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# TEMPERATURE SENSOR IC

## WSEN-TIDS

### USER MANUAL

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2521020222501

VERSION 1.1

FEBRUARY 4, 2021

## Revision history

Manual version	Notes	Date
1.0	<ul style="list-style-type: none"><li>Initial release of the manual</li></ul>	December 2019
1.1	<ul style="list-style-type: none"><li>updated register type in section 10.2 &amp; 10.3</li></ul>	February 2021

## Abbreviations

Abbreviation	Description
ASIC	Application Specific Integrated Circuit
BDU	Block Data Update
ESD	Electrostatic Discharge
HBM	Human Body Model
I <sup>2</sup> C	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

<b>1 Introduction</b>	<b>5</b>
1.1 Applications . . . . .	5
1.2 Key features . . . . .	5
1.3 Ordering information . . . . .	5
<b>2 Sensor specifications</b>	<b>6</b>
2.1 General information . . . . .	6
2.2 Absolute maximum ratings . . . . .	6
2.3 Temperature sensor specification . . . . .	7
2.4 Electrical specifications . . . . .	7
<b>3 Pinning information</b>	<b>8</b>
3.1 Pin configuration . . . . .	8
3.2 Pin description . . . . .	8
<b>4 Digital interface</b>	<b>9</b>
4.1 General characteristics . . . . .	9
4.2 SDA and SCL logic levels . . . . .	10
4.3 Communication phase . . . . .	10
4.3.1 Idle state . . . . .	10
4.3.2 START(S) and STOP(P) condition . . . . .	10
4.3.3 Data validity . . . . .	11
4.3.4 Byte format . . . . .	11
4.3.5 Acknowledge(ACK) and No-Acknowledge(NACK) . . . . .	11
4.3.6 Slave address for the sensor . . . . .	12
4.3.7 Read/Write operation . . . . .	13
4.4 I <sup>2</sup> C timing parameters . . . . .	15
<b>5 Application circuit</b>	<b>16</b>
<b>6 Quick start guide</b>	<b>17</b>
6.1 Power-up sequence . . . . .	17
6.2 Communication with host controller . . . . .	17
6.3 Sensor operation: single conversion mode . . . . .	18
6.4 Sensor operation: continuous mode . . . . .	19
6.5 Modes of operation . . . . .	20
6.6 Power-down mode . . . . .	20
6.7 Single conversion mode . . . . .	21
6.8 Continuous mode . . . . .	22
<b>7 Reading temperature data</b>	<b>23</b>
<b>8 Interrupt functionality</b>	<b>25</b>
8.1 Interrupt output . . . . .	26
<b>9 Register map</b>	<b>27</b>

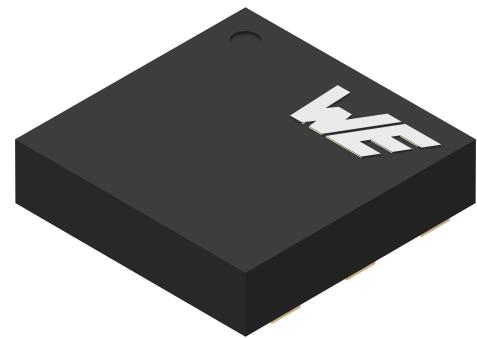
<b>10 Register description</b>	<b>28</b>
10.1 DEVICE_ID (0x01) . . . . .	28
10.2 T_H_LIMIT (0x02) . . . . .	28
10.3 T_L_LIMIT (0x03) . . . . .	28
10.4 CTRL (0x04) . . . . .	29
10.5 STATUS (0x05) . . . . .	31
10.6 DATA_T_L (0x06) . . . . .	32
10.7 DATA_T_H (0x07) . . . . .	32
10.8 SOFT_RESET (0x0C) . . . . .	32
<b>11 Physical dimensions</b>	<b>33</b>
11.1 Sensor drawing . . . . .	33
11.2 Footprint . . . . .	34
<b>12 Manufacturing information</b>	<b>35</b>
12.1 Moisture sensitivity level . . . . .	35
12.2 Soldering . . . . .	35
12.2.1 Reflow soldering . . . . .	35
12.2.2 Cleaning and washing . . . . .	37
12.2.3 Potting and coating . . . . .	37
12.2.4 Storage conditions . . . . .	37
12.2.5 Handling . . . . .	37
<b>13 Important notes</b>	<b>39</b>
13.1 General customer responsibility . . . . .	39
13.2 Customer responsibility related to specific, in particular safety-relevant applications . . . . .	39
13.3 Best care and attention . . . . .	39
13.4 Customer support for product specifications . . . . .	39
13.5 Product improvements . . . . .	40
13.6 Product life cycle . . . . .	40
13.7 Property rights . . . . .	40
13.8 General terms and conditions . . . . .	40
<b>14 Legal notice</b>	<b>41</b>
14.1 Exclusion of liability . . . . .	41
14.2 Suitability in customer applications . . . . .	41
14.3 Usage restriction . . . . .	41
<b>15 License terms for Würth Elektronik eiSos GmbH &amp; Co. KG sensor product software and source code</b>	<b>43</b>
15.1 Limited license . . . . .	43
15.2 Usage and obligations . . . . .	43
15.3 Ownership . . . . .	44
15.4 Disclaimer of warranty . . . . .	44
15.5 Limitation of liability . . . . .	44
15.6 Applicable law and jurisdiction . . . . .	44
15.7 Severability clause . . . . .	45
15.8 Miscellaneous . . . . .	45

# 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<sup>2</sup>C 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 °C
- 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<sup>2</sup>C
- Interrupt pin functionality: programmable temperature threshold

## 1.3 Ordering information

WE order code	Temperature range	Dimensions	Description
2521020222501	-40 °C to +125 °C	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°C up to 125°C
Storage conditions	<40°C; <75% RH
Communication interface	I <sup>2</sup> C
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 $V_{DD}$ 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:  
 $T=25\text{ }^{\circ}\text{C}$ ,  $V_{DD}=3.3\text{ V}$ .

