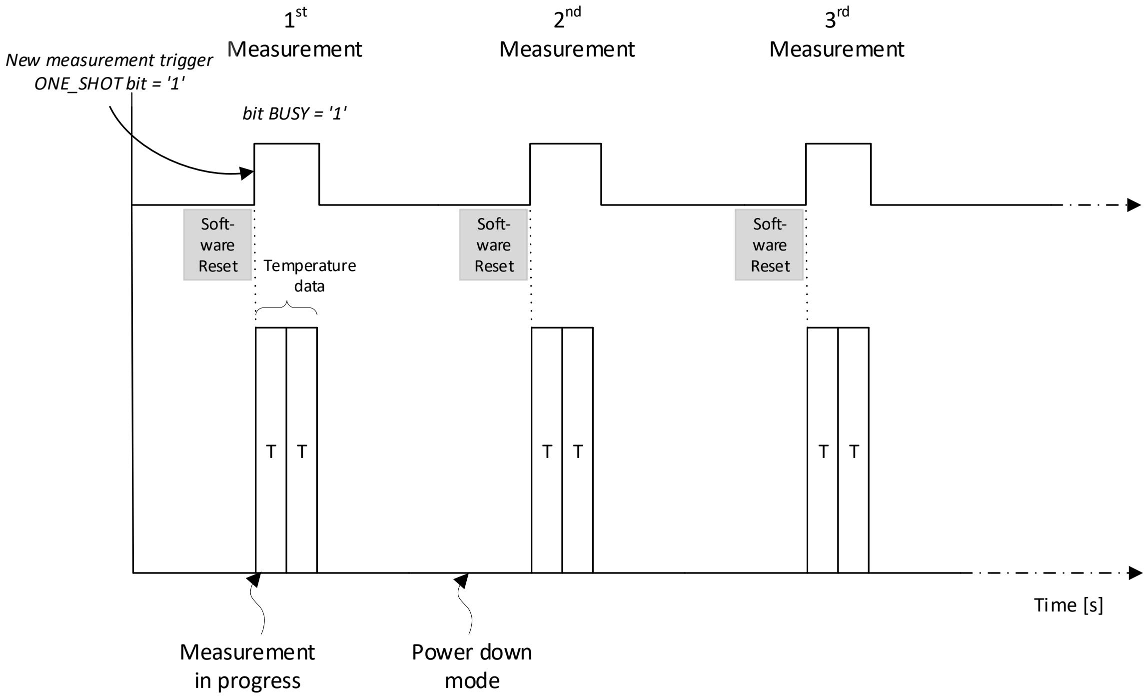


Figure 11: Application circuit with I^{2}C interface (sensor bottom view)

6.8 Continuous mode

The sensor is configured in the continuous mode when the FREERUN bit of *CTRL* register (0x04) is set to '1'. The continuous mode constantly samples new temperature measurements and writes the data to the temperature data registers. The measurement rate is defined by the user selectable output data rate (ODR) which can be set by AVG[1:0] bits of *CTRL* register. Selectable ODR and corresponding register settings are shown in the table 9.

FREERUN	AVG[1:0]	Output data rate [Hz]
1	00	25
1	01	50
1	10	100
1	11	200

Table 9: Output data rate selection

7 Reading temperature data

Once the device is configured in one of the operating modes, temperature values are sampled and stored in the temperature data registers, available for the user to read.

It is recommended to read the data registers starting from the lower address to the higher address.

Temperature values are stored in the two data registers: *DATA_T_L* (0x06) and *DATA_T_H* (0x07). Each register contains 8-bits data. The complete temperature data is a 16-bit signed two's complement word. This can be obtained by concatenating the two 8-bit temperature data registers: *DATA_T_H* & *DATA_T_L*, with *DATA_T_H* being most significant byte and *DATA_T_L* being least significant byte.

After calculating the 16-bit digital temperature value, it must be multiplied with the sensitivity parameter, SEN_T (see table 4) in order to obtain the corresponding temperature in SI unit (℃).

Step 1: Reading raw data from the two temperature data registers

1. *DATA_T_L* (0x06)
2. *DATA_T_H* (0x07)

Step 2: Concatenating the temperature data registers to obtain complete 16-bit temperature value

$$T_{16bit} = DATA\_T\_H \,\&\, DATA\_T\_L$$

Step 3: Obtaining temperature value in SI unit [℃] by multiplying with sensitivity parameter

$$\text{Temperature [℃]} = T_{16bit}\ \text{[digit]} \times 0.01\ \text{[℃/digit]}$$

