XENSIV™ PAS CO2 Datasheet

Description

Infineon has leveraged its knowledge in sensors and MEMS technologies to develop a disruptive gas sensor for CO2 sensing. The XENSIV™ PAS CO2 is a real CO2 sensor combining NDIR technology with Infineon's high SNR MEMS microphones, allowing for state-of-the-art accuracy in an exceptionally small form factor.

The sensor is based on the photoacoustic spectroscopy (PAS) principle, where CO2 molecules within the sensor cavity absorb infrared light, generating small pressure changes that are detected by an acoustic detector. CO2 concentration is then delivered in the form of a direct ppm readout, thanks to the integrated microcontroller. Highly accurate CO2 readings are guaranteed.

Features

- **Operating range:** 0 ppm to 32000 ppm
- **Accuracy:** ± (30 ppm +3%) of reading between 400 ppm and 3000 ppm
- **Maintenance:** Maintenance-free when using ABOC feature (Automatic Baseline Offset Correction)
- **Lifetime:** 10 years
- **Interface:** I2C, UART, and PWM
- **Package dimension:** 13.8 x 14 x 7.5 mm^3
- **RoHs compliant**

Potential applications

High accuracy, compact size, and SMD capability make the XENSIV™ PAS CO2 ideal for indoor air quality monitoring solutions in the market with numerous potential applications.

- **HVAC (Heating, Ventilation, Air Conditioning)**
- **Home appliances**
- **Smart home IoT devices**
- **Agriculture/ Greenhouses**
- **In-cabin air quality monitoring unit**

