XENSIV™ Integrated Thermal Conductivity Gas Sensor ASIL B

AEC Qualified

RoHS

ISO 26262 compliant

Features

- Thermal conductivity sensing principle
- Insensitive to sensor poisoning
- Low lifetime offset drift of maximal ±0.1 vol%H2
- Fully factory calibrated sensor, no need for further recalibration in the field
- Firmware compensates temperature, humidity- and pressure-effects
- Hydrogen measurement range 0 to 16 vol%
- Fast response time < 100ms
- Measurement accuracy up to ±0.12 vol%H2
- Ultra-low power consumption: typ. 112 µA @1 meas./sec
- 1 Mbit/s I2C interface and 3.3 V supply voltage
- Autonomous operating mode for system level power saving
- ISO 26262 safety element out of context for safety requirements up to ASIL B
- 15 Years lifetime

Potential applications

- Automotive fuel cell hydrogen leakage measurement
- Automotive battery monitoring systems (thermal runaway detection)
- General industrial hydrogen leakage measurement

Product validation

- Qualified for automotive applications according to AEC-Q100, grade 2
- Qualified for industrial applications according to the relevant tests of JEDEC JESD47L, JESD22, and J-STD-020

Description

The product is designed for measuring the thermal conductivity of gases, e.g. hydrogen in air. It comprises a resistive full sensor bridge and an ASIC which provides a calibrated and temperature compensated digital output signal.

Product name	Package	Marking	Ordering code
TCI-B	PG-DSOSP-14-84	TCIB	SP006101806

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1 Functional block diagram

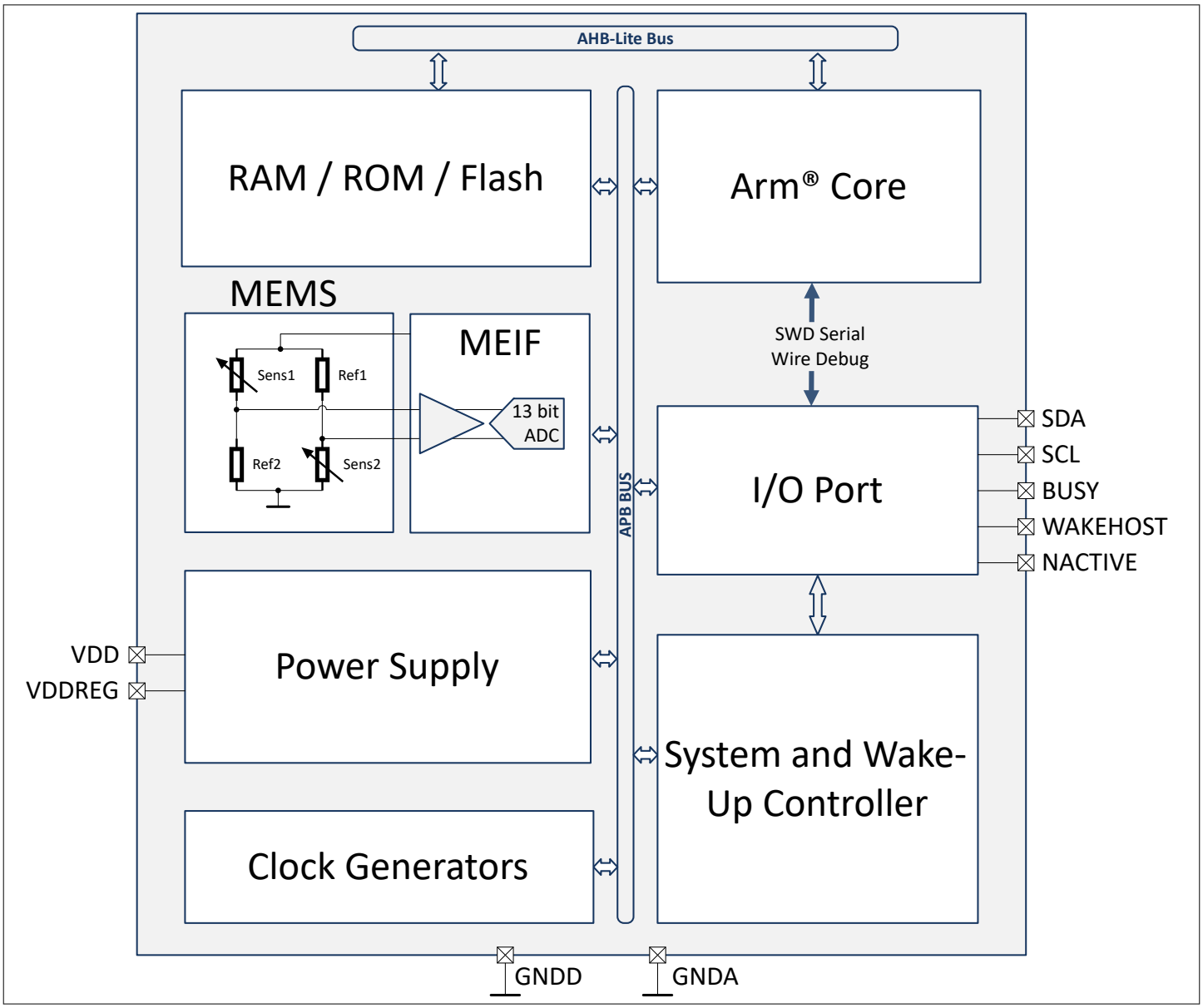

Figure 1 Functional block diagram

2 Pin configuration

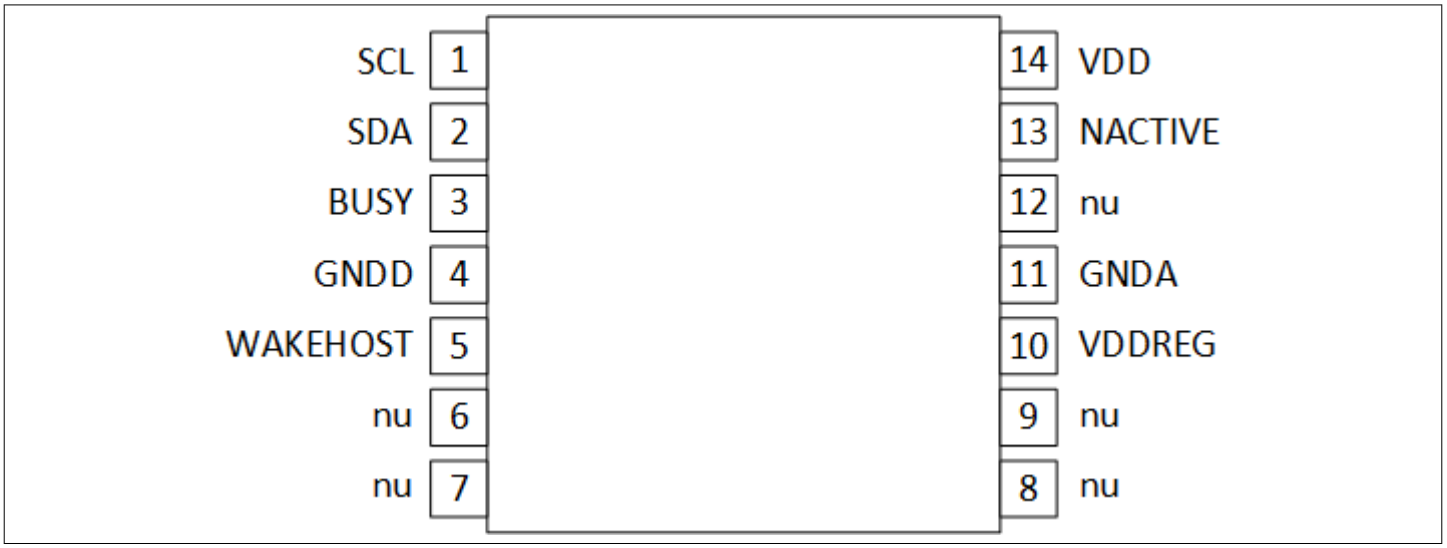

Figure 2 Pin configuration

Table 1 Pin definitions and function

Pin no.	Symbol	Function
1	SCL	I2C-SCL
2	SDA	I2C-SDA or wake-up input[1)]
3	BUSY	Device busy output (active high) or wake-up input[1)]
4	GNDD	Digital ground
5	WAKEHOST	Output for host wake-up
6	nu	not used, do not connect
7	nu	not used, do not connect
8	nu	not used, do not connect
9	nu	not used, do not connect
10	VDDREG	Internal power supply stabilization, connect via 10nF±10% capacitor to ground.
11	GNDA	Analog and Power amplifier Ground
12	nu	not used, do not connect
13	NACTIVE	Active high output for indicating device not in Active State. If pin 3 is configured as wake-up this pin also indicates device busy.
14	VDD	Power Supply

[1)] only SDA pin *or* BUSY pin can be configured as wake-up at a time.