Parameter	Symbol	Test conditions	Value			Unit
			Min	Typ	Max	
Measurement range	$T_{RANGE}$		-40		125	$^{\circ}\text{C}$
Absolute accuracy	$T_{ACC\_ABS}$	$T = -10 \text{ to } 60\text{ }^{\circ}\text{C}$	-0.5	$\pm 0.25$	0.5	$^{\circ}\text{C}$
Total accuracy	$T_{ACC\_TOT}$	$T = -40 \text{ to } 125\text{ }^{\circ}\text{C}$	-1.0	$\pm 0.7$	1.0	$^{\circ}\text{C}$
Resolution	$RES_T$			16		bit
Sensitivity	$SEN_T$			0.01		$^{\circ}\text{C}/\text{digit}$
Output data rate	ODR	Continuous mode	25		200	Hz
Noise (RMS) <sup>1</sup>	$T_{NOISE}$	ODR= 25 Hz		0.025		$^{\circ}\text{C RMS}$
		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:  
 $T=25\text{ }^{\circ}\text{C}$ ,  $V_{DD}=3.3\text{V}$ .

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		$\mu\text{A}$
Current consumption in single conversion mode <sup>2</sup>	$I_{DD\_SC}$			1.75		$\mu\text{A}$
Peak current consumption	$I_{DD\_PEAK}$	During measurement		120	180	$\mu\text{A}$

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

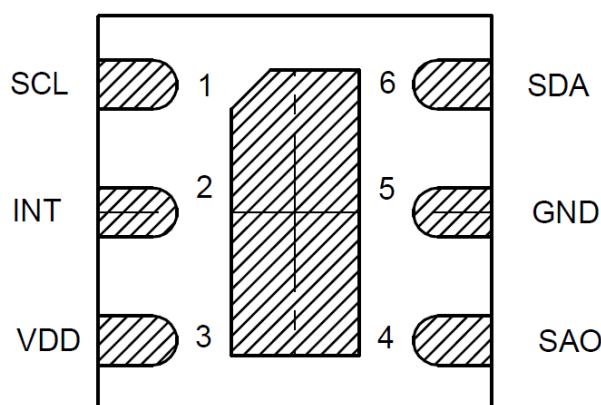


Figure 1: Pin specifications (top view)

#### 3.2 Pin description

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

Table 6: Pin description

## 4 Digital interface

The sensor supports standard I<sup>2</sup>C (Inter-IC) bus protocol. Further information about the I<sup>2</sup>C interface can be found at <https://www.nxp.com/docs/en/user-guide/UM10204.pdf>. I<sup>2</sup>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<sup>2</sup>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<sup>2</sup>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<sup>2</sup>C bus.

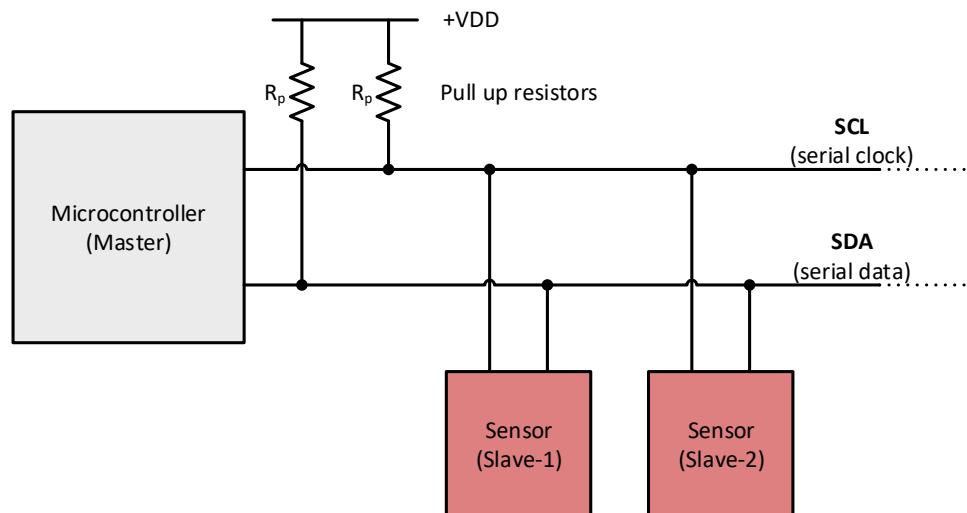


Figure 2: Master-slave concept

## 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  $V_{DD}$ . Input reference levels for this sensor are set as  $0.8 * V_{DD}$  (for logic high) and  $0.2 * V_{DD}$  (for logic low). Explained in the figure 3.

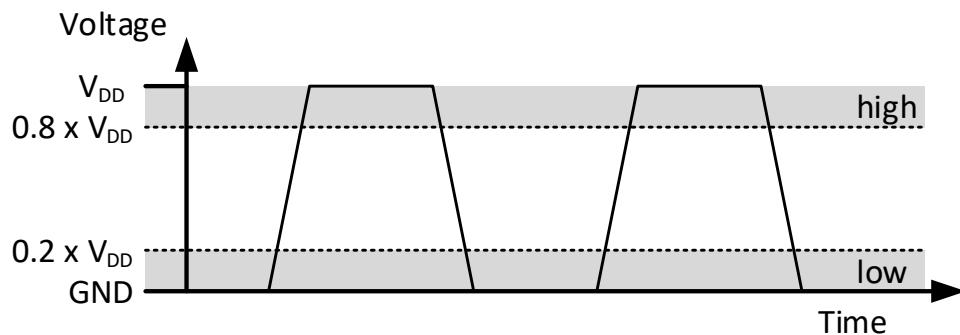


Figure 3: *SDA* and *SCL* logic levels

## 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<sup>2</sup>C 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.