Table 1 Order information of PASCO2V01

OPN Number	SP Number	RoHS Compliant
PASCO2V01AUMA3	SP006037335	Yes

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1 Block diagram

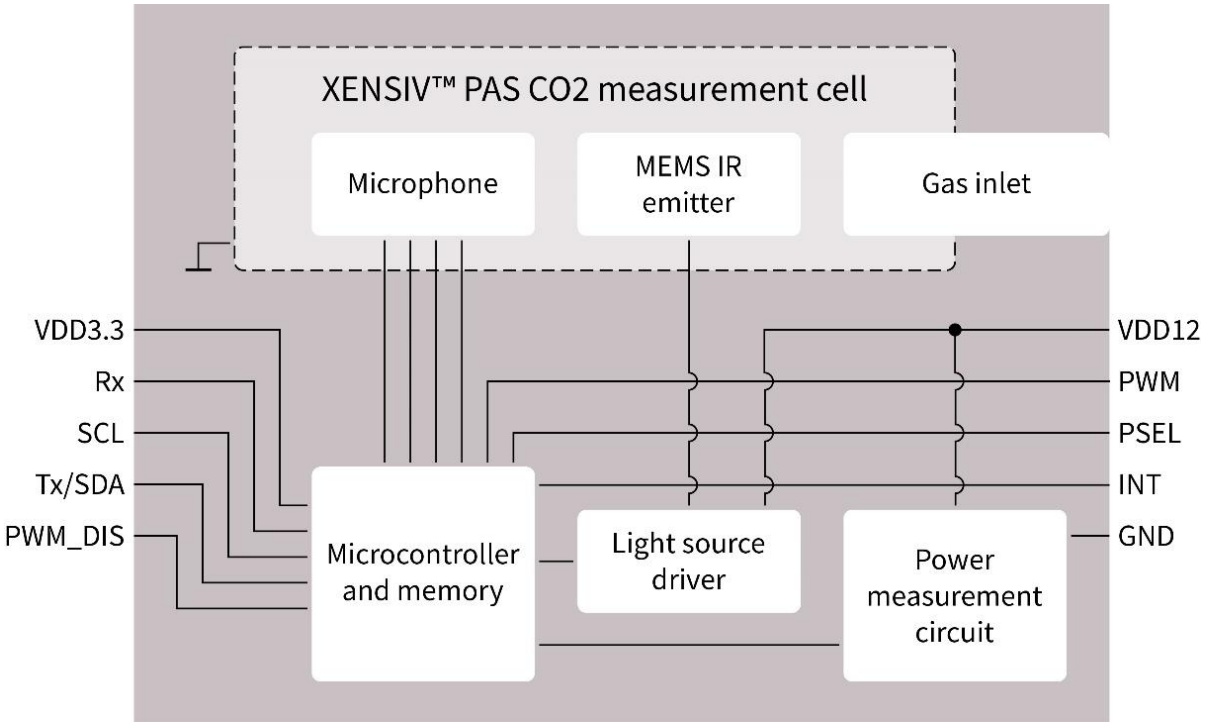

Figure 1 Block diagram of XENSIV™ PAS CO2

2 Pin-out diagram

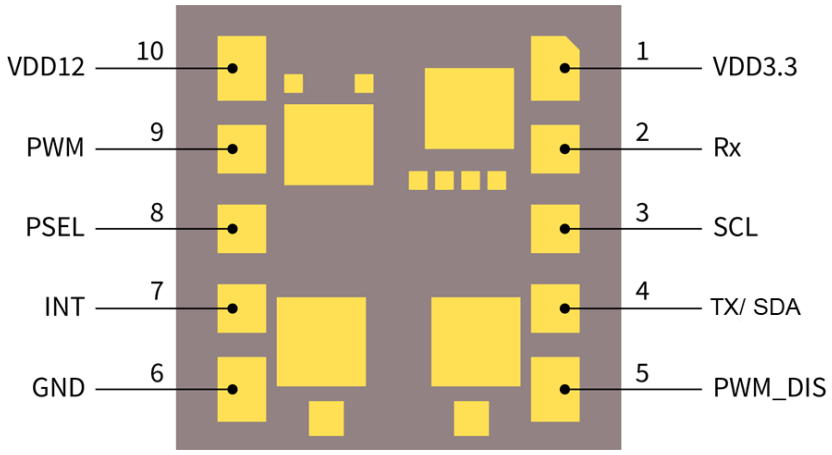

Figure 2 Pin-out diagram (Bottom view)

Table 2 Pin Description

PIN	Symbol	Type	Description
1	VDD3.3	Power supply (3.3V)	3.3V digital power supply
2	Rx	Input/ Output	UART receiver pin (3.3V domain)
3	SCL	Input/ Output	I2C clock pin (3.3V domain)
4	TX/ SDA	Output	UART transmitter pin (3.3V domain) / I2C data pin (3.3V domain)
5	PWM_DIS	Input	PWM disable input pin (3.3V domain)
6	GND	Ground	Ground
7	INT	Output	Interrupt output pin (3.3V domain)
8	PSEL	Input	Communication interface select input pin (3.3V domain)
9	PWM	Output	PWM output pin (3.3V domain)
10	VDD12	Power supply (12V)	12V power supply for the IR emitter

3 The typical sensor response to the CO_2 concentration change

Measurement condition: VDD12 = 12.0V, VDD3.3=3.3V, T_{amb} = 25°C, P = 1013 hPa and %r.H. = 30%

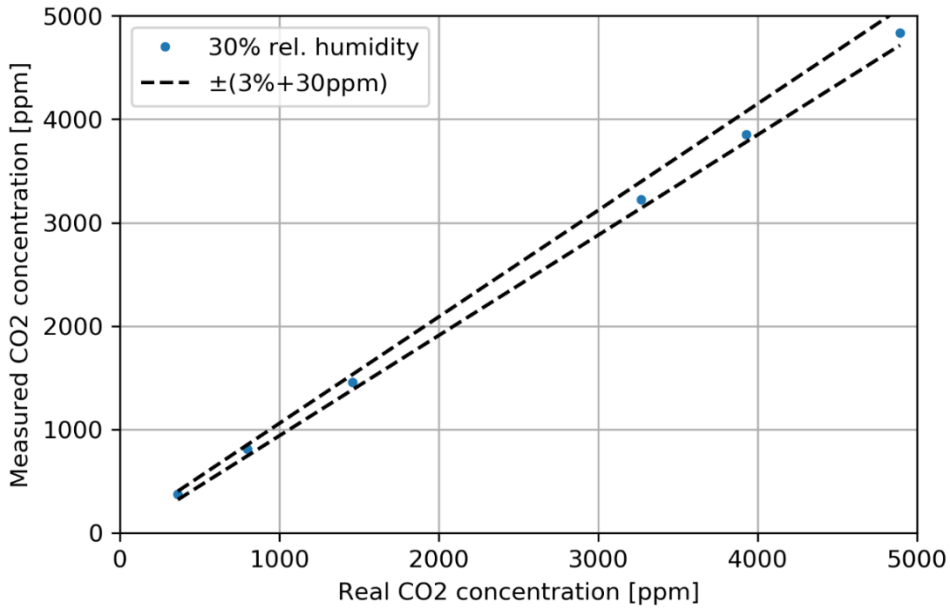

Figure 3 The typical sensor response to the CO_2 concentration change.