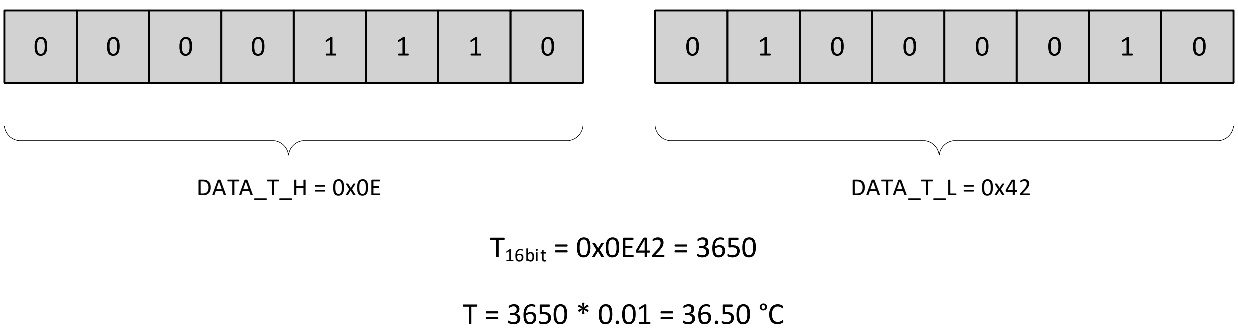


Figure 12: Reading temperature data

Example:

If values obtained from temperature data registers are:

DATA_T_L = 0x42
DATA_T_H = 0x0E

Concatenating these 2 registers (0x0E42) to obtain 16-bit signed decimal value and multiplying with sensitivity parameter

$$T_{16bit}[\text{digit}] = 3650\ [\text{digit}]$$

$$T[^\circ C] = 3650\ [\text{digit}] * 0.01\ [^\circ C/\text{digit}] = 36.50\ ^\circ C$$

8 Interrupt functionality

The sensor has a dedicated interrupt generator, which generates an interrupt event based on user defined threshold temperatures. Following two interrupt events are generated

- Temperature high
- Temperature low

Threshold temperatures for the temperature high and low limit interrupt events are defined in two 8 bit interrupt registers, *TEMP_H_LIMIT* (0x02) and *TEMP_L_LIMIT* (0x03) respectively. If both the registers are '0', the interrupt generation is disabled.

$$\text{Threshold Temperature (°C)} = (\text{TEMP\_x\_LIMIT} - 63) \times 0.64$$

The temperature threshold value in °C is calculated based on the formula above. The threshold value ranges from -39.68 °C to 122.88 °C with the step value of 0.64 °C.

When enabled, temperature high and low interrupts are routed to the *INT* pin of the sensor. The status of the interrupt event can be monitored through the *STATUS* (0x05) register.

Register Value (*TEMP_H_LIMIT* / *TEMP_L_LIMIT*)	Threshold Temperature (°C)
0	Interrupt generation is disabled
1	-39.68
2	-39.04
3	-38.40
...	...
...	...
62	-0.64
63	0
64	0.64
...	...
...	...
254	122.24
255	122.88

Table 10: Temperature threshold

8.1 Interrupt output

The sensor has a dedicated *INT* pin, to which the interrupt events are routed. The open drain *INT* pin is asserted to low state when the measured temperature has exceeded the user-defined temperature high-limit or fallen below the temperature low-limit. Even if the temperature falls back between the high and low limits, the *INT* pin will remain asserted. The *INT* pin is de-asserted, once the *STATUS*(0x05) is read. If the triggering condition is still true, the *INT* pin will be re-asserted at the next temperature conversion.

The *INT* pin is an open drain output. When used, the pin must be connected to *VDD* via a pull-up resistor.