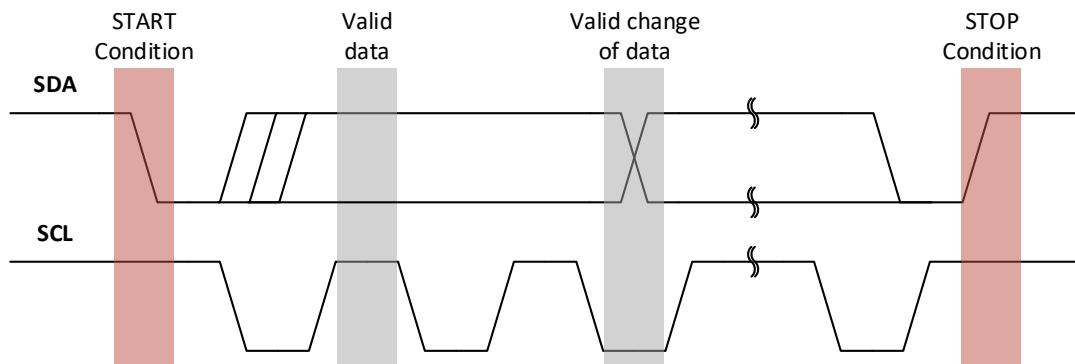


Figure 4: Data validity, START and STOP condition

### 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<sup>2</sup>C 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).

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

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.

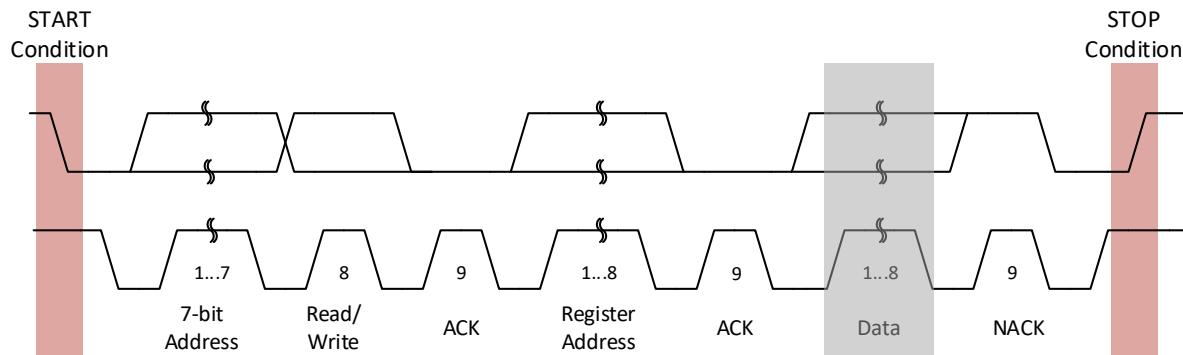


Figure 5: Complete data transfer

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).

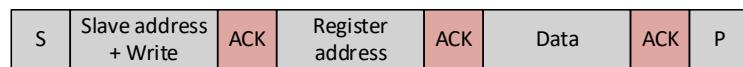
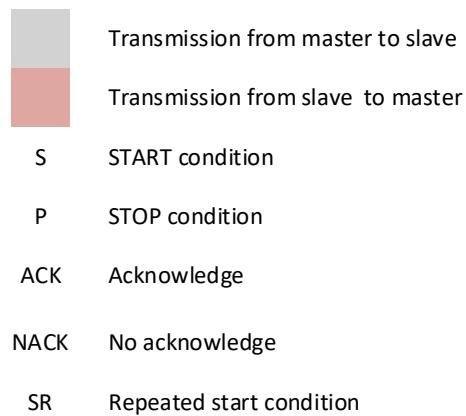
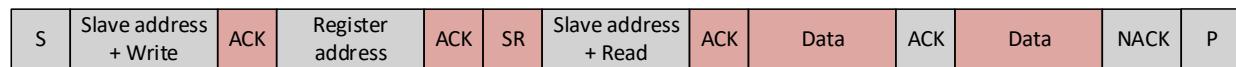
**a) I<sup>2</sup>C write: Master writing data to slave****b) I<sup>2</sup>C read: Master reading multiple data bytes from slave**

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 I<sup>2</sup>C timing parameters

Parameter	Symbol	$V_{DD} < 3 \text{ V}^1$		$V_{DD} > 3 \text{ V}^1$		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		$\mu\text{s}$
HIGH period for SCL clock	$t_{HIGH\_SCL}$	0.6		0.16		$\mu\text{s}$
Hold time for START condition	$t_{HD\_S}$	0.6		0.26		$\mu\text{s}$
Setup time for (repeated) START condition	$f_{SCL}$	0.6		0.26		$\mu\text{s}$
SDA setup time	$t_{SU\_SDA}$	100		0.5		$\mu\text{s}$
SDA data hold time	$t_{HD\_SDA}$	0		0		$\mu\text{s}$
Setup time for STOP condition	$t_{SU\_P}$	0.6		0.26		$\mu\text{s}$
Bus free time between STOP and START condition	$t_{BUF}$	1.3		0.5		$\mu\text{s}$