4 Characteristics and parameters

4.1 Specification

4.1.1 Operating condition

All parameters specified in the following sections refer to these operating conditions unless otherwise specified.

Table 3 Operating range

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
CO2 measurement range[1)]	C_{CO2}	0		32000	ppm	Functional measurement range
Ambient temperature[1)]	T_{amb}	0		50	°C	
Relative humidity[1)]	r.H.	0		85	%	Non-condensing
Pressure[1)]	p	750	1013	1150	hPa	
Supply voltage[1)]	VDD3.3	3	3.3	3.6	V	
	VDD12	10.8	12	13.2	V	
Lifetime[1)]	t_{life}		10		Year	Depends on the mission profile

4.1.2 Storage condition

Storage condition refers to Dry pack: Packed, non-evacuated, desiccant[2], Humidity Indicator Card (HIC) sealed moisture barrier bag.

Table 4 Storage condition

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Storage temperature[1)]	$T_{storage}$	5		40	°C	<90% r.H.[3]
Storage time[1)]	$t_{storage}$			3	Year	
Storage temperature during transport[1)]	$T_{storage\_transport}$	-20		60	°C	
Storage time during transport[1)]	$t_{storage\_transport}$			10	Day	

1) Not subject to production test. This parameter is verified by design/ characterization.
2) Number of desiccant units to be calculated according to JEDEC Standard 033.
3) Condensation and bedewing shall be avoided.

4.1.3 Timing characteristics

Table 5 Timing characteristics

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Sampling time[1)]	$t_{sampling}$	10	60	4095	s	Sensor accuracy might be impacted for sampling rates faster than 1 meas/ min.
Time to sensor ready[1)]	t_{sensor_rdy}			1	s	
Time to early notification[1), 2)]	t_{early_noti}		2		s	
I2C Clock frequency[1)]	f_{I2C}		100 400		kHz	
PWM frequency[1)]	f_{pwm}		80		Hz	
UART baud rate[1)]	f_{baud}		9.6		kBps	

Typical measurement timing sequence has been illustrated in figure 4.

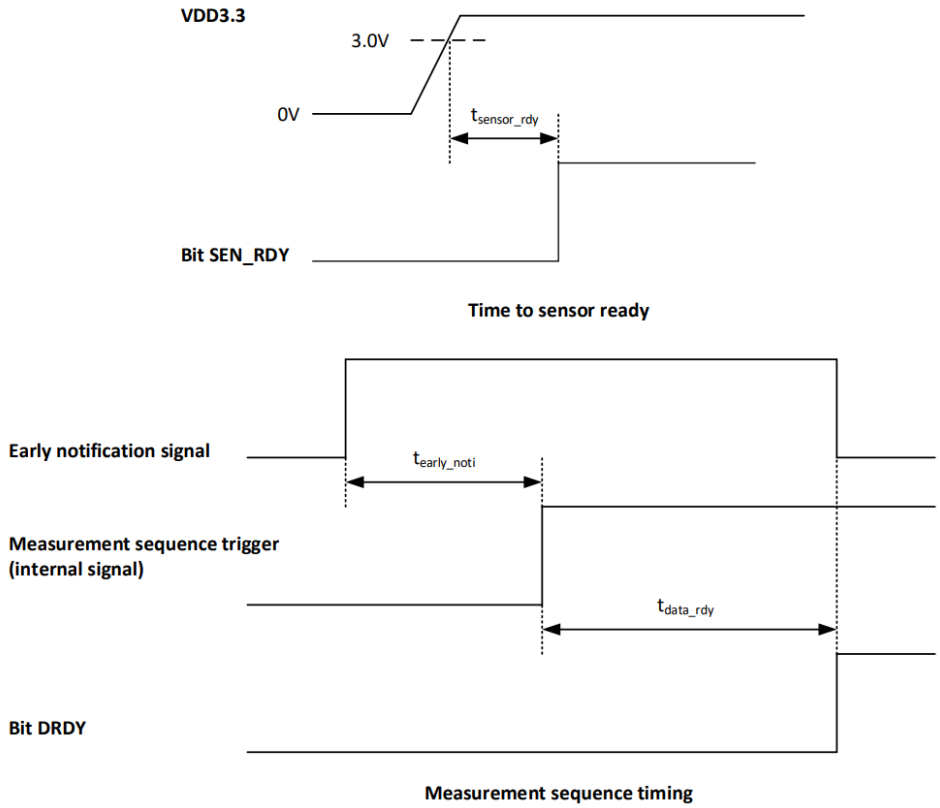

Figure 4 Illustration of the timing characteristic parameters

1) Not subject to production test. This parameter is verified by design/ characterization.
2) Relevant for continuous mode of operation.