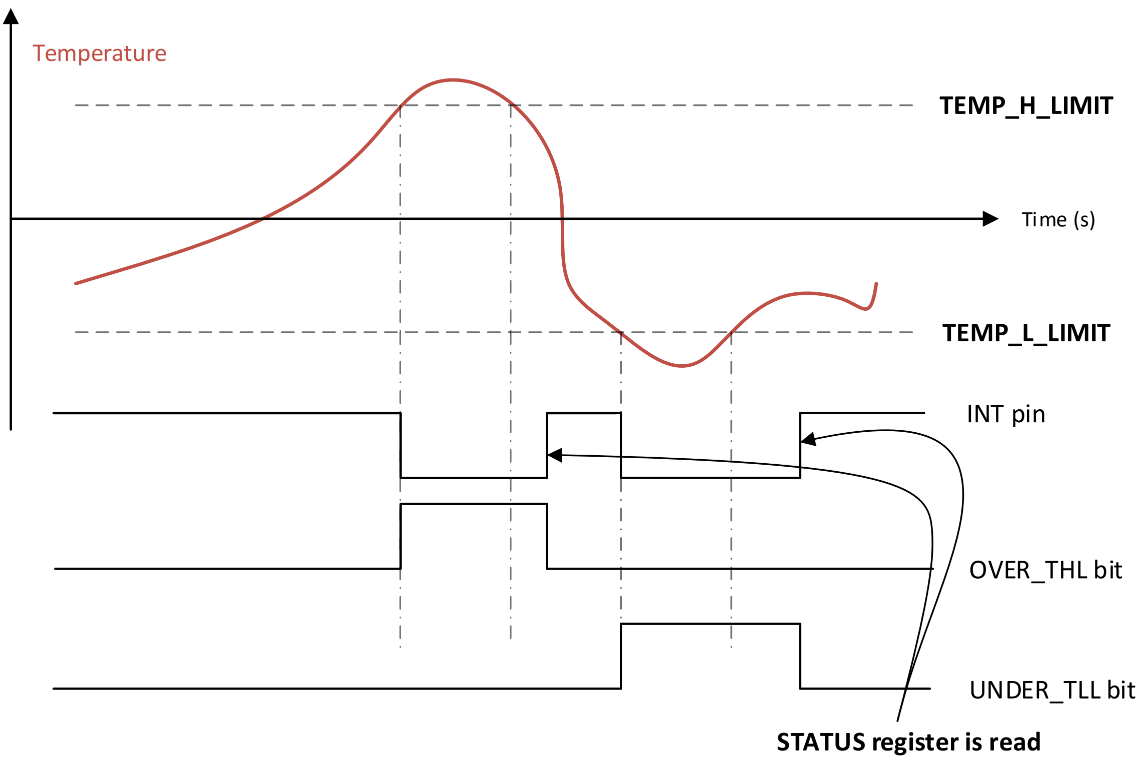


Figure 13: Interrupt output

The interrupt event status can also be monitored through UNDER_TLL and OVER_THL flags in the *STATUS* (0x05) registers. UNDER_TLL and OVER_THL flags are automatically set to '0', once the *STATUS* (0x05) register is read.

9 Register map

Addr.	Register Name	Type	Bits 7	6	5	4	3	2	1	0	Comments
0x01	*DEVICE_ID*	R	1	0	1	0	0	0	0	0	Device ID register
0x02	*T_H_LIMIT*	R/W	THL[7:0]								Temperature limit register
0x03	*T_L_LIMIT*	R/W	TLL[7:0]								
0x04	*CTRL*	R/W	0	BDU	AVG[1:0]		IF_ADD_INC	FREE-RUN	0	ONE_SHOT	Control register
0x05	*STATUS*	R	0	0	0	0	0	UNDER_TLL	OVER_THL	BUSY	Status register
0x06	*DATA_T_L*	R	DATA_T[7:0]								Temperature output registers
0x07	*DATA_T_H*	R	DATA_T[15:8]								
0x0C	*SOFT_RESET*	R/W	0	0	0	0	0	0	SW RESET	0	Software reset register

STOP

Writing to reserved registers may cause permanent damage to the device. Register addresses not listed in the above table, must not be accessed and content must not be modified.

10 Register description

10.1 DEVICE_ID (0x01)

Address: 0x01
Type: R
Default Value: 10100000b (0xA0)

7	6	5	4	3	2	1	0
1	0	1	0	0	0	0	0

Device ID for this sensor is a fixed number (0xA0) which is stored in this register.

10.2 T_H_LIMIT (0x02)

Address: 0x02
Type: R/W
Default Value: 00000000b

7	6	5	4	3	2	1	0
THL[7:0]							

THL[7:0] Unsigned value of high-limit threshold. Refer table 10 for more information.
Threshold Temperature = (T_H_LIMIT - 63) ×0.64 ℃

10.3 T_L_LIMIT (0x03)

Address: 0x03
Type: R/W
Default Value: 00000000b

7	6	5	4	3	2	1	0
TLL[7:0]							

TLL[7:0] Unsigned value of low-limit threshold. Refer table 10 for more information.
Threshold Temperature = (T_L_LIMIT - 63) ×0.64 ℃

10.4 CTRL (0x04)

Address: 0x04
Type: R/W
Default Value: 00000000b

7	6	5	4	3	2	1	0
0	BDU	AVG[1:0]		IF _ADD _INC	FREE-RUN	0	ONE _SHOT

BDU — Block data update feature

0: data register updates continuously; 1: data registers not updated until MSB and LSB has been read.

AVG[1:0] — ODR selection in continuous mode (if FREERUN bit = '1' in *CTRL* register).

AVG[1:0]	Output Data Rate [Hz]
00	25
01	50
10	100
11	200

Table 11: Output data rate selection

Sensor is configured in continuous mode by setting FREERUN bit to '1'.

IF_ADD_INC — Register address is automatically incremented during multiple byte access

0: disabled; 1: enabled

This is a multi-read/write feature that enables a repeated read/write operation during a single bus transaction by automatically incrementing the register address.

FREERUN — Enables continuous mode with a defined ODR

0: Continuous mode disabled; 1: Continuous mode enabled

ONE_SHOT	Enables single data acquisition of temperature. For more information refer to section 6.7. 0: normal operation; 1: a new data set is acquired

BDU: Block data update feature

While reading the output data, this feature can be enabled to inhibit the values of data registers to be updated until all bytes of temperature data registers have been read.

This feature should be enabled when the reading of the data is slower than the output data rate (ODR). By default, the BDU bit is set to '0' and data registers are updated continuously. When BDU feature is enabled, reading of the temperature values sampled at different times can be avoided.