Table 8: I<sup>2</sup>C timing parameters

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

## 5 Application circuit

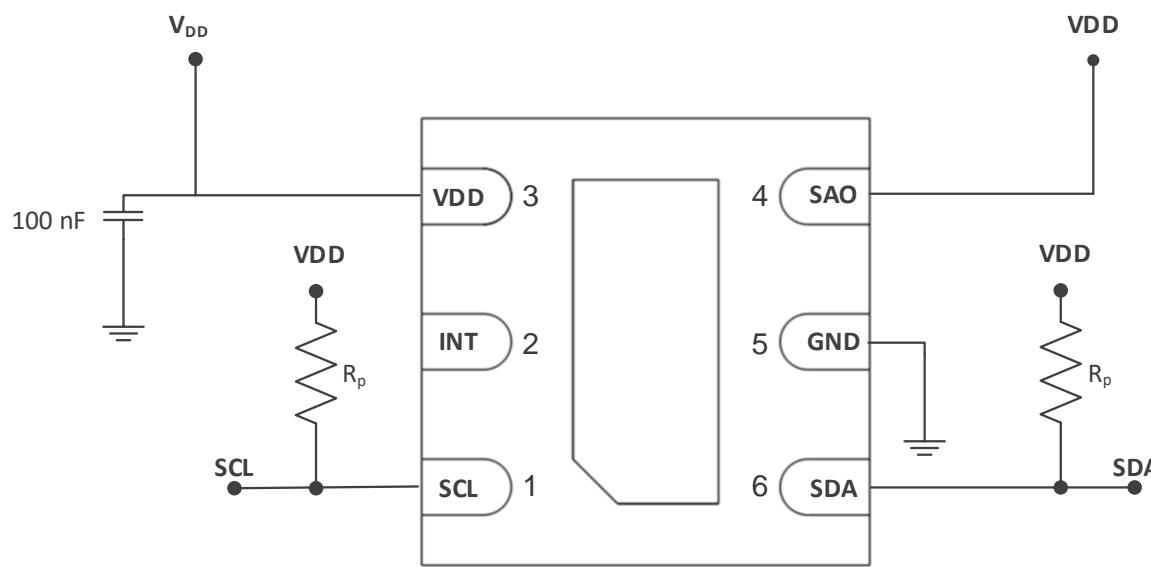


Figure 7: Application circuit with I<sup>2</sup>C interface (sensor bottom view)

*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  $\mu$ F) could be placed parallel to the 100 nF capacitor.

Figure 7 shows a typical application circuit for I<sup>2</sup>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<sup>2</sup>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 I<sup>2</sup>C 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 I<sup>2</sup>C interface can be checked by reading the *DEVICE\_ID* register (0x01). Device ID for this sensor is 0xA0.

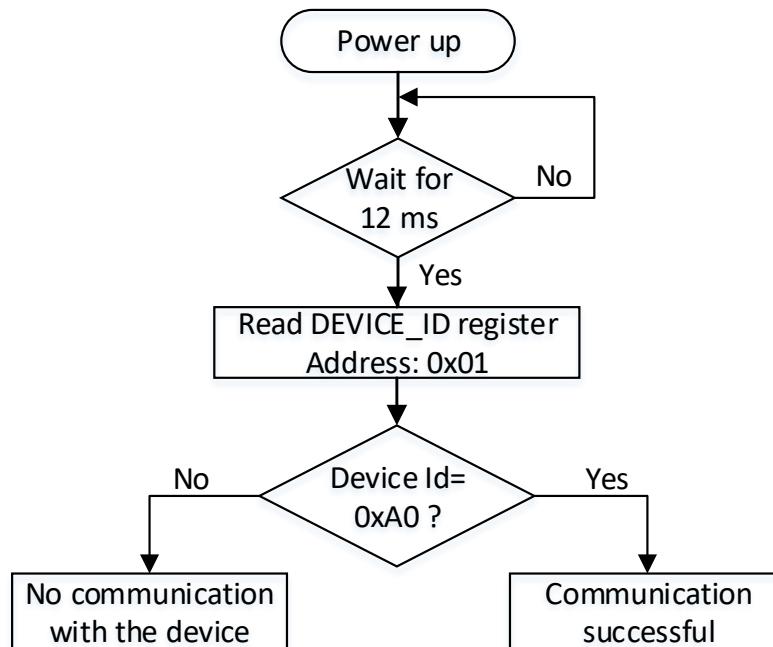


Figure 8: Communication check between host controller and the sensor

## 6.3 Sensor operation: single conversion mode

Flow chart shows sensor operation in the single conversion mode.