3 General product characteristics

3.1 Absolute maximum ratings

Table 2 Absolute maximum ratings

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
DC Current	I_{DC}	-10		10	mA	Maximum Input/Output Current at any Pin
Transient Latch-up Current	I_{LU}	±100			mA	Maximum transient current at any pin according JEDEC78 class II level A
ESD robustness HBM	V_{HBM}	±2000			V	All pins tested according to AEC-Q100-002
ESD robustness CDM, Corner Pins	$V_{CDM\,C}$	±750			V	Corner pins tested according to AEC-Q100-011
ESD robustness CDM	V_{CDM}	±500			V	Non-corner pins tested according to AEC-Q100-011
Storage temperature	$T_{STORAGE}$	-50		150	°C	Maximal 1000 hours accumulated over lifetime between 125°C and 150°C. Maximum 1000 hours between -40°C and -50°C. Device not powered. Temperature cycling only allowed between -40°C and 125°C.
Maximum Pressure	p_{MAX}			600	kPa	Static
Max. Supply voltage	V_{DD_MAX}	-0.3		3.8	V	Voltage at VDDBAT pin
Pin Input voltage	V_{IN_Pin}	-0.3		VDD+ 0.3	V	

Attention**: **Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the section "functional range" is not implied. Furthermore, only single error cases are assumed. More than one stress/error case may also damage the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. During absolute maximum rating overload conditions the voltage on VDD pins with respect to ground shall not exceed the values defined by the absolute maximum ratings. Lifetime statements are an anticipation based on an extrapolation of Infineon's qualification test results. The actual lifetime of a component depends on its form of application and type of use etc. and may deviate from such statement. Lifetime statements shall in no event extend the agreed warranty period.

3.2 Functional range

The following functional range shall not be exceeded in order to ensure correct operation of the device. All parameters specified in the following sections refer to these operating conditions unless otherwise indicated.

Table 3 Functional range

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Operating Ambient Temperature	T_{amb}	-40		105	°C	
Flash Programming Temperature Range	T_{FLASH}	-20		90	°C	Temperature range for flash erasing/programming.
Flash write cycles	N_{WRITE}			100		-20°C ≤ T_{amb} ≤ 90°C
Analysis Gas Pressure	p_{GAS}	50		130	kPa	Absolute Pressure
Supply Voltage Range	V_{DD}	3.3 - 5%	3.3	3.3 + 5%	V	Target supply voltage is 3.3V
External Capacitor at VDDREG	C_{VDD_REG}	7	10	13	nF	
Relative Humidity	*RH*	0		100	%	no condensation
Hydrogen Measurement Range	c_{H2}	0		4	vol%	Without external ignition protection
Extended Hydrogen Measurement Range	c_ext_{H2}	4		16	vol%	External ignition protection in place
Operating Hours	t_{op}			15	y	Valid for the specified temperature mission profile.

3.3 Current Consumption

Table 4 Supply Currents

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Stand-by Current, RT	I_{STDBY_RT}		2.3	6	µA	T_{amb} = 25°C
Sensor Peak Current at RT	I_{Peak_RT}		5	7	mA	
Current during flash write access	I_{FLASH_WRITE}			6	mA	T_{amb} = 25°C

4 Product features

4.1 Functional description

4.1.1 Firmware

4.1.1.1 Device States

The device has three states:

- Active State where the I2C interface is active and I2C commands can be executed.
- Stand-By State where no commands or measurements are executed and the I2C interface is disabled.
- Autonomous State where measurements are automatically executed and the I2C interface is disabled.

The following diagram shows how and when transitions between the states take place.

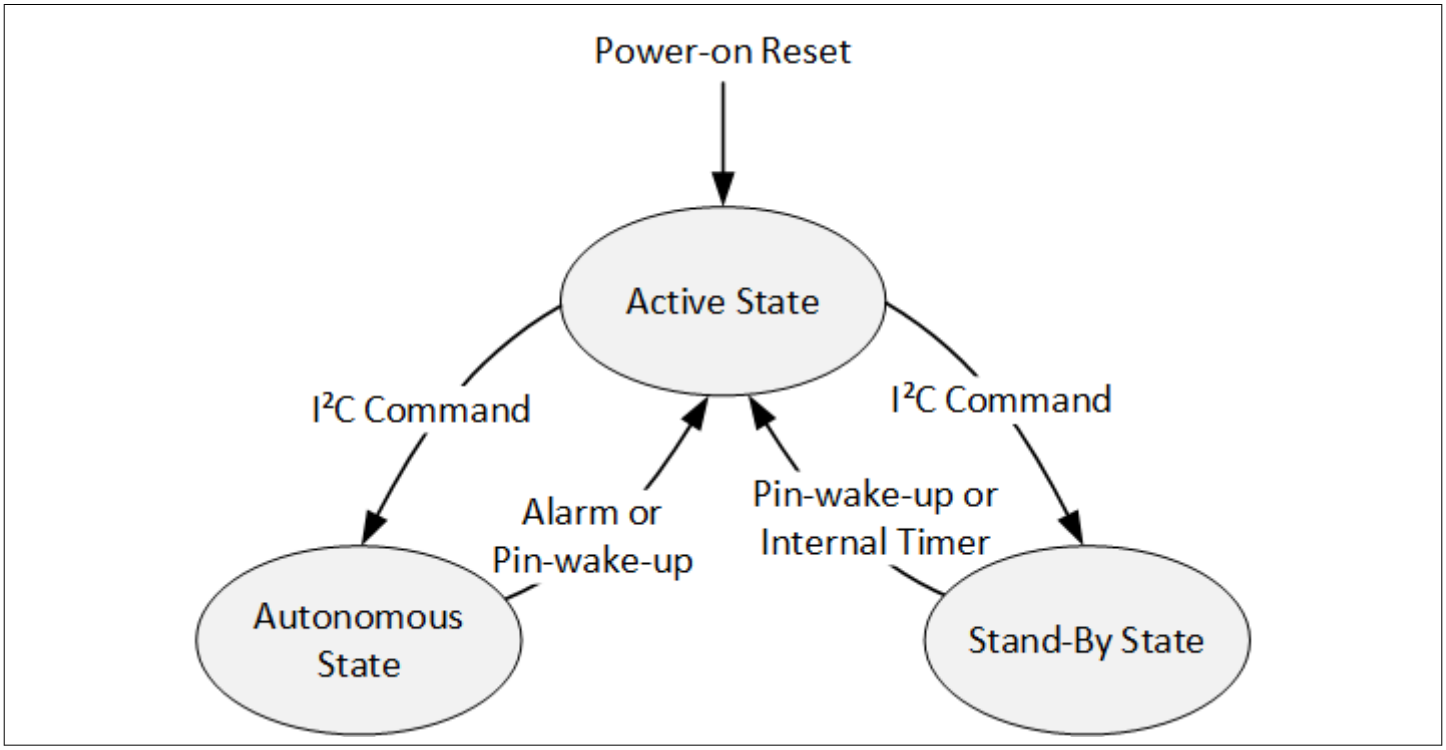

Figure 3 Device State Transitions

4.1.1.2 Sensor Operating Concept

4.1.1.2.1 I2C Operation

- The device is implemented as I2C slave. The 7 bit slave address is 0x36.
- The device also acknowledges the address byte with the reserved I2C address 0x2E. However, full I2C commands send to this address are not acknowledged, not executed, and will block the I2C interface. The interface blocking can only be canceled by a device reset.
- The master writes an I2C command, then waits for a defined processing time and finally reads a result from the slave.
- In case the I2C write command initiates a transition from Active State to Stand-by State or Autonomous State the read command can be sent only after wake-up from Stand-by State or Autonomous State.
- In the I2C protocol all values (including the CRC) are transmitted with highest byte first.
- The I2C commands as well as the I2C reply are secured by a 16 bit CRC value. The CRC is calculated according to CRC-16/CCITT-FALSE standard with initialization value = 0xFFFF.
- Commands are not executed in case of an erroneous CRC value.
- The device provides a BUSY signal that, in any device state, is high whenever measurements are executed, or data is processed.
- The device provides the NACTIVE signal which is always high when the device is in Stand-by State or in Autonomous State.
- The I2C interface is disabled when either the BUSY or the NACTIVE or both signals are high.