For example, when reading of the register *DATA_T_L* is initialized, the remaining part of the temperature data registers *DATA_T_H* is not updated until both bytes (L and H) have been read.

It is strongly recommended to enable BDU feature. This avoids an update of the DATA_T_x registers until all the parts of the corresponding DATA_T registers have been read.

If BDU feature is enabled, *DATA_T_L* register must be read first.

10.5 STATUS (0x05)

Address: 0x05
Type: R
Default Value: Output

7	6	5	4	3	2	1	0
0	0	0	0	0	UNDER_TLL	OVER_THL	BUSY

UNDER_TLL Temperature lower than low limit

0: Temperature is above the low limit or disabled; 1: Temperature exceeded the low limit

OVER_THL Temperature higher than high limit

0: Temperature is below the high limit or disabled; 1: Temperature exceeded the high limit

Bits UNDER_TLL and OVER_THL are automatically reset to '0' when *STATUS* register is read.

BUSY Temperature data conversion status flag during single conversion mode (bit ONE_SHOT ='1' in *CTRL* register)

0: data conversion is complete. New temperature data is available; 1: Data conversion in progress

This bit is always '0' during continuous mode (bit FREERUN = '1' in *CTRL* register).

10.6 DATA_T_L (0x06)

Address: 0x06
Type: R
Default Value: Output

7	6	5	4	3	2	1	0
DATA_T[7:0]							

DATA_T[7:0] Low part of the temperature data.
Combine this value with *DATA_T_H* register value to form a 16-bit number expressed in a two's complement, that gives the temperature value.

10.7 DATA_T_H (0x07)

Address: 0x07
Type: R
Default Value: Output

7	6	5	4	3	2	1	0
DATA_T[15:8]							

DATA_T[15:8] High part of the temperature data.
Combine this value with *DATA_T_L* register value to form a 16-bit number expressed in a two's complement, that gives the temperature value.

10.8 SOFT_RESET (0x0C)

Address: 0x0C
Type: R/W
Default Value: 0x00

7	6	5	4	3	2	1	0
0	-	0	0	0	0	SW RESET	0

SWRESET Performs software reset
0: Software reset disabled and operating mode enabled; 1: Resets all digital blocks