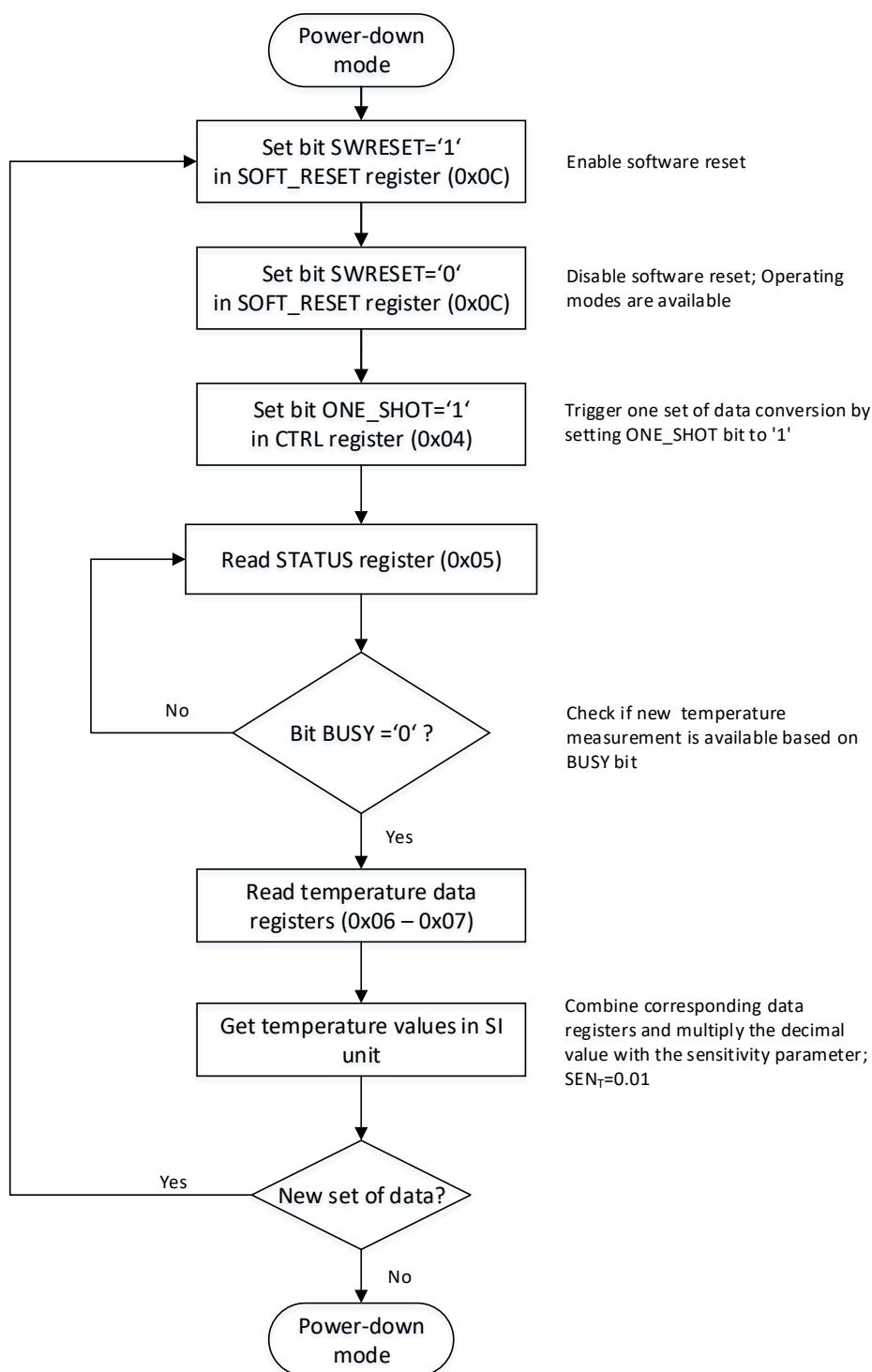


Figure 9: Sensor operation: single-conversion mode

## 6.4 Sensor operation: continuous mode

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

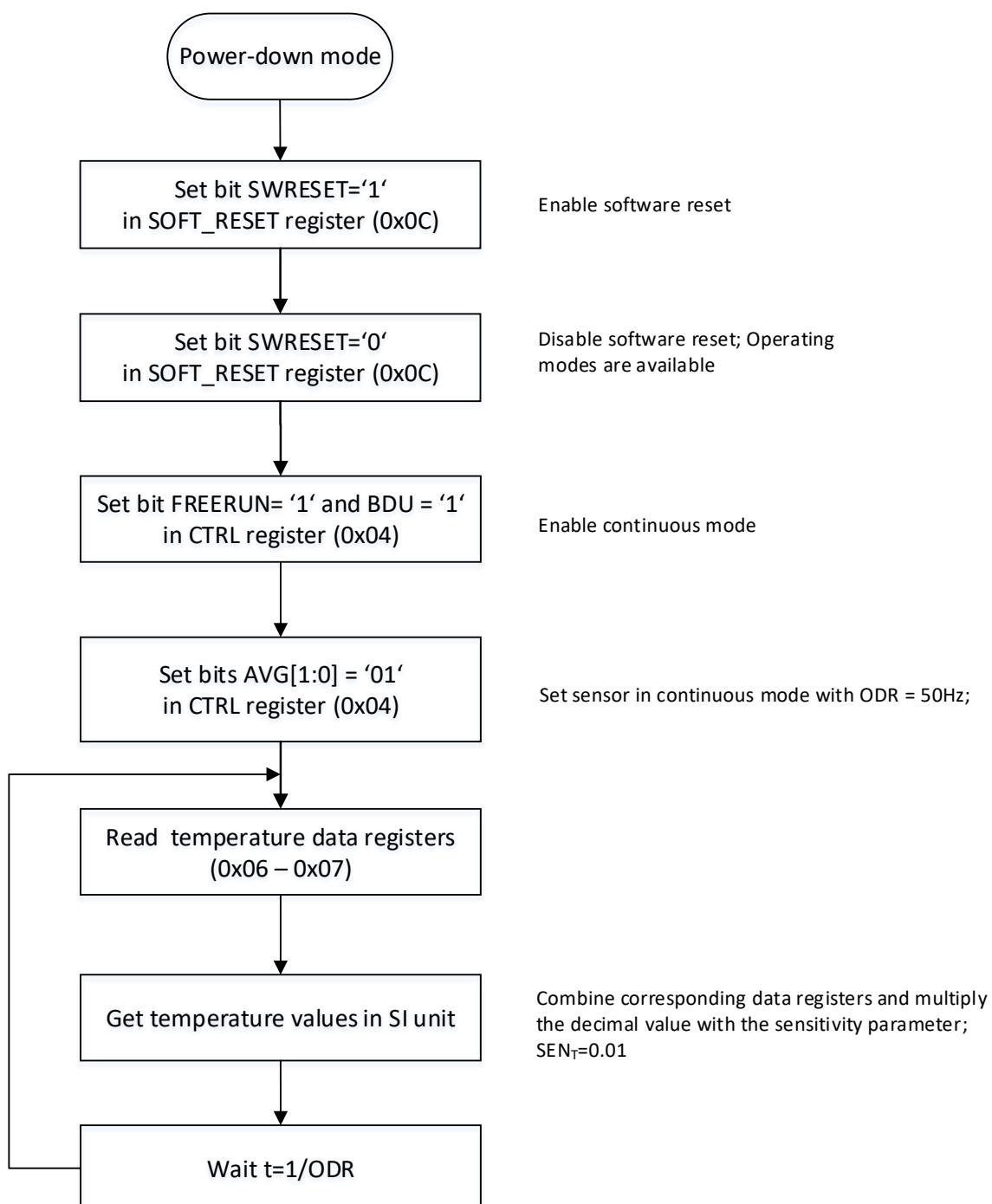


Figure 10: Sensor operation: continuous mode

## 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 I<sup>2</sup>C 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