4.1.1.2.2 Stand-by Control

- The device may be configured such that it goes automatically into Stand-by State after the measurement result has been read. The automatic stand-by functionality is disabled by default.
- Alternatively the device may be put into Stand-by State via a dedicated I2C command.
- The device provides an output pin that indicates the device is in Stand-by State.
- If the device is in Stand-by State and before sending the actual measurement triggering command, the master needs to wake-up the slave.
- Wake-up can be either accomplished via a separate pin or by pulling SDA low for t_{pull}. The time between the wake-up and the following I2C command must be greater than the stand-by resume time t_{RES_STBY}.
- The wake-up method (via dedicated pin or via SDA line) is configurable by the user.

Note: If the device is not periodically resumed from stand-by by the host-controller, it will resume automatically after typically 15.9 min. (This time has a tolerance, the minimum is 12.2 min, the maximum is 22.7 min.) In this situation the NACTIVE pin can be used to wake-up the host-controller.

4.1.1.2.3 Invalid I2C Commands

- If the device receives a command with invalid CRC it will reply with status 0x40, followed by the CRC bytes 0xA9 and 0x34.
- In case of an invalid command the status 0x80 is transmitted, followed by the CRC bytes 0x70 and 0x78
- Note: During Stand-By State, Autonomous State and if the device is busy, I2C commands are not acknowledged

4.1.1.3 Trigger Concentration Measurement Command

This command triggers a concentration measurement. For humidity compensation an external humidity and external temperature value may be provided via this command. This temperature is the temperature from the external humidity sensor and is only used for calculating the absolute humidity. For the actual temperature compensation an internal temperature sensor is used. Therefore, if the sensor is configured to perform only the temperature compensation this value is ignored. Further an external pressure value may be provided if pressure compensation is required. The command contains following fields:

Address	0xA8	Config	RH	T	p	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xA8	Command identifier
Config	Bit <7...6>: RH resolution enhancement. 1LSB=0.25%, see note 1 Bit <5> =1: Field contamination check enabled, see note 2 Bit <5> =0: Field contamination check disabled Bit <4> =1: EoL contamination check enabled, see note 2 Bit <4> =0: EoL contamination check disabled Bit <3> =1: MEMS voltage regulator bypassed, see note 3 Bit <3> =0: MEMS voltage regulator not bypassed (recommended) Bit <2>: unused, must be 0 Bit <1...0> =11_b: The raw value is provided, no compensation Bit <1...0> =10_b: Only temperature and humidity compensation Bit <1...0> =01_b: Only temperature compensation Bit <1...0> =00_b: The fully compensated concentration is provided
RH	RH (relative humidity): 1%/LSB, range: 0 to 100, see note 4
T	T (temperature at RH sensor): 1°C / LSB, range: -40 to 105 (signed), see note 4 This value is used to calculate the absolute humidity. If this value is set to 0x7F the value is not used, but the on-chip temperature value instead.
p	Ambient pressure used for compensation. 1kPa / LSB, range: 50 to 130. If no pressure value is available p=100 is recommended. See also note 4.
CRCH, CRCL	16 bit CRC value calculated from 5 bytes, 0xA8 to p

Note 1: This bit field may be used to increase the resolution of the input parameter RH by two bits to achieve a more accurate humidity compensation. If the external humidity sensor does not provide this accuracy the bitfield should be set to zero. Config<7> represents 0.5%RH and Config<6> 0.25%RH.

Note 2: The End of Line (EoL) contamination check is more sensitiv than the field contamination check and should not be used in the field. If the EoL contamination check is enabled then Config<5> will be ignored, i.e. for Config<4>=Config<5> = 1 only the EoL check will be executed.

Note 3: Depending on the supply voltage, bypassing the MEMS regulator can increase the concentration measurement sensitivity. However, the concentration value will no longer be correctly calibrated and it is the users responsibility to do the calibration based on the raw value. Furthermore, bypassing the MEMS regulator requires a well regulated supply voltage.

Note 4: If the parameter is out of range the concentration measurement command is still executed and the corresponding status bit is set in the response.

This read command is used to fetch the reply from the device after a processing time of t_{conc_meas}:

Address	Status	Conc_H	Conc_L	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: measurement valid. Bit<7...6> unused, always 0 Bit<5> indicates a flash ECC1 error Bit<4> indicates a RAM or software execution error Bit<3> indicates a MEMS error or contamination check fail Bit<2> indicates an "input parameter out of range" condition. Bit<1> indicates VDD out of range, concentration not in spec. Bit<0> indicates a MEIF or an ADC error
Conc_H, Conc_L	Depending on "Config" a fully compensated, a partially compensated, or the ADC raw value is provided. (see note 1.)
CRCH, CRCL	16 bit CRC value calculated from 3 bytes, Status to Conc_L

Note 1: The fully and partially compensated concentration values are 16 bit signed integer values with unit 0.01%H2/LSB if H2 calibration is selected. The sensitivity of the uncompensated concentration raw value is individual for each device.

4.1.1.4 Trigger Temperature Measurement Command

This command triggers a temperature measurement. The command contains following fields:

Address	0xA9	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xA9	Command identifier
CRCH, CRCL	16 bit CRC value calculated from 1 byte, 0xA9

This read command is used to fetch the reply from the device after a processing time of t_{T_meas}:

Address	Status	T	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: measurement valid. Bit<7...2> unused, always 0 Bit<1> indicates an ADC overflow error Bit<0> indicates an ADC underflow error
T	Signed 8 bit on-chip temperature 1°C / LSB
CRCH, CRCL	16 bit CRC value calculated from 2 bytes, Status and T

4.1.1.5 Configuration Command

This command has following purposes:

1. enable the automatic Stand-By after reading the measurement result.
2. select the wake-up pin.
3. select the sensitive level of the wake-up pin

Address	0xC4	Cfg_1	Cfg_2	Cfg_3	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xC4	Command identifier
Cfg_1	Bit <7...4> Not used, should be 0 Bit <3> =1: Spike filter enabled, see note 1 Bit <3> =0: Spike filter disabled Bit <2> =1: "Busy pin" wake-up on high level Bit <2> =0: "Busy pin" wake-up on low level Bit <1> =1: "Busy pin" is used as wake-up pin and busy signal is put on NACTIVE Bit <1> =0: SDA pin is used as wake-up pin (default), see note 2 Bit <0> =1: Automatic Stand-By after reading result from command 0xA8 or 0xA9 Bit <0> =0: Automatic Stand-By disabled (default)
Cfg_2	reserved, should be 0
Cfg_3	reserved, should be 0
CRCH, CRCL	16 bit CRC value calculated from 4 bytes, 0xC4 to Cfg_3

Notes:

1. *The spike filter is disabled by default after power on. It can be enabled if spikes on the I2C lines are expected. If the filter is enabled the I2C communication speed is limited to 800 kbit/s.*
2. *In case SDA pin is used for wake-up, wake-up is always triggered on low level.*

This read command is used to fetch the reply from the device after a processing time of t_{STWU_cfg}:

Address	Status	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Always 0. In case of an invalid command a dedicated error message is replied.
CRCH, CRCL	16 bit CRC value calculated from1 byte, Status

4.1.1.6 Stand-By Command

This command puts the sensor into Stand-by:

Address	0xC3	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xC3	Command identifier
CRCH, CRCL	16 bit CRC value calculated from byte 0xC3

Note: If the SDA line is configured as wake-up line any I2C command (read or write) following the 0xC3 command will immediately resume the device from Stand-by. The command used for resuming the device will not be executed and not acknowledged.