4.1.4 Absolute maximum ratings

Table 6 Absolute maximum ratings[1)]

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Moisture Sensitivity Level	MSL		3			
Maximum ambient temperature	T_{amb_max}	-10		60	°C	
Maximum relative humidity	rH_{max}	0		95	%	
12V Supply voltage	V_{VDD12}	9.6		14.4	V	
3.3V Supply voltage	$V_{VDD3.3}$	3.0		3.6	V	
Reflow temperature	T_r			245	°C	JEDEC J-STD-020E
ESD Human Body Model	V_{ESD_HBM}	-2		2	kV	HBM (JS001)
ESD Charge Discharge Model	V_{ESD_CDM}			500	V	CDM (JS002)

Note: Stresses above the values listed as "Absolute Maximum Ratings" may cause permanent damage to the devices. Exposure to absolute maximum rating conditions for extended period of time may affect device reliability.

4.1.5 The current rating and power consumption

All parameters specified in the following sections refer to the operating conditions unless otherwise specified: VDD3.3 = 3.3V, VDD12 = 12.0V, T_{amb} = 25°C, % r.H. = 30 %, p = 1013 hPa and $t_{sampling}$ = 1 meas/ min.

Table 7 Current rating

Parameter	Symbol	Pin	Values			Unit	Note or Test Condition
			Min.	Typ.	Max.		
Peak current[1)]	$I_{peak\ 12}$	VDD12		130	150	mA	
Peak current[1)]	$I_{peak\ 3.3}$	VDD3.3		10		mA	
Average current[1)]	$I_{avg\ 12}$	VDD12		0.8		mA	
Average current[1)]	$I_{avg\ 3.3}$	VDD3.3		6.1		mA	
Average power[1)]	P_{avg}			30		mW	

Power consumption can be optimized further. For more details please refer to our application note section at the product web page.

1) Not subject to production test. This parameter is verified by design/ characterization.

4.1.6 CO2 Transfer Function

All parameters specified in the following sections refer to the operating conditions unless otherwise specified:

VDD3.3 = 3.3V, VDD12 = 12.0V, T_{amb} = 25°C, % r.H. = 30 %, p = 1013 hPa and $t_{sampling}$ = 1 meas/ min.

Table 8 CO2 Transfer Function

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Accuracy[1)]	Acc	-30 ppm- 3% of reading		+30 ppm+3% of reading	ppm	C_{CO2}: 400 - 3000 ppm
Accuracy[1)]	Acc		±(30 ppm + 3% of reading)		ppm	C_{CO2}: 3001 - 5000 ppm
Response time[2)]	t_{63}		90		s	
Resolution[2)]	Res		1		ppm	
Repeatability [2,3)]	R			10	ppm	3 times standard deviation at fixed C_{CO2}: 1000 ppm
Pressure stability[2)]	p_{error}		0		%/hPa	With pressure compensation feature
Acoustic stability[2)]	SPL_{error}	3	6	15	ppm	Up to 95 dB for Pink noise from 100 Hz to 10 kHz

1) Accuracy verified using certified calibration gas mixtures and high-precision reference sensors. Uncertainty in calibration gas mixtures of ±2% needs to be considered. Temporary deviations in accuracy caused by assembly, rough handling or harsh environmental conditions can be compensated using Forced Calibration Scheme (FCS) or Automatic Baseline Offset Correction (ABOC).
2) Not subject to production test. This parameter is verified by design/ characterization.
3) Stepwise Reactive IIR filter is enabled.

4.2 Peripheral timing

4.2.1 I2C characteristics

Table 9 I2C Standard mode timing[1)]

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Fall time of both SDA and SCL	t_1			300	ns	
Rise time of both SDA and SCL	t_2			1000	ns	
Data hold time	t_3	0			µs	
Data set-up time	t_4	250			ns	
LOW period of SCL clock	t_5	4.7			µs	
HIGH period of SCL clock	t_6	4.0			µs	
Hold time for a (repeated) START condition	t_7	4.0			µs	
Set-up time for (repeated) START condition	t_8	4.7			µs	
Set-up time for STOP condition	t_9	4.0			µs	
Bus free time between a STOP and START condition	t_{10}	4.7			µs	
Capacitive load for each bus line	C_b			400	pF	

1) Due to the wired-AND configuration of an I2C bus system, the port drivers on the SCL and SDA signal lines need to operate in open-drain mode. The high level of these lines must be held by an external pull-up device, approximately 10 kOhm for operation at 100 kbits/s, approximately 2 kOhm for operation at 400 kbits/s.