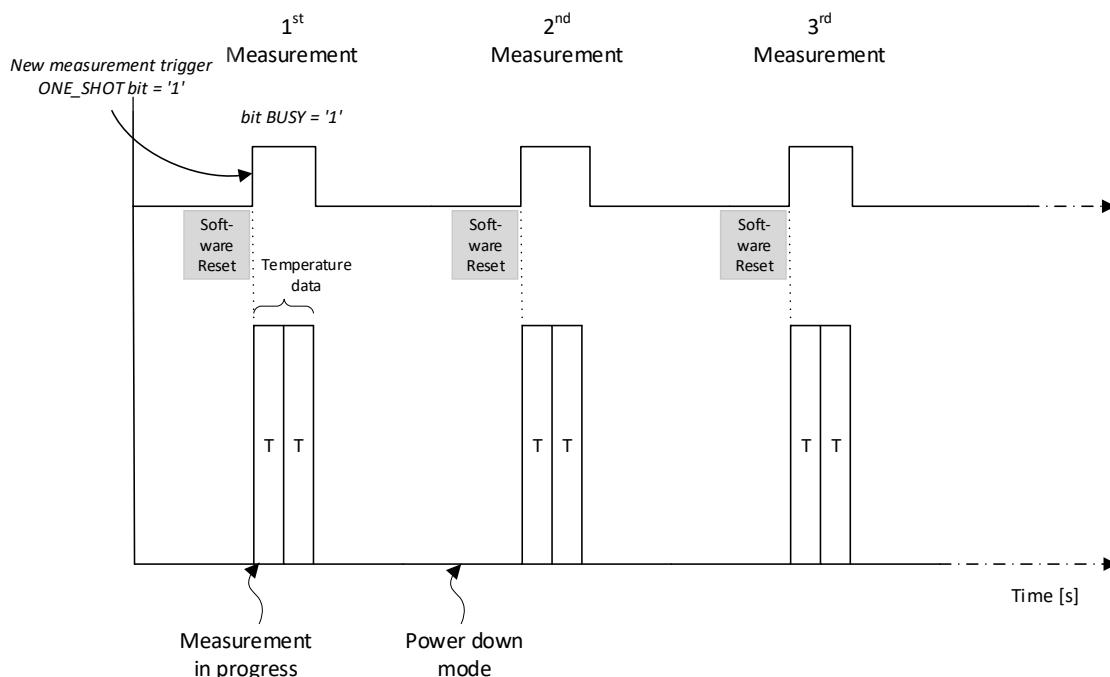


Figure 11: Application circuit with I<sup>2</sup>C interface (sensor bottom view)

## 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 2'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 ( $^{\circ}\text{C}$ ).

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

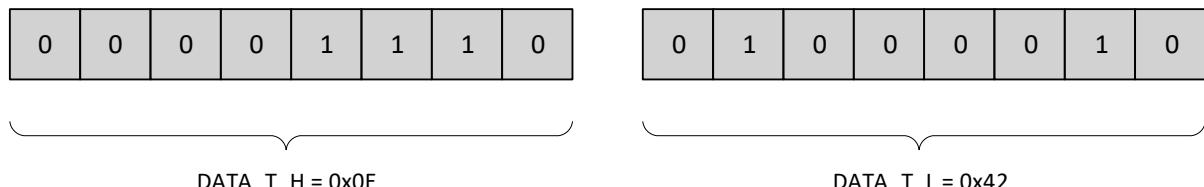
1. *DATA\_T\_L* (0x06)
2. *DATA\_T\_H* (0x07)

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

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

Step 3: Obtaining temperature value in SI unit [ $^{\circ}\text{C}$ ] by multiplying with sensitivity parameter

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



$$T = 3650 * 0.01 = 36.50 {}^{\circ}\text{C}$$

Figure 12: Reading temperature data

**Example:**

If values obtained from temperature data registers are:

$$\text{DATA\_T\_L} = 0x42$$

$$\text{DATA\_T\_H} = 0x0E$$

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

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

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

## 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.

$$\text{Threshold Temperature } (\text{ }^{\circ}\text{C}) = (\text{TEMP}_x\text{LIMIT} - 63) \times 0.64$$

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 ( <i>TEMP_H_LIMIT</i> / <i>TEMP_L_LIMIT</i> )	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.