4.1.1.7 Read ID Command

This command allows to read the following parameter from the sensor:

- Unique sensor ID.
- Product code
- FW revision number
- Manufacturer identifier

The command contains following fields:

Address	0xC2	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xC2	Command identifier
CRCH, CRCL	16 bit CRC value calculated from byte 0xC2

This read command is used to fetch the reply from the device after a processing time of t_{read_ID}:

Address	Status	ID3	ID2	ID1	ID0	PC_H	PC_L	FW_H	FW_L	MANU	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Always 0. In case of an invalid command a dedicated error message is replied.
ID3, ID2, ID1, ID0	32 bit Sensor ID

PC_H, PC_L	16 bit Product Code, PC = 0x0001
FW_H, FW_L	16 bit Firmware revision number
MANU	8 bit Manufacturer Code
CRCH, CRCL	16 bit CRC value calculated from 10 bytes, Status to MANU

4.1.1.8 Autonomous State

- The Autonomous State (AS) is controlled via I2C commands which are used to configure the autonomous sampling interval, the alarm thresholds, and the output-wake-up pin (Wakehost pin) for waking up the host controller in case of an alarm.
- The AS is entered with a dedicated command which is also used to provide the device with the external humidity-, pressure-, and temperature-value used for compensating the concentration measurement.
- Once the device is in AS no I2C communication is possible, but communication is carried out via the wake-up lines.
- Once in Autonomous State (AS) the firmware automatically carries out compensated measurements and compares the result with all four user defined thresholds. If no threshold is exceeded/underrun, the device waits in stand-by until the next measurement is triggered by an internal timer.
- In case a threshold is exceeded/underrun an alert is raised. Also, an alert is raised if any self-diagnosis test (carried out at the measurement) fails.
- If AS is configured to "stop after alarm" (default setting) if will stop regardless of the alarm source. If it is configured to "continue after alarm" (optional) it will stop in case of a diagnosis fail but continue in case of a threshold violation.
- The alert (Wakehost signal) is kept until the next valid I2C command is received from the host.
- The Wakehost active level is high.
- The host can always terminate AS via wake-up pin.
- The sensor is either woken-up from AS by the host controller via the configured input-wake-up pin or the AS is stopped in case of an alarm.
- The input-wake-up pin in AS is the same pin which is configured to wake-up from stand-by.
- When the device receives a wake-up an ongoing measurement is not interrupted but completed and after that the transition to AS is done, i.e. the NActive line stays asserted until the measurement is done.

4.1.1.9 Configure Autonomous State Command

This command defines the following parameters of the autonomous state:

1. The interval at which measurements are performed autonomously.
2. The alarm thresholds.
3. Behavior of autonomous state after an alarm.

Address	0xC5	Config	SIH	SIL	UAAT	LAAT	UCAT	LCAT	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xC5	Command identifier
Config	Bit <7...4>: number n of measurements for gradient calculation. 2≤n≤12. Bit <3...1>: unused Bit <0> =1: Autonomous state continuous after alarm Bit <0> =0: Autonomous state stops after alarm (default setting)
SIH, SIL	16 bit Sampling Interval (SI). 1 LSB =100ms. Range: 1 ≤SI≤ 600.
UAAT	Upper Absolute Alarm Threshold. Range: 0 to 255. 1 LSB =0.1%H2
LAAT	Lower Absolute Alarm Threshold. Range: 0 to 255. 1 LSB =-0.1%H2
UCAT	Upper Change Alarm Threshold. Range: 0 to 255. 1 LSB=0.1%H2/SI
LCAT	Lower Change Alarm Threshold. Range: 0 to 255. 1 LSB=-0.1%H2/SI
CRCH, CRCL	16 bit CRC value calculated from 8 bytes, 0xC5 to LCAT

Note: Any threshold set to 0 means it is disabled

This read command is used to fetch the reply from the device after a processing time of t_{STWU_cfg}:

Address	Status	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7...3> unused, always 0 Bit<2> indicates an "input parameter out of range" condition. Bit<1...0>: unused, always 0
CRCH, CRCL	16 bit CRC value calculated from1 byte, Status

Note: In case a non-zero Status is returned the command was not executed, i.e. no configuration change was performed.

4.1.1.10 Enter Autonomous State Command

This command starts the autonomous state if at least one threshold is enabled. If no threshold was enabled with the *Configure Autonomous State Command* the AS will not be entered.

The command contains following fields:

Address	0xC6	RH	T	p	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xC6	Command identifier
RH	RH (relative humidity): 1%/LSB, range: 0 to 100, see note 1
T	T (temperature at RH sensor): 1°C / LSB, range: -40 to 105 (signed), see note 1 This value is used to calculate the absolute humidity. If this value is set to 0x7F the value is not used, but the on-chip temperature value instead.
p	Ambient pressure used for compensation. 1kPa / LSB, range: 50 to 130. If no pressure value is available p=100 is recommended. See also note 1.
CRCH, CRCL	16 bit CRC value calculated from 4 bytes, 0xC6 to p.

Note 1: If the parameter is out of range Autonomous State will not be entered.

This read command is used to fetch a status from the device after wake-up from Autonomous State or if Autonomous State was not entered.

It must be executed right after wake-up from Autonomous State and before any other write command is sent.

Address	Status	M_Status	RSRVD	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7> unused, always 0 Bit<6> indicates that no alarm threshold is enabled, see note 2 Bit<5...3> unused, always 0 Bit<2> indicates an "input parameter out of range" condition. Bit<1...0> unused, always 0

M_Status	ORed status of all measurements since entering AS M_Status =0: all measurements are valid. Bit<7> unused, always 0 Bit<6> indicates a measurement interval timer error Bit<5> indicates a flash ECC1 error Bit<4> indicates a RAM or software execution error Bit<3> indicates a MEMS error or contamination check fail Bit<2> unused, always 0 Bit<1> indicates VDD out of range, concentration not in spec. Bit<0> indicates a MEIF or an ADC error
RSRVD	Reserved byte, always 0x00
CRCH, CRCL	16 bit CRC value calculated from 3 bytes, Status to RSRVD.

Note 2: If all alarm thresholds are disabled Autonomous State is not entered.

4.1.1.11 Retrieve Past Concentration Measurements Command

The last 12 concentration measurements are continuously stored in a ring buffer. This command allows to read the ring buffer.

The command contains following fields:

Address	0xAA	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xAA	Command identifier
CRCH, CRCL	16 bit CRC value calculated from byte 0xAA

This read command is used to fetch the reply from the device after a processing time of $t_{retrieve}$:

Address	Status	C0H	C0L	C1H	C1L	...	C11H	C11L	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7...4> unused, always 0 Bit<3...0>: 4 bit value representing the number of invalid concentration values. Possible values are 0 to 12. See note1.
C0H, C0L	Latest 16 bit signed concentration value in the ring buffer. Scaling: 0.01%H2 / LSB
...	...
C11H, C11L	Oldest 16 bit signed concentration value in the ring buffer. Scaling: 0.01%H2 / LSB

CRCH, CRCL	16 bit CRC value calculated from 25 bytes, Status to C11L

Note 1: the number of invalid values refers to a situation when the ring buffer is not yet full. If, for example, the number is 3 then the oldest 3 concentration values (C9, C10, C11) are invalid. If the number is 0, all 12 concentration values (C0 to C11) are valid.

4.1.1.12 Retrieve Past Temperature Measurements Command

The last 12 temperature measurements are continuously stored in a ring buffer. This command allows to read the ring buffer.

The command contains following fields:

Address	0xAB	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xAB	Command identifier
CRCH, CRCL	16 bit CRC value calculated from byte 0xAB

This read command is used to fetch the reply from the device after a processing time of $t_{retrieve}$:

Address	Status	T0	T1	T2	...	T11	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7...4> unused, always 0 Bit<3...0>: 4 bit value representing the number of invalid concentration values. Possible values are 0 to 12. See note1.
T0	Latest 8 bit signed temperature value in the ring buffer. Scaling: 1°C / LSB
...	...
T11	Oldest 8 bit signed temperature value in the ring buffer. Scaling: 1°C / LSB
CRCH, CRCL	16 bit CRC value calculated from 13 bytes, Status to T11

Note 1: the number of invalid values refers to a situation when the ring buffer is not yet full. If, for example, the number is 3 then the oldest 3 temperature values (T9, T10, T11) are invalid. If the number is 0, all 12 temperature values (T0 to T11) are valid.

4.1.1.13 Write User Flash Line

This command is used to write a line of 16 bytes into the freely usable user flash memory.

Address	0xB1	Key	ADDRH	ADDRL	Data0	...	Data15	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xB1	Command identifier
Key	0x9D
ADDRH, ADDRL	16 bit address. Valid range is 0x0000 to 0x03E0 in steps of 0x20
Data0	1st byte of the 16 byte flash line to be written.
...	
Data15	16th byte of the 16 byte flash line to be written.
CRCH, CRCL	16 bit CRC value calculated from 20 bytes, 0xB1 to Data15

This read command is used to fetch the reply from the device after a processing time of t_{write_line}:

Address	Status	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7>: write verification failed Bit<6...4>: reserved, always 0 Bit<3>: indicates a key mismatch Bit<2>: reserved, always 0 Bit<1>: indicates address out of range or not multiple of 0x20 Bit<0>: ORing of status bits 1 to 7
CRCH, CRCL	16 bit CRC value calculated from1 byte, Status

Note: If Status<1> or Status<3> is set the command was not executed.