11 Physical specifications

11.1 Sensor drawing

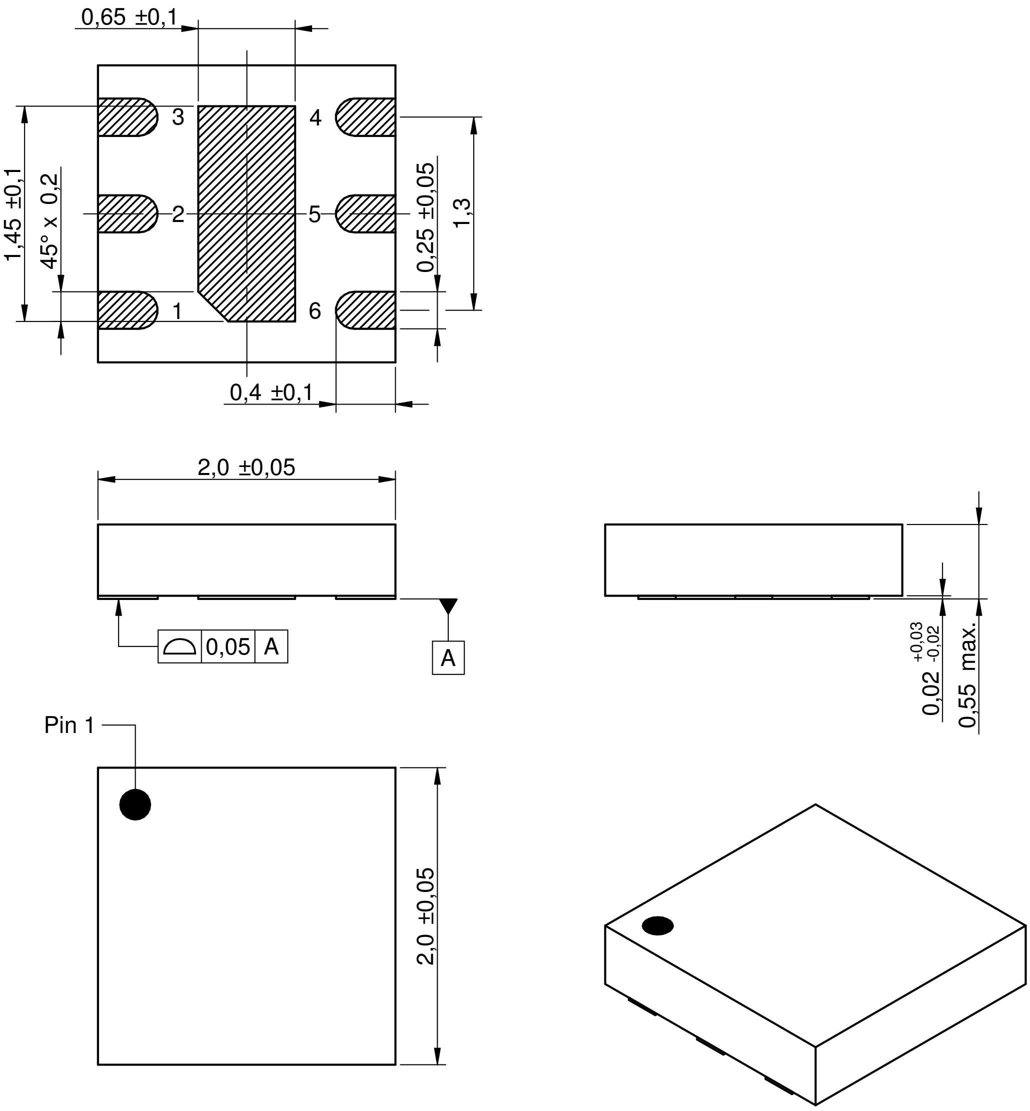


Figure 14: Sensor dimensions [mm]

11.2 Footprint

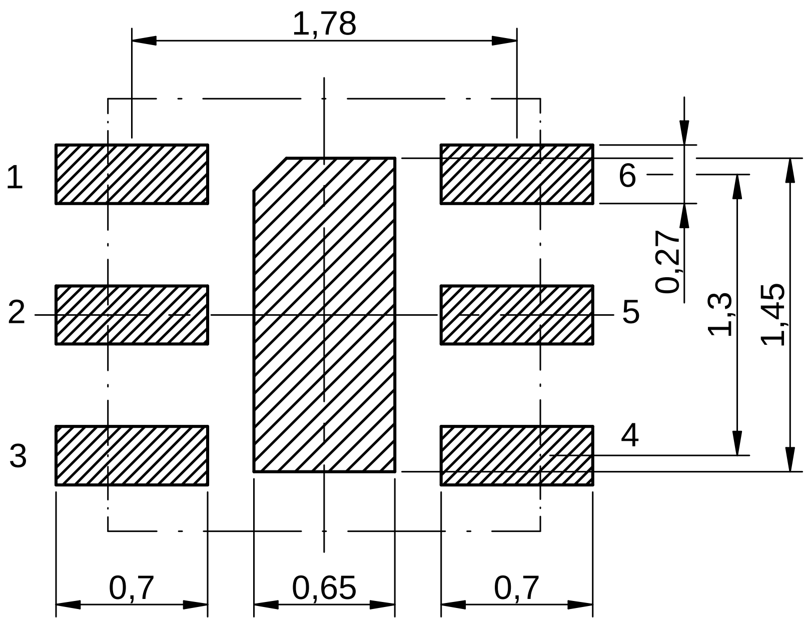


Figure 15: Recommended land pattern [mm] (top view)

12 Manufacturing information

12.1 Moisture sensitivity level

The sensor product is categorized as JEDEC Moisture Sensitivity Level 1 (MSL1), which requires special handling.

More information regarding the MSL requirements can be found in the IPC/JEDEC J-STD-020 standard on *www.jedec.org*. More information about the handling, picking, shipping and the usage of moisture/re-flow and/or process sensitive products can be found in the IPC/JEDEC J-STD-033 standard on *www.jedec.org*.

12.2 Soldering

12.2.1 Reflow soldering

Attention must be paid on the thickness of the solder resist between the host PCB top side and the modules bottom side. Only lead-free assembly is recommended according to JEDEC J-STD020.

Profile feature		Value
Preheat temperature Min	$T_{S\ Min}$	150 °C
Preheat temperature Max	$T_{S\ Max}$	200 °C
Preheat time from $T_{S\ Min}$ to $T_{S\ Max}$	t_S	60 - 120 seconds
Ramp-up rate (T_L to T_P)		3 °C / second max.
Liquidous temperature	T_L	217 °C
Time t_L maintained above T_L	t_L	60 - 150 seconds
Peak package body temperature	T_P	see table below
Time within 5 °C of actual preak temperature	t_P	20 - 30 seconds
Ramp-down Rate (T_P to T_L)*		6 °C / second max.
Time 20 °C to T_P		8 minutes max.

Table 12: Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E

*** In order to reduce residual stress on the sensor component, the recommended ramp-down temperature slope should be lower than 3 °C /s.**

Package thickness	Volume mm³ <350	Volume mm³ 350-2000	Volume mm³ >2000
< 1.6mm	260 ℃	260 ℃	260 ℃
1.6mm - 2.5mm	260 ℃	250 ℃	245 ℃
> 2.5mm	250 ℃	245 ℃	245 ℃

Table 13: Package classification reflow temperature, PB-free assembly, Note: refer to IPC/-JEDEC J-STD-020E

It is recommended to solder the sensor on the last re-flow cycle of the PCB. For solder paste use a LFM-48W or Indium based SAC 305 alloy (Sn 96.5 / Ag 3.0 / Cu 0.5 / Indium 8.9HF / Type 3 / 89%) type 3 or higher.