Table 10 I2C fast mode timing[1)]

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Fall time of both SDA and SCL	t_1	20 + 0.1*C_b		300	ns	C_b refers to the total capacitance of one bus line in pF.
Rise time of both SDA and SCL	t_2	20 + 0.1*C_b		300	ns	C_b refers to the total capacitance of one bus line in pF.
Data hold time	t_3	0			µs	
Data set-up time	t_4	100			ns	
LOW period of SCL clock	t_5	1.3			µs	
HIGH period of SCL clock	t_6	0.6			µs	
Hold time for a (repeated) START condition	t_7	0.6			µs	
Set-up time for (repeated) START condition	t_8	0.6			µs	
Set-up time for STOP condition	t_9	0.6			µs	
Bus free time between a STOP and START condition	t_{10}	1.3			µs	
Capacitive load for each bus line	C_b			400	pF	

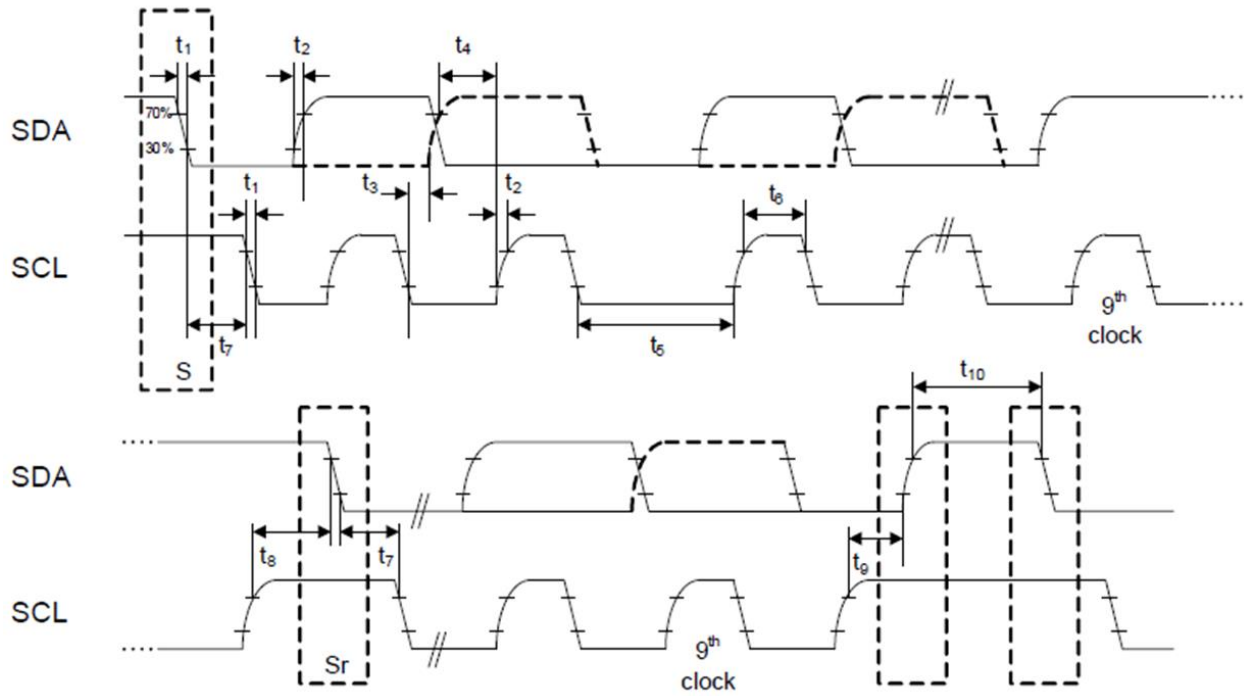

Figure 5 I2C Standard and Fast mode timing.

1) Due to the wired-AND configuration of an I2C bus system, the port drivers on the SCL and SDA signal lines need to operate in open-drain mode. The high level of these lines must be held by an external pull-up device, approximately 10 kOhm for operation at 100 kbits/s, approximately 2 kOhm for operation at 400 kbits/s.