4.1.1.14 Read User Flash Line

This command is used to read a line of 16 bytes from the user flash memory.

Address	0xB2	ADDRH	ADDRL	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0> = 0
0xB2	Command identifier
ADDRH, ADDRL	16 bit address. Valid range is 0x0000 to 0x03E0 in steps of 0x20
CRCH, CRCL	16 bit CRC value calculated from 3 bytes, 0xB2 to ADDRL

This read command is used to fetch the reply from the device after a processing time of t_{read_line}:

Address	Status	Data0	...	Data15	CRCH	CRCL

Definition of the fields:

Address	Bit <7...1>=7 bit slave address Bit <0>=1
Status	Status =0: ok Bit<7...2>: reserved, always 0 Bit<1>: indicates address out of range or not multiple of 0x20 Bit<0>: ORing of status bits 1 to 7
Data0	1st byte of the user flash line
...	
Data15	16th byte of the user flash line
CRCH, CRCL	16 bit CRC value calculated from 17 bytes, Status to Data15

Note: If Status<1> is set the command was not executed.

4.2 Electrical characteristics

4.2.1 TC Sensor Characteristics

4.2.1.1 General TC Sensor Characteristics

Table 5 TC Sensor Characteristics

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Response/ Recovery Time (t90, t10)	$t_{90,10}$			100	ms	Analysis-gas present at device gas-inlet at start of measurement.
Digital Resolution	$Sens_{H2}$		0.01		vol%H2 /LSB	
RMS Noise Level	σ_{H2}		0.015	0.02	vol%H2	

4.2.1.2 Total Measurement Error

Notes:

1. The following accuracy values are valid if the external humidity sensor used for compensation does not exceed a tolerance of ±1.5%RH and ±1 °C. For the accuracy values with pressure compensation, the external pressure sensor must not exceed a tolerance of ±2 kPa.
2. %RD stands for percent of concentration reading.
3. Note that for fulfilling the total measurement error specification at $c_{H2} > 5\%$ the following output signal correction is required:

   $c_{H2\_corrected} = 1.15 * c_{H2\_uncorrected} - 0.75$ vol%H2

   This correction must be done on system level, it is not performed in the TCI.

4.2.1.2.1 Total Measurement Error with Pressure Compensation

Table 6 Total Thermal Conductivity Measurement Error With Pressure Compensation

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Total Measurement Error	*TME*	-0.12		0.12	vol%H2	0 vol.% ≤ c_{H2} ≤ 1 vol.% 80kPa ≤ p_{GAS} ≤ 120kPa 0% ≤ RH ≤ 100% -5°C ≤ T_{amb} ≤35°C

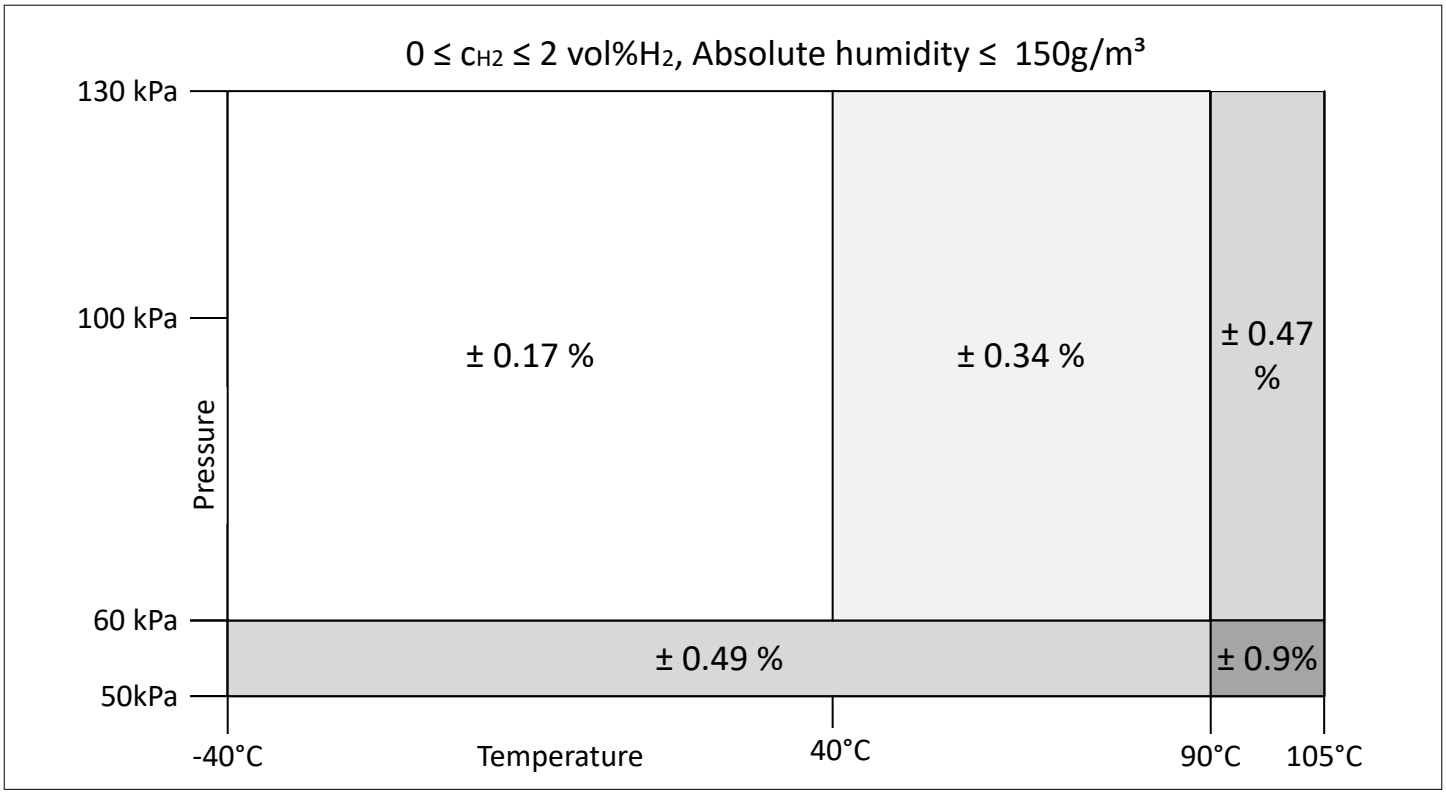

Figure 4 **Total measurement error with p-compensation, low concentration range**