The reflow profile must be adjusted based on the thermal mass of the entire populated PCB, heat transfer efficiency of the re-flow oven and the specific type of solder paste used. Based on the specific process and PCB layout the optimal soldering profile must be adjusted and verified. Other soldering methods (e.g. vapor phase) have not been verified and have to be validated by the customer at their own risk. Rework is not recommended.

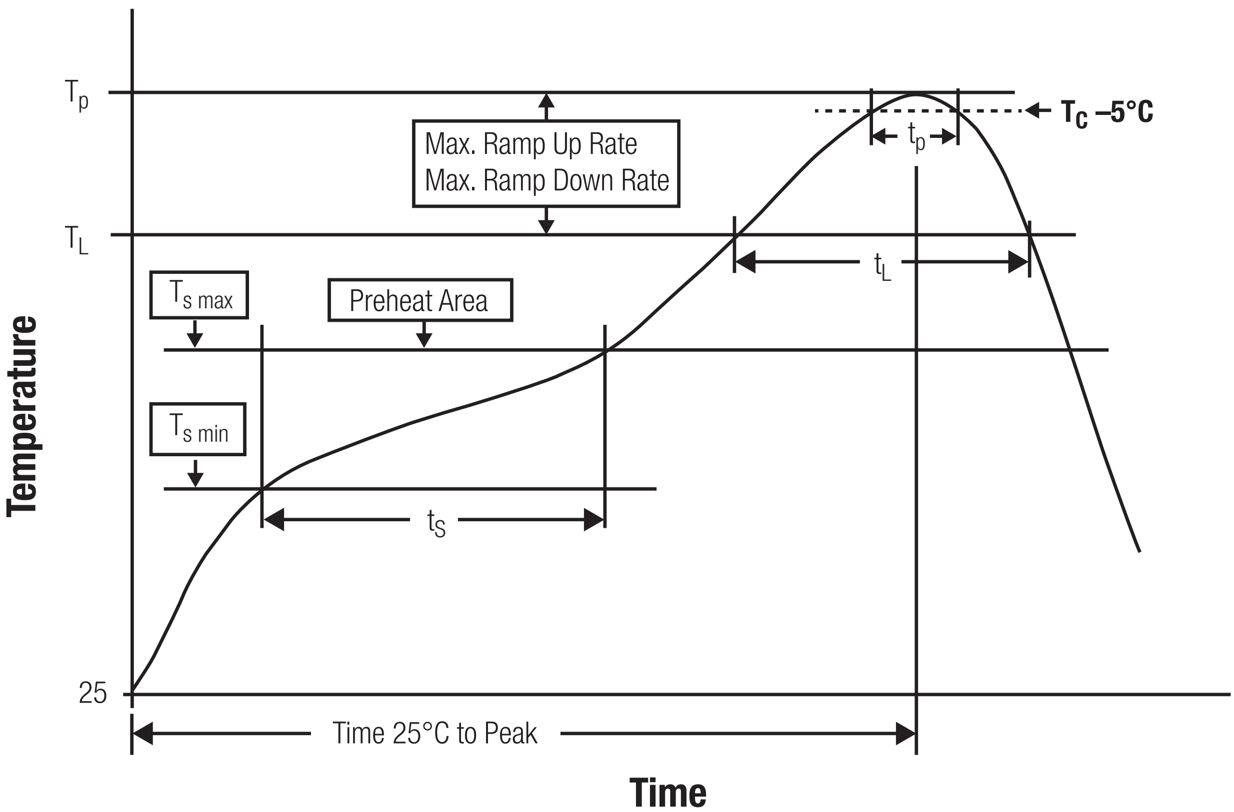


Figure 16: Reflow soldering profile

After reflow soldering, visually inspect the board to confirm proper alignment

12.2.2 Cleaning and washing

Do not clean the product. Any residue cannot be easily removed by washing. Use a "no clean" soldering paste and do not clean the board after soldering.

- Washing agents used during the production to clean the customer application might damage or change the characteristics of the component. Washing agents may have a negative effect on the long-term functionality of the product.
- Using a brush during the cleaning process may damage the component. Therefore, we do not recommend using a brush during the PCB cleaning process

12.2.3 Potting and coating

- Potting material might shrink or expand during and after hardening. This might apply mechanical stress on the components, which can influence the characteristics of the transfer function. In addition, potting material can close existing openings in the housing. This can lead to a malfunction of the component. Thus, potting is not recommended.
- Conformal coating may affect the product performance. We do not recommend coating the components.