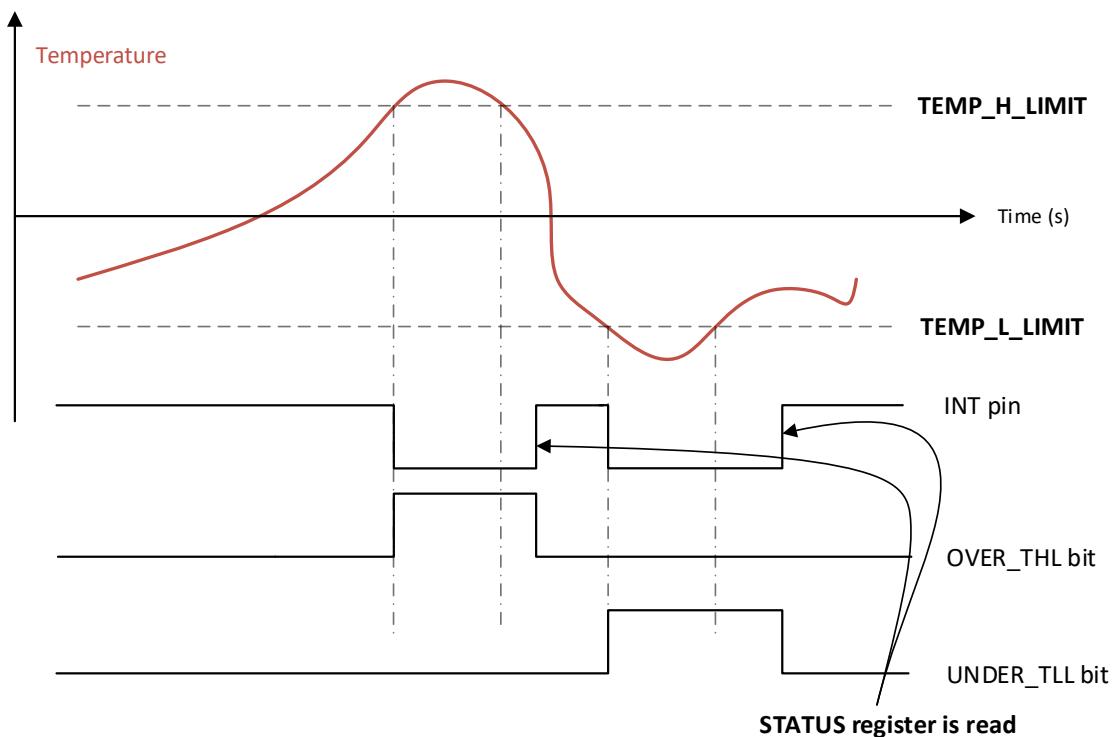


Figure 13: Interrupt output

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								Comments
			7	6	5	4	3	2	1	0	
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



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.  
 $\text{Threshold Temperature} = (\text{T\_H\_LIMIT} - 63) \times 0.64 \text{ } ^\circ\text{C}$

### 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.  
 $\text{Threshold Temperature} = (\text{T\_L\_LIMIT} - 63) \times 0.64 \text{ } ^\circ\text{C}$

## 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 dimensions

## 11.1 Sensor drawing

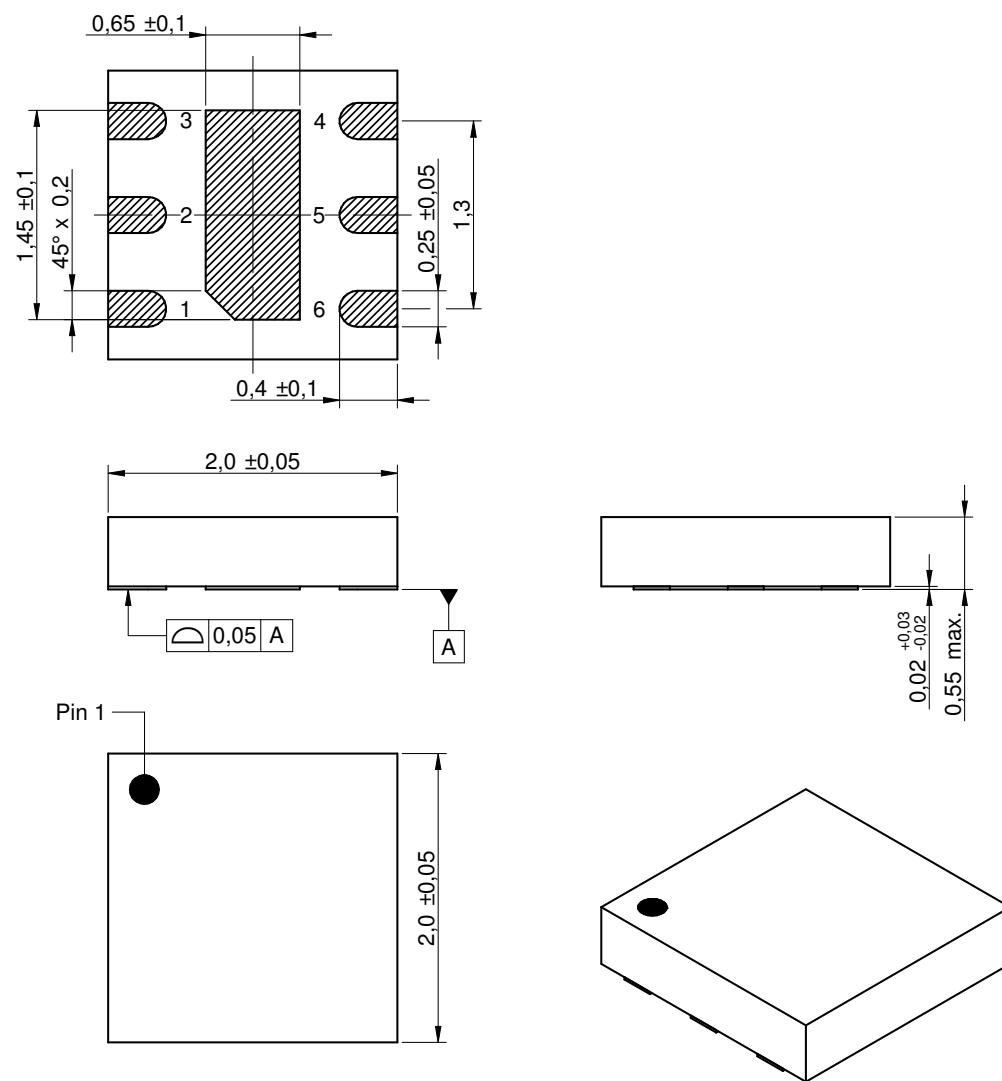


Figure 14: Sensor dimensions [mm]

## 11.2 Footprint

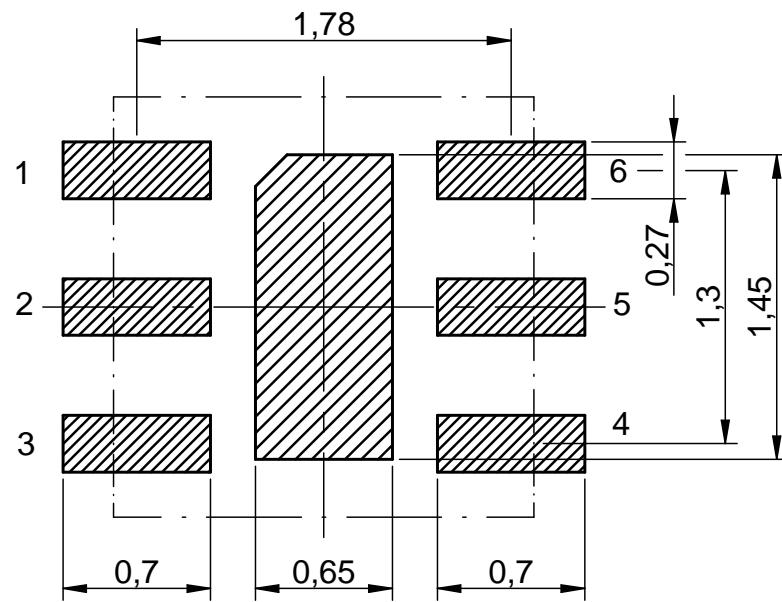


Figure 15: Recommended land pattern [mm] (top view)