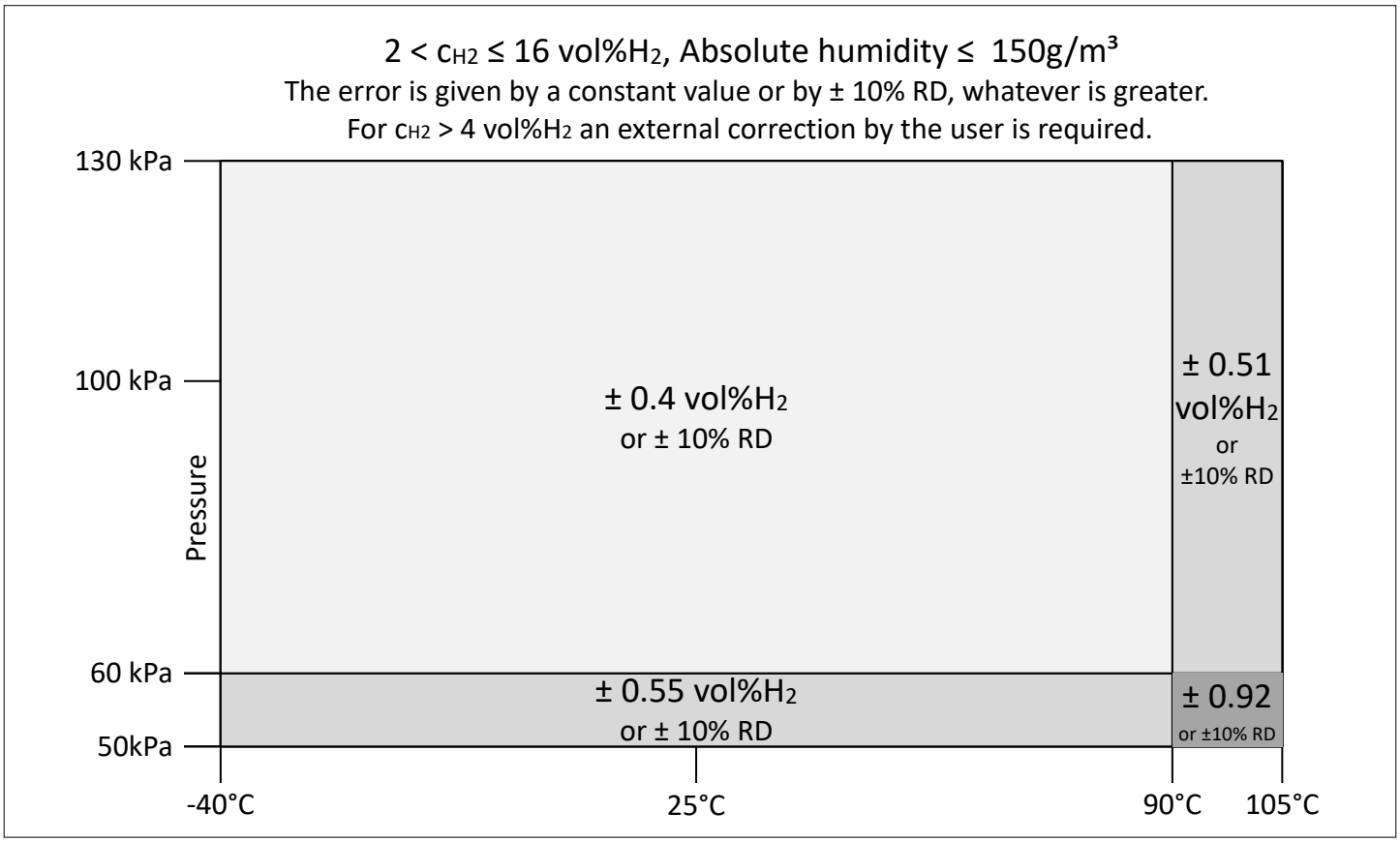

Figure 5 **Total measurement error with p-compensation, high concentration range**

4.2.1.2.2 Total Measurement Error w/o Pressure Compensation

Table 7 Total Thermal Conductivity Measurement Error Without Pressure Compensation

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Total Measurement Error w/o p-compensation	$TME_{no\_p\_comp}$	-0.2		0.2	vol%H2	0 vol.% ≤ c_{H2} ≤ 1 vol.% 80kPa ≤ p_{GAS} ≤ 120kPa 0% ≤ RH ≤ 100% -5°C ≤ T_{amb} ≤35°C