12.2.4 Storage conditions

- A storage of Würth Elektronik eiSos products for longer than 12 months is not recommended. Within other effects, the terminals may suffer degradation, resulting in bad solderability. Therefore, all products shall be used within the period of 12 months based on the day of shipment.
- Do not expose the components to direct sunlight.
- The storage conditions in the original packaging are defined according to DIN EN 61760 - 2.
- For a moisture sensitive component, the storage condition in the original packaging is defined according to IPC/JEDEC-J-STD-033. It is also recommended to return the component to the original moisture proof bag and reseal the moisture proof bag again.

12.2.5 Handling

- Violation of the technical product specifications such as exceeding the nominal rated supply voltage, will void the warranty.
- Violation of the technical product specifications such as but not limited to exceeding the absolute maximum ratings will void the conformance to regulatory requirements.
- ESD prevention methods need to be followed for manual handling and processing by machinery.

- The edge castellation is designed and made for prototyping, i.e. hand soldering purposes only.
- The applicable country regulations and specific environmental regulations must be observed.
- Do not disassemble the product. Evidence of tampering will void the warranty.

13 Important notes

The following conditions apply to all goods within the wireless connectivity and sensors product range of Würth Elektronik eiSos GmbH & Co. KG:

General customer responsibility
Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to the customer to evaluate, where appropriate to investigate and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the documentation is current before placing orders.

Customer responsibility related to specific, in particular safety-relevant applications
It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. The same statement is valid for all software source code and firmware parts contained in or used with or for products in the wireless connectivity and sensor product range of Würth Elektronik eiSos GmbH & Co. KG. In certain customer applications requiring a high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health, it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

Best care and attention
Any product-specific data sheets, manuals, application notes, PCNs, warnings and cautions must be strictly observed in the most recent versions and matching to the products revisions. These documents can be downloaded from the product specific sections on the wireless connectivity and sensors homepage.

Customer support for product specifications
Some products within the product range may contain substances, which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case, the Business Development Engineer (BDM) or the internal sales person in charge should be contacted who will be happy to support in this matter.

Product improvements
Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the Business Development Engineer (BDM), the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 13 and 13 remains unaffected.
All software like ¨wireless connectivity SDK¨, ¨Sensor SDK¨ or other source codes as well as all PC software tools are not subject to the Product Change Notification information process.

Product life cycle
Due to technical progress and economical evaluation, we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this, we cannot ensure that all products within our product range will always be available. Therefore, it needs to be verified with the Business Development Engineer (BDM) or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

Property rights
All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

General terms and conditions
Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at *www.we-online.com*.

14 Legal notice

Exclusion of liability
Würth Elektronik eiSos GmbH & Co. KG considers the information in this document to be correct at the time of publication. However, Würth Elektronik eiSos GmbH & Co. KG reserves the right to modify the information such as technical specifications or functions of its products or discontinue the production of these products or the support of one of these products without any written announcement or notification to customers. The customer must make sure that the information used corresponds to the latest published information. Würth Elektronik eiSos GmbH & Co. KG does not assume any liability for the use of its products. Würth Elektronik eiSos GmbH & Co. KG does not grant licenses for its patent rights or for any other of its intellectual property rights or third-party rights.
Notwithstanding anything above, Würth Elektronik eiSos GmbH & Co. KG makes no representations and/or warranties of any kind for the

provided information related to their accuracy, correctness, completeness, usage of the products and/or usability for customer applications. Information published by Würth Elektronik eiSos GmbH & Co. KG regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof.

Suitability in customer applications
The customer bears the responsibility for compliance of systems or units, in which Würth Elektronik eiSos GmbH & Co. KG products are integrated, with applicable legal regulations. Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Würth Elektronik eiSos GmbH & Co. KG components in its applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos GmbH & Co. KG. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences lessen the likelihood of failures that might cause harm and take appropriate remedial actions. The customer will fully indemnify Würth Elektronik eiSos GmbH & Co. KG and its representatives against any damages arising out of the use of any Würth Elektronik eiSos GmbH & Co. KG components in safety-critical applications.

Trademarks
AMBER wireless is a registered trademark of Würth Elektronik eiSos GmbH & Co. KG. All other trademarks, registered trademarks, and product names are the exclusive property of the respective owners.

Usage restriction
Würth Elektronik eiSos GmbH & Co. KG products have been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover, Würth Elektronik eiSos GmbH & Co. KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. Würth Elektronik eiSos GmbH & Co. KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component, which is used in electrical circuits that require high safety and reliability function or performance. By using Würth Elektronik eiSos GmbH & Co. KG products, the customer agrees to these terms and conditions.

15 License terms for Würth Elektronik eiSos GmbH & Co. KG sensor product software and source code

These license terms will take effect upon the purchase and usage of the Würth Elektronik eiSos GmbH & Co. KG sensor products. You hereby agree that these license terms are applicable to the product and the incorporated software, firmware and source codes (collectively, "Software") made available by Würth Elektronik eiSos in any form, including but not limited to binary, executable or source code form.
The software included in any Würth Elektronik eiSos sensor product is purchased to you on the condition that you accept the terms and conditions of these license terms. You agree to comply with all provisions under these license terms.