4.2.2 UART characteristics

The main characteristics of the UART interface are described below:

- Point to point operation – no bus support.
- Slave operation only.
- f_{baud} = 9.6 kBps
- Format: 1 start bit, 8 Data bits, no parity bit, 1 stop bit.
- Supports direct connection with terminal program.

For further details on UART and I2C communication protocol, please refer to our application note section in the product webpage.

4.3 Application Circuit Example

4.3.1 I2C application circuit example

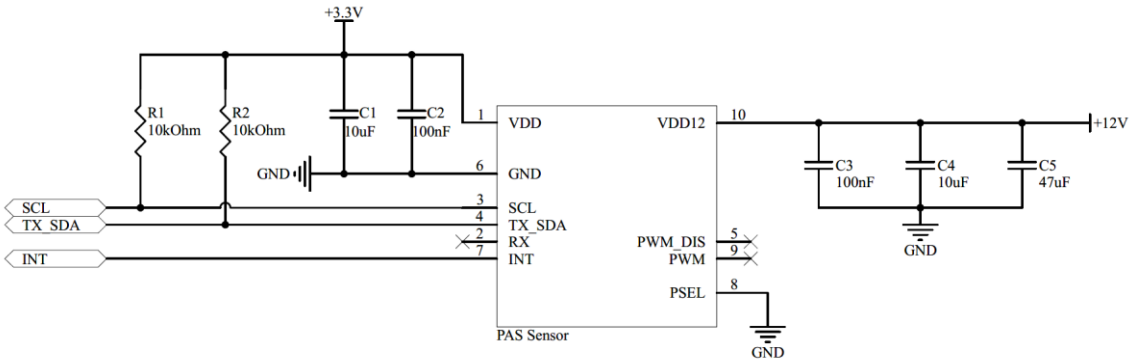

Figure 6 Application circuit example for I2C

With this configuration the device will start in idle mode of operation. Internal pull up is present on PWM_DIS pin.

4.3.2 UART application circuit example

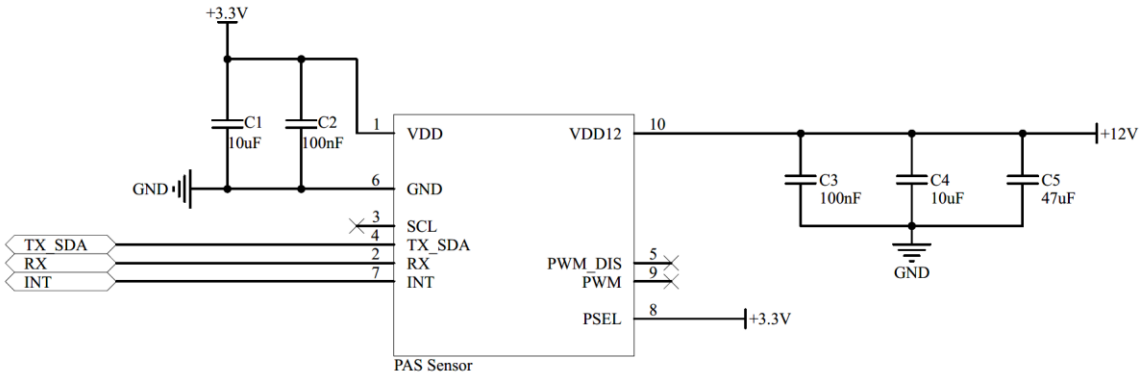

Figure 7 Application circuit example for UART

With this configuration the device will start in idle mode of operation. Internal pull up is present on PWM_DIS pin.