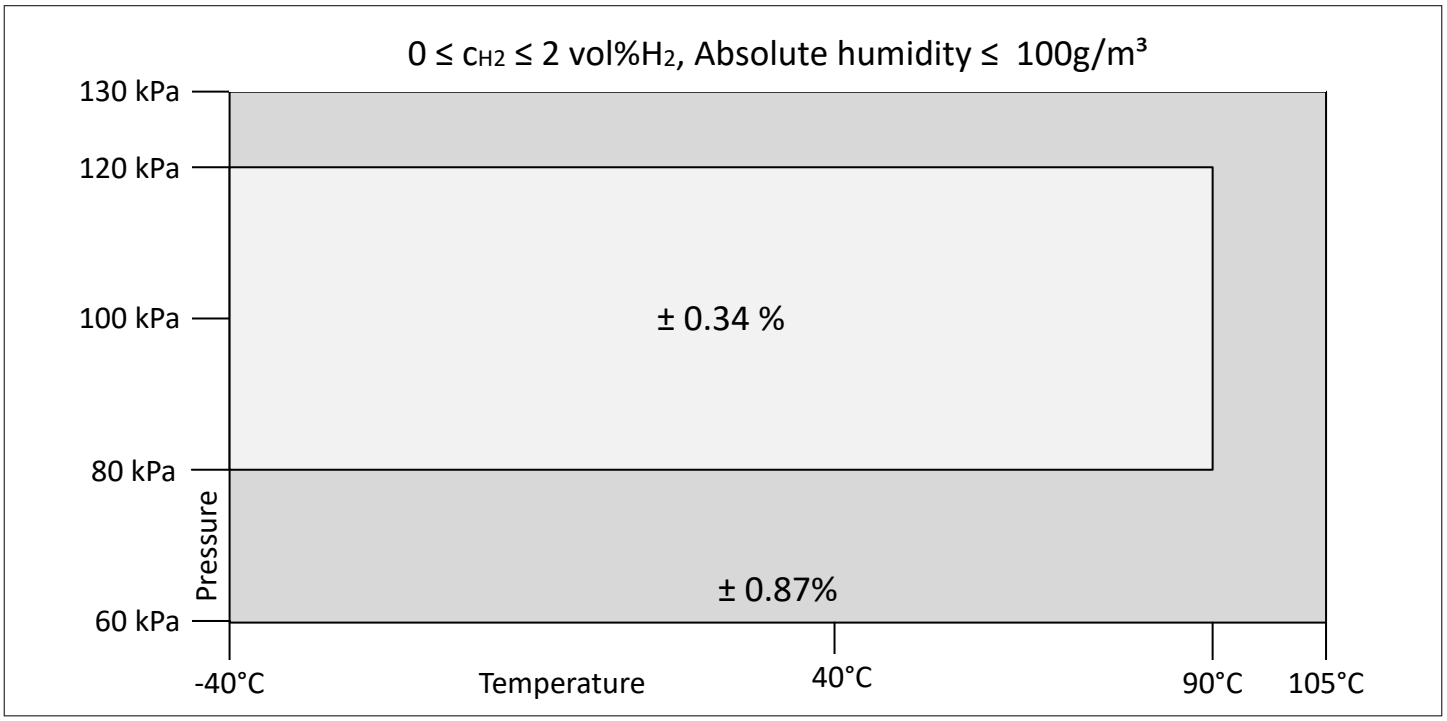

Figure 6 Total measurement error w/o p-compensation, low concentration range

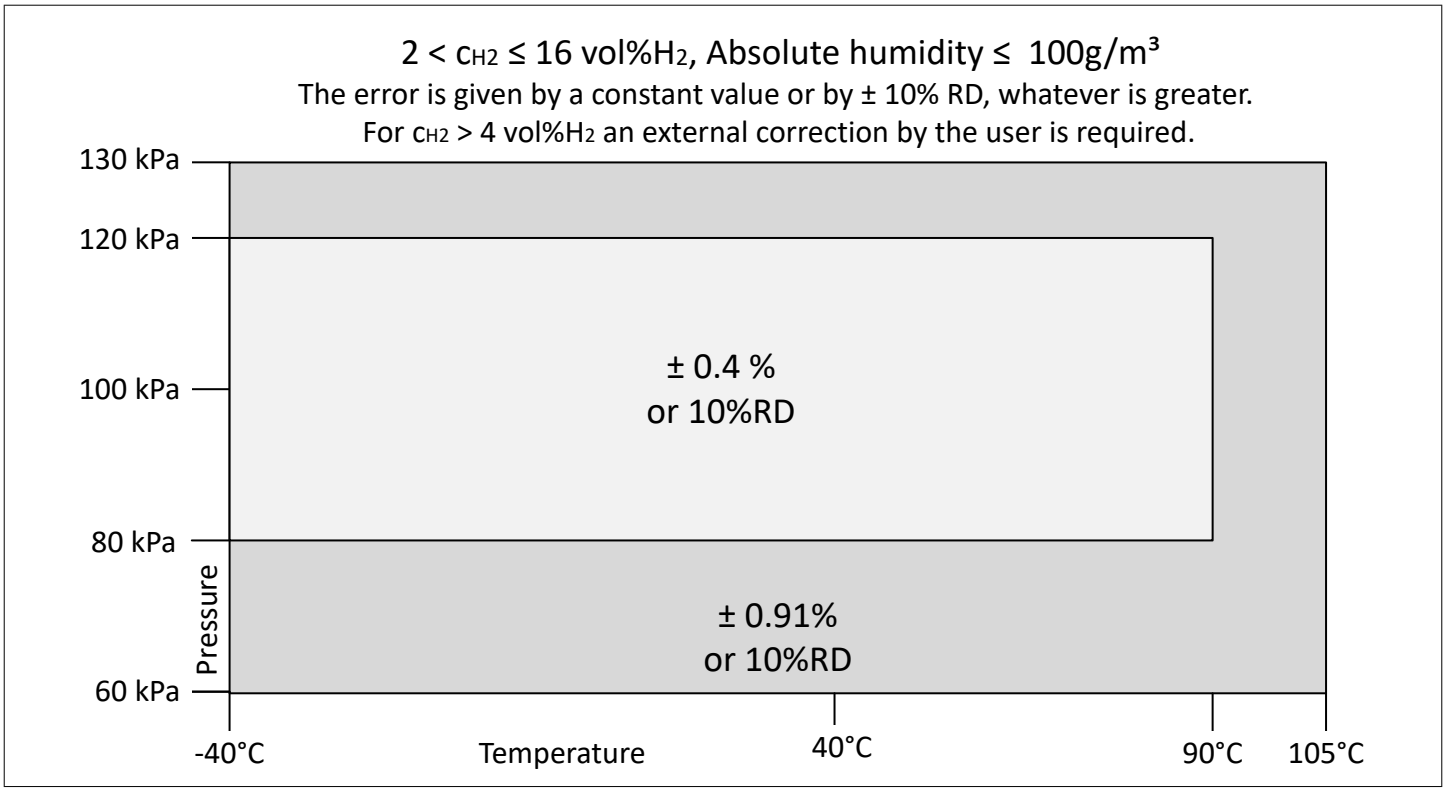

Figure 7 Total measurement error w/o p-compensation, high concentration range

4.2.2 Temperature Sensor

Table 8 Temperature Sensor

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Temperature Measurement Range	T_{MEAS_RANGE}	-40		125	°C	
Temperature Sensor Physical Resolution	T_{RES}		0.2	1	°C	
Temperature Sensor Total Error	T_{ERR}	-5		5	°C	The measurement error is understood as total error, including random error (noise)
Temperature Sensor Total Error, RT	T_{ERR_RT}	-3		3	°C	T_{amb} = -20°C to +90°C;
Temperature RMS Noise	T_{NOISE}			0.25	°C	Refers to compensated temperature values. Random Error is included in Total Error.

4.2.3 Digital Input and Output Pins

Table 9 Input and Output Pins

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Output High Voltage	V_{OH}	V_{DD} -0.3			V	I_{load} = 1mA
Output Low Voltage	V_{OL}			0.3	V	I_{load} = -1mA
Input High Voltage	V_{IH}	0.8V_{DD}			V	
Input Low Voltage	V_{IL}			0.2V_{DD}	V	
Pin Input Capacitance	C_{IN}			10	pF	
Input Pin Leakage Current	I_{IN_Pin}	-2		2	µA	
Equivalent Pull Resistor at Pin 3	R_{PULL}	10		70	kΩ	V_{IN} = 1.5V, VDD=3.3V. Applies if pin 3 is configured as wake-up.
Equivalent I2C pull-up resistor	R_{PULL_I2C}	5.9	8.4	11	kΩ	V_{IN} = 1.5V, VDD=3V; Internal pull-up at SCL and SCA pin.
I2C High Datarate	DR_{I2C_HIGH}	1000			kbit/s	Maximum load capacitance at SCL or SDA is 80pF
I2C Medium Datarate	DR_{I2C_med}	400			kbit/s	
I2C Low Datarate	DR_{I2C_low}	100			kbit/s	

4.2.4 Voltage Monitoring

Table 10 Voltage Monitoring

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Under Voltage Reset	V_{UVR}	1.6		1.7	V	Measured at V_{DD} pin.
Reset release threshold	V_{THR}	1.8		1.9	V	Device releases from Reset when voltage at VDD pin exceeds V_{THR}.

4.2.5 Timing

Table 11 Timing

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Stand-By Resume Time	t_{RES_STBY}			400	µs	1)
Autonomous State Resume Time	t_{wupAS}			50	ms	1)
Concentration Measurement Time	t_{conc}			30	ms	2)
Concentration Measurement Interval	t_{conc_int}	50			ms	Time between two consecutive concentration measurement commands.
Temperature Measurement Time	t_T			250	µs	2)
Read ID Time	t_{read_ID}			200	µs	2)
Configuration Command Time	t_{CFG_CMG}			200	µs	2)
Configure Autonomous State Command Time	t_{CFG_AM}			300	µs	2)
Retrieve Concentration Measurements Command Time	$t_{retrieve\_conc}$			600	µs	2)
Retrieve Temperature Measurements Command Time	$t_{retrieve\_T}$			200	µs	2)
Write Flash Line Time	t_{write_line}			8	ms	-20°C ≤ T_{amb} ≤ 90°C
Read Flash Line Time	t_{read_line}			1	ms	-20°C ≤ T_{amb} ≤ 90°C
Autonomous State Sampling Interval Tolerance	Tol_{SI}	-30		+30	%	

(table continues...)

Table 11 (continued) Timing

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Power on time	t_{INI}			20	ms	Time from V_{DD} exceeding V_{THR} until serial interface ready. 3)
VDD rise time	t_{RISE_VDD}			1	s	Linear rise to V_{DD} = 2.2V

1) Time from change of level at wake-up pin until device ready for receiving a new I2C command.
2) Time from I2C command fully received until device ready for receiving the next I2C command. It does not include the I2C communication time.
3) The power on time is only valid if at least one of the two pins SCL and SDA is either not connected or connected to high level. If both pins are actively connected to ground the power on time will prolong to approx. 3 seconds.