Limited license
Würth Elektronik eiSos hereby grants you a limited, non-exclusive, non-transferable and royalty-free license to use the software and under the conditions that will be set forth in these license terms. You are free to use the provided software only in connection with one of the products from Würth Elektronik eiSos to the extent described in these license terms.
You are entitled to change or alter the source code for the sole purpose of creating an application embedding the Würth Elektronik eiSos sensor product. The transfer of the source code to third parties is allowed to the sole extent that the source code is used by such third parties in connection with our product or another hardware provided by Würth Elektronik eiSos under strict adherence of these license terms. Würth Elektronik eiSos will not assume any liability for the usage of the incorporated software and the source code.
You are not entitled to transfer the source code in any form to third parties without prior written consent of Würth Elektronik eiSos.
You are not allowed to reproduce, translate, reverse engineer, decompile, disassemble or create derivative works of the incorporated software and the source code in whole or in part.
No more extensive rights to use and exploit the products are granted to you.

Usage and obligations
The responsibility for the applicability and use of the Würth Elektronik eiSos sensor product with the incorporated software in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to you to evaluate and investigate, where appropriate, and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for your respective application or not.
You are responsible for using the Würth Elektronik eiSos sensor product with the incorporated software in compliance with all applicable product liability and product safety laws. You acknowledge to minimize the risk of loss and harm to individuals and bear the risk for failure leading to personal injury or death due to your usage of the product.
Würth Elektronik eiSos' products are not authorized for use in safety-critical applications, or where a failure of the product is reasonably expected to cause severe personal injury or death. Moreover, Würth Elektronik eiSos' products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. You shall inform Würth Elektronik eiSos about the intent of such usage before design-in stage. In certain customer applications requiring a very high level of safety and in which the malfunction or failure of an electronic component could endanger human life or health, you must ensure to have all necessary expertise in the safety and regulatory ramifications of your applications. You acknowledge and agree that you are solely responsible for all legal, regulatory and safety-related requirements concerning your products and any use of Würth Elektronik eiSos' products in such safety-critical applications, notwithstanding any applications-related

information or support that may be provided by Würth Elektronik eiSos. YOU SHALL INDEMNIFY WÜRTH ELEKTRONIK EISOS AGAINST ANY DAMAGES ARISING OUT OF THE USE OF WÜRTH ELEKTRONIK EISOS' PRODUCTS IN SUCH SAFETY-CRITICAL APPLICATIONS.

Ownership
The incorporated software created by Würth Elektronik eiSos is and will remain the exclusive property of Würth Elektronik eiSos.

Disclaimer of warranty
THE SOFTWARE AND IT'S SOURCE CODE IS PROVIDED "AS IS". YOU ACKNOWLEDGE THAT WÜRTH ELEKTRONIK EISOS MAKES NO REPRESENTATIONS AND WARRANTIES OF ANY KIND RELATED TO, BUT NOT LIMITED TO THE NON-INFRINGEMENT OF THIRD PARTIES' INTELLECTUAL PROPERTY RIGHTS OR THE MERCHANTABILITY OR FITNESS FOR YOUR INTENDED PURPOSE OR USAGE. WÜRTH ELEKTRONIK EISOS DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH THE WÜRTH ELEKTRONIK EISOS' PRODUCT WITH THE INCORPORATED SOFTWARE IS USED. INFORMATION PUBLISHED BY WÜRTH ELEKTRONIK EISOS REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WÜRTH ELEKTRONIK EISOS TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

Limitation of liability
Any liability not expressly provided by Würth Elektronik eiSos shall be disclaimed.
You agree to hold us harmless from any third-party claims related to your usage of the Würth Elektronik eiSos' products with the incorporated software and source code. Würth Elektronik eiSos disclaims any liability for any alteration, development created by you or your customers as well as for any combination with other products.

Applicable law and jurisdiction
Applicable law to these license terms shall be the laws of the Federal Republic of Germany. Any dispute, claim or controversy arising out of or relating to these license terms shall be resolved and finally settled by the court competent for the location of Würth Elektronik eiSos registered office.

Severability clause
If a provision of these license terms is or becomes invalid, unenforceable or null and void, this shall not affect the remaining provisions of the terms. The parties shall replace any such provisions with new valid provisions that most closely approximate the purpose of the terms.

Miscellaneous
Würth Elektronik eiSos reserves the right at any time to change this terms at its own discretion. It is your responsibility to check at Würth Elektronik eiSos homepage for any updates. Your continued usage of the products will be deemed as the acceptance of the change.
We recommend you to be updated about the status of new software, which is available on our website or in our data sheet, and to implement new software in your device where appropriate.
By ordering a product, you accept these license terms in all terms.

List of Figures

List of Tables

Contact
Würth Elektronik eiSos GmbH & Co. KG
Division Wireless Connectivity & Sensors

Max-Eyth-Straße 1
74638 Waldenburg
Germany

Tel.: +49 651 99355-0
Fax.: +49 651 99355-69
www.we-online.com/wireless-connectivity