4.3.3 PWM application circuit example

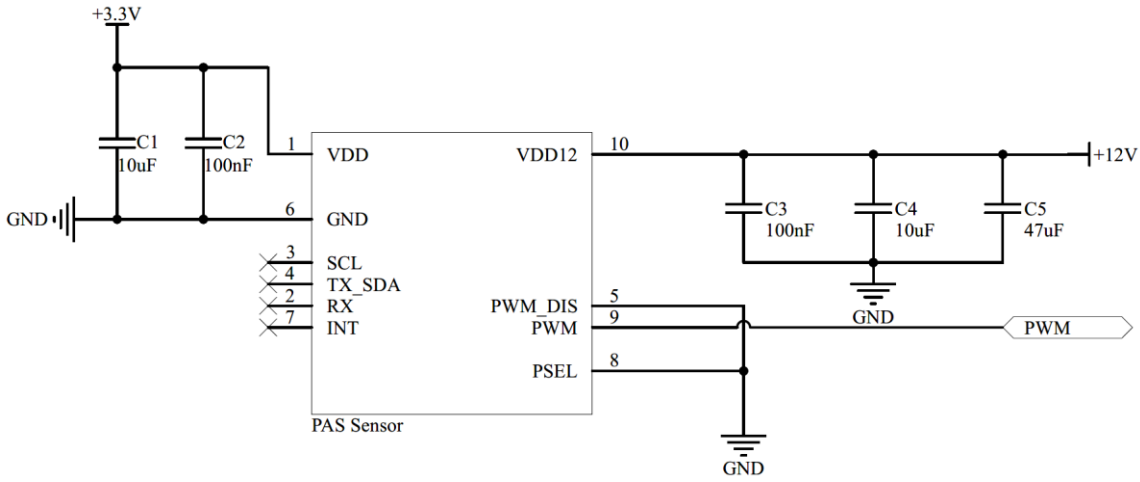

Figure 8 Application circuit example for PWM

4.4 Functional description

This section describes the operation of the sensor while measuring CO2 concentrations. At any moment the device can be in one out of two different states: active and inactive. At active state, the CPU controlling the device is operating and can perform tasks such as: running a measurement sequence, serving an interrupt, etc. When the device has no specific task to perform, it goes to an inactive state. A transition from active to inactive state may occur at the end of a measurement sequence. In an inactive state, the CPU controlling the device is in sleep mode to optimize power consumption. Several events can wake up the device: the reception of a message on the serial communication interface, a falling edge on pin **PWM_DIS**, the internal generation of a measurement request in continuous measurement mode.

4.4.1 Operating Modes

The operating mode can be programmed via the serial communication interface by using the bit field **MEAS_CFG.OP_MODE**.

The sensor module supports three operating modes:

- **Idle mode:** The device does not perform any CO2 concentration measurement. The device remains inactive until it becomes active shortly to serve interrupts before going back to an inactive state.
- **Continuous mode:** In this mode, the device periodically triggers a CO2 concentration measurement sequence. Once a measurement sequence is completed, the device goes back to an inactive state and wakes up automatically for the next measurement sequence. The measurement period is programmable from 5 sec to 4095 sec.
- **Single-shot mode:** In this mode, the device triggers a single measurement sequence. At the end of the measurement sequence, the device goes back automatically to idle mode.

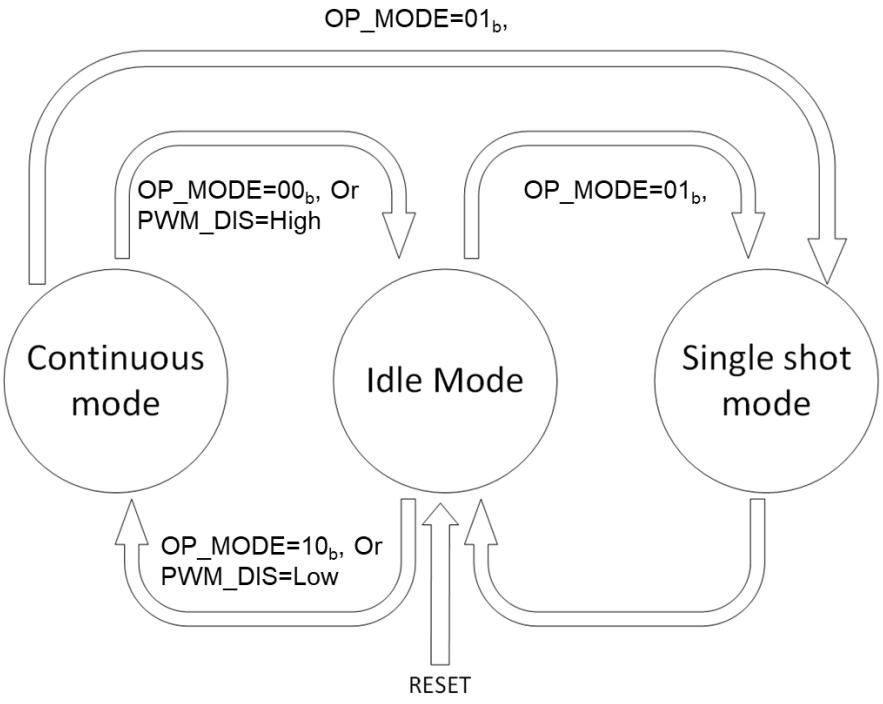

Figure 9 Operating mode transition

4.4.2 Data post-processing

Once the CO_2 concentration data has been acquired, several post-processing schemes can be applied to utilize different functionality.