5 Package

5.1 Package Outline

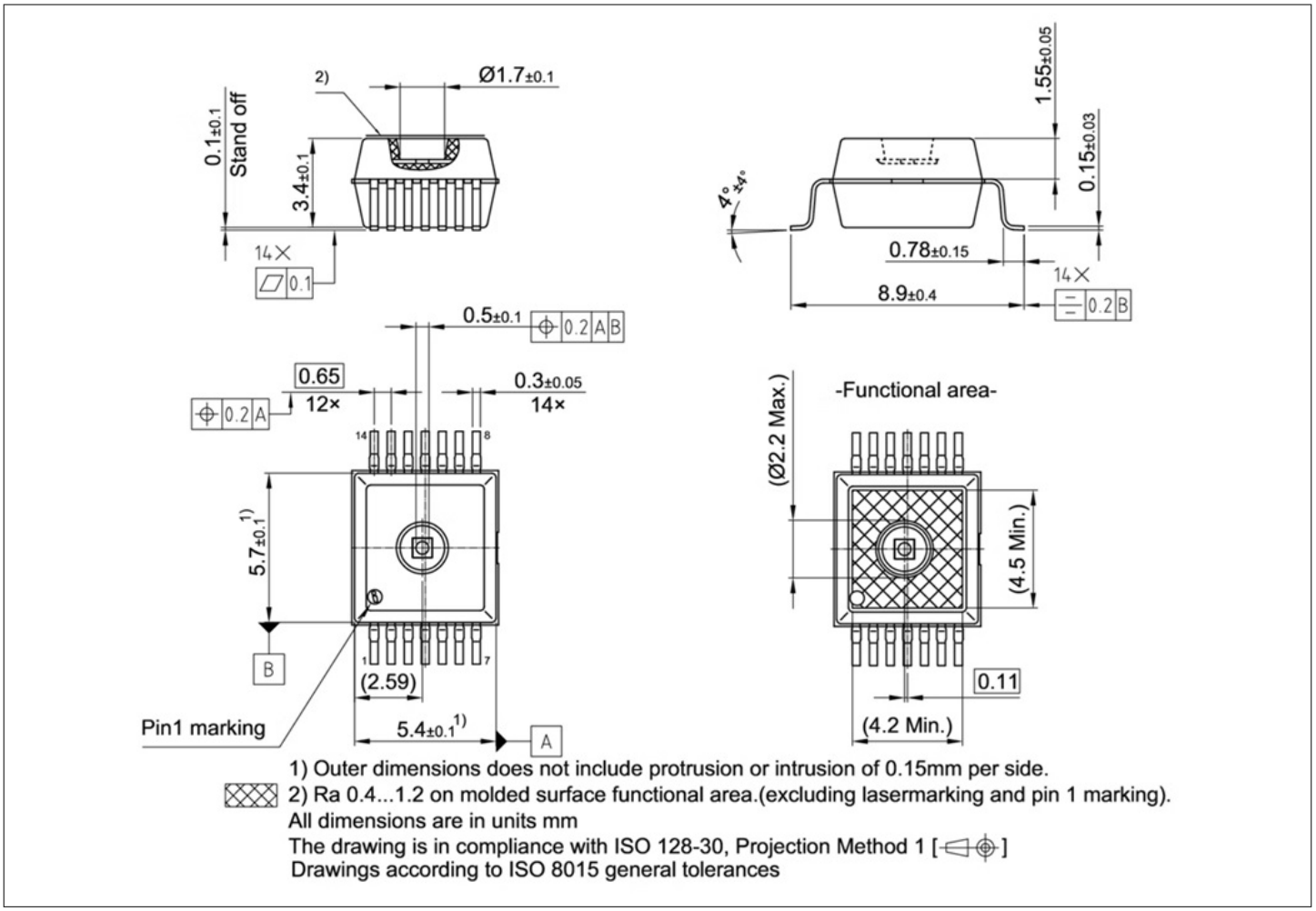

Figure 8 PG-DSOSP-14-84 package outline

5.2 Package Marking

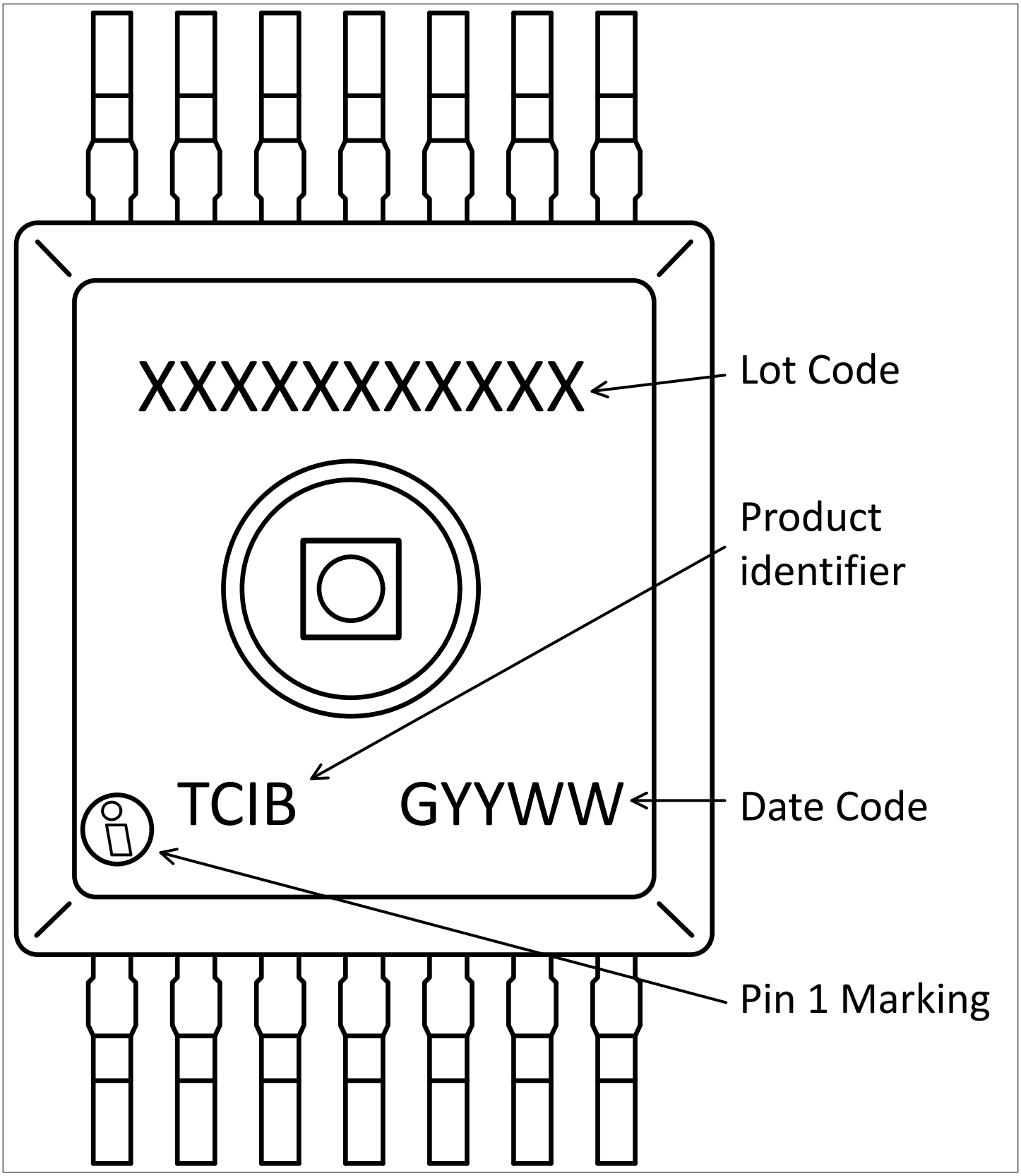

Figure 9 Product marking

6 Temperature Mission Profile

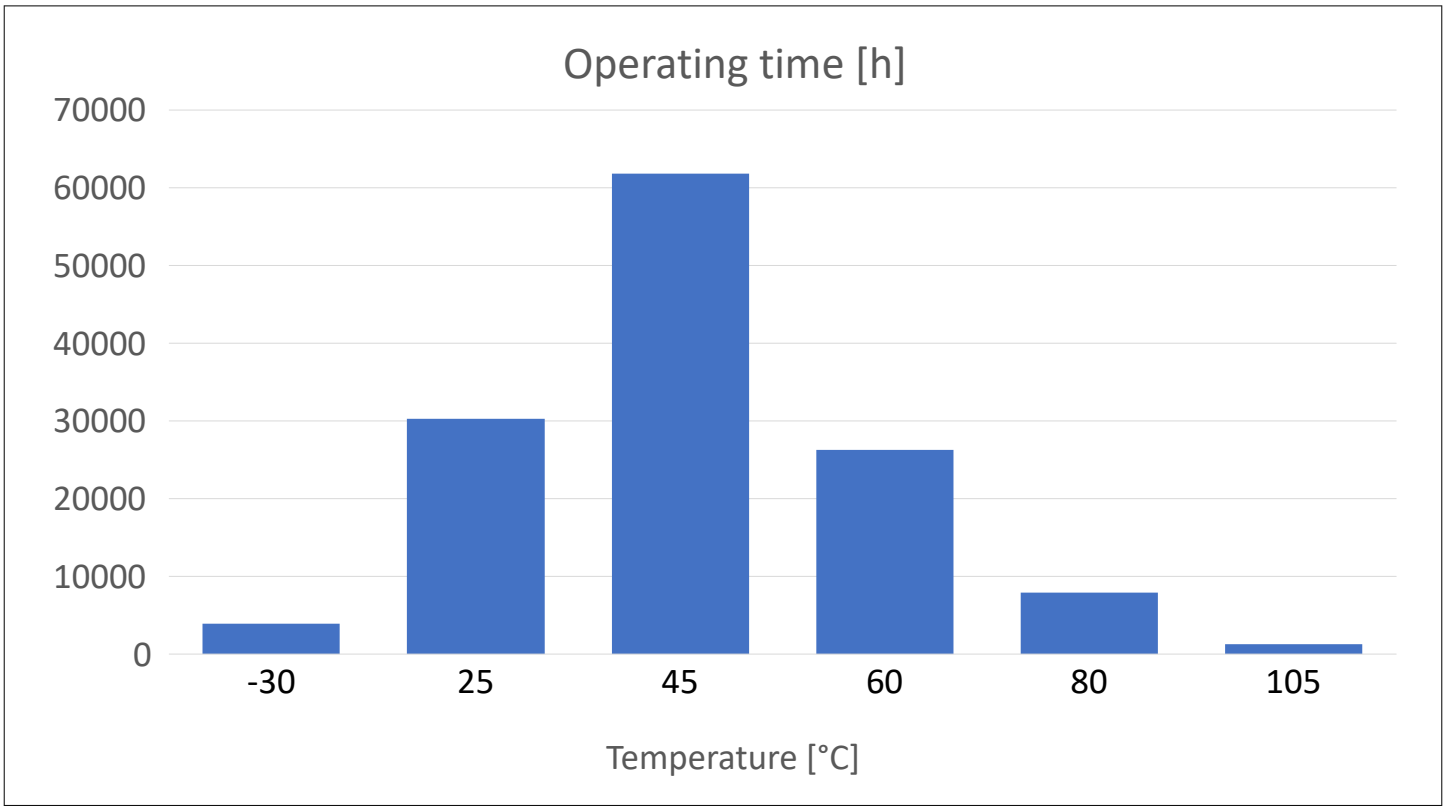

Figure 10 Temperature Mission Profile

Note: This is a typical temperature mission profile for which the lifetime of 15y is valid

7 Device Contamination

The very fine gas-sensitive structures are nested inside the component and are therefore protected from direct contact. However, contaminants in the form of small particles can still reach these structures and alter the sensor properties. Therefore, depending on the environmental conditions, the sensor must be installed in a way that protects it from such particles.

See the app note “Appnote_TCIx_Assembly&Testing” for more information.

8 Revision History

Table 12 Revision History

Document version	Date of release	Description of changes
1.00	2025-11-21	Initial revision

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