## 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](http://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](http://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	$T_S \text{ Min}$	150 °C
Preheat temperature Max	$T_S \text{ Max}$	200 °C
Preheat time from $T_S \text{ Min}$ to $T_S \text{ Max}$	$t_S$	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 mm <sup>3</sup> <350	Volume mm <sup>3</sup> 350-2000	Volume mm <sup>3</sup> >2000
< 1.6mm	260 °C	260 °C	260 °C
1.6mm - 2.5mm	260 °C	250 °C	245 °C
> 2.5mm	250 °C	245 °C	245 °C

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.

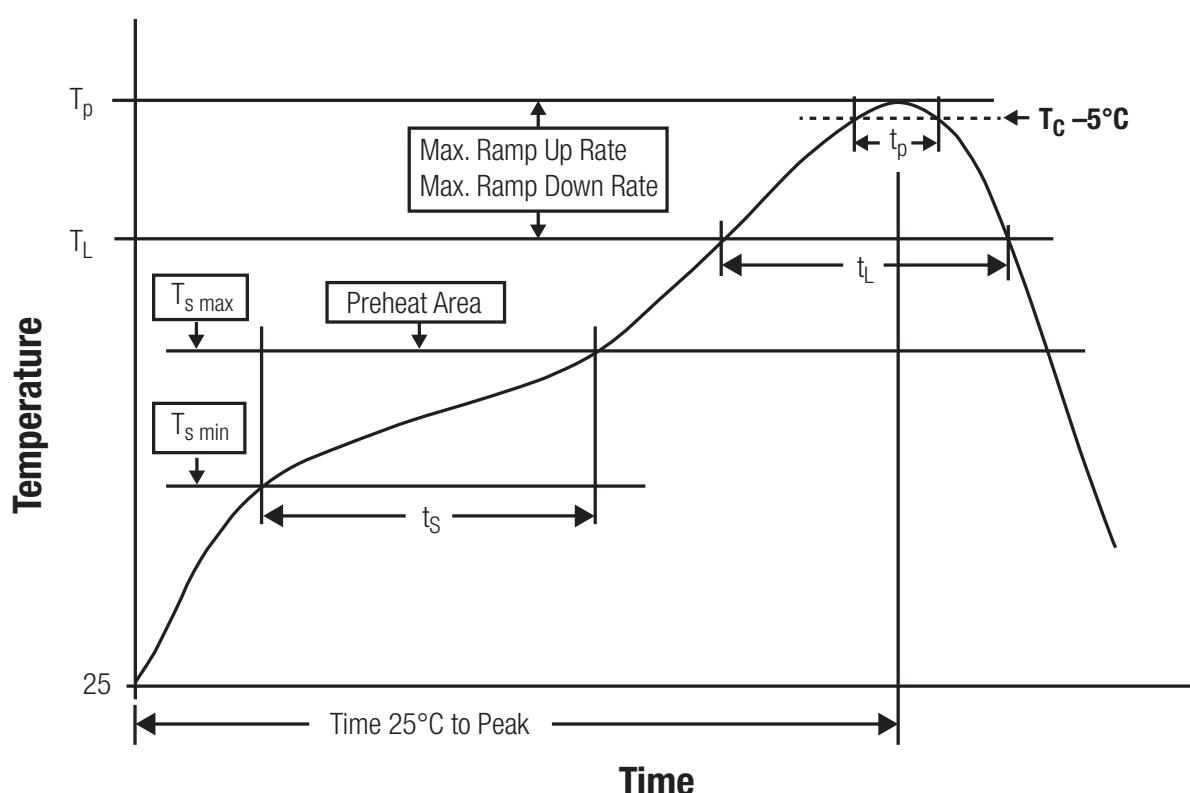


Figure 16: Reflow soldering profile

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.

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## List of Figures

1	Pin specifications (top view) . . . . .	8
2	Master-slave concept . . . . .	9
3	SDA and <i>SCL</i> logic levels . . . . .	10
4	Data validity, START and STOP condition . . . . .	11
5	Complete data transfer . . . . .	13
6	Write and read operations with the device . . . . .	14
7	Application circuit with $I^2C$ interface (sensor bottom view) . . . . .	16
8	Communication check between host controller and the sensor . . . . .	17
9	Sensor operation: single-conversion mode . . . . .	18
10	Sensor operation: continuous mode . . . . .	19
11	Application circuit with $I^2C$ interface (sensor bottom view) . . . . .	21
12	Reading temperature data . . . . .	23
13	Interrupt output . . . . .	26
14	Sensor dimensions [mm] . . . . .	33
15	Recommended land pattern [mm] (top view) . . . . .	34
16	Reflow soldering profile . . . . .	36

## List of Tables

1	Ordering information . . . . .	5
2	General information . . . . .	6
3	Absolute maximum ratings . . . . .	6
4	Temperature sensor specifications . . . . .	7
5	Electrical specifications . . . . .	7
6	Pin description . . . . .	8
7	Slave address and Read/Write commands . . . . .	12
8	$I^2C$ timing parameters . . . . .	15
9	Output data rate selection . . . . .	22
10	Temperature threshold . . . . .	25
11	Output data rate selection . . . . .	29
12	Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E . . . . .	35
13	Package classification reflow temperature, PB-free assembly, Note: refer to IPC/JEDEC J-STD-020E . . . . .	36



# more than you expect



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## 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](http://www.we-online.com/wireless-connectivity)