4.4.2.1 Pressure compensation

The CO2 concentration value acquired by the sensor is dependent on the external atmospheric pressure. To compensate for this effect, the application system can provide the value of the atmospheric pressure by writing into the specific registers, i.e. **PRESSREF_H** and **PRESSREF_L**. At the end of a measurement sequence, the device reads the pressure value and applies for compensation on the CO2 concentration value before storing it into the result registers.

4.4.2.2 Automatic Baseline Offset Correction

To correct slow drifts caused by aging during operation, the device supports Automatic Baseline Offset Compensation. Every week of operation, the device computes an offset to correct the baseline of the device. The device must be in contact with the reference concentration (e.g. fresh air at. 400 ppm of CO2 concentration) at least 30 minutes per operating week to make sure proper baseline compensation. The device supports different configurations for compensation. **The ABOC setpoint may only be set between 350 and 1500 ppm.**

4.4.2.3 Forced compensation

Forced compensation provides a means to speed up the offset compensation process. Before forced compensation is enabled, the device shall be physically exposed to the reference CO2 concentration. The device will use the **3 next measurements to calculate the compensation offset**. The user shall ensure constant exposure to the reference CO2 concentration during that time. **It is recommended to operate at 1 measurement per 10 seconds while implementing the forced compensation scheme**. When 3 measurement sequences are completed, the device automatically reconfigures itself with the newly computed offset applied to the subsequent CO2 concentration measurement results.

4.4.2.4 Alarm Threshold

The device can be configured via interrupt to perform an alarm threshold check each time a new CO2 concentration data is acquired. At the end of each measurement sequence, the computed CO2 value (after all applicable offset compensations) is compared to the concatenated value in **ALARM_TH_H** and **ALARM_TH_L**. In case of a threshold violation, the sticky bit **MEAS_STS.ALARM** is set. This also sets pin **INT** to active level due to configuration as alarm. Bit **MEAS_STS.ALARM** is cleared by reading register **MEAS_STS.ALARM_CLR**.

4.5 Monitoring mechanism as advanced functionality

The device supports several mechanisms to monitor the correct operation of the sensor.

Table 11 Functionality description

Mechanism	Description
Sensor Ready status	After each power-on reset, bit **SENS_STS.SEN_RDY** is set to confirm that the sensor has initialized correctly.
Scratchpad register	To check the integrity of the communication layer of the serial communication interface, register **SCRATCH_PAD** can be used. This register can use this memory field to write any value and verify that the data received by the device is correct. It can also be used to verify that a soft reset has been executed, using the following sequence: 1. The user writes a non-default value to register **SCRATCH_PAD**. 2. The user reads back register **SCRATCH_PAD** to verify the writ commend has been correctly executed. 3. The user writes register **SENS_RST** to trigger a soft reset. 4. The user reads register **SCRATCH_PAD** to verify that it has been reset to its default value.
VDD12V verification	At power-up and the beginning of each measurement sequence, the device measures automatically the voltage at **VDD12**. If the measured voltage exceeds the specified operating range of the device, bit **SENS_STS.ORVS** is set. The measurement sequence is however completed normally. Bit **SENS_STS.ORVS** can be cleared by setting bit **SENS_STS.ORVS_CLR**
Internal temperature verification	At the beginning of each measurement sequence, the device measures automatically its internal temperature. If the measured temperature exceeds the specified operating ranged of the device, sticky bit **SENS_STS.ORTMP** is set. The measurement sequence is however completed normally. Bit **SENS_STS.ORTMP** can be cleared by setting bit **SENS_STS.ORTMP_CLR**.

4.6 Digital interface

The XENSIV™ PAS CO2 supports I2C, UART, and PWM. The communication protocols have been covered in separate application notes.

4.6.1 I2C interface

The device complies with the I2C protocol. When I2C is selected as a serial communication interface, the device acts as an I2C slave. The main characteristics of the interface are described below:

- Slave mode only.
- I2C Clock frequency: 100 kHz and 400 kHz
- 7-bit slave address: 0x28
- No CRC.
- The device supports clock stretching.
- 8bit addressing mode supported (7bit address + RW)
- Bulk read and write supported (device auto-increments automatically the address).
- Address 0x00 not supported.

Further details of the protocol are covered in the separate application note.

4.6.2 I2C transaction format

The I2C transaction has the following structure: a start condition followed by four bytes followed a stop condition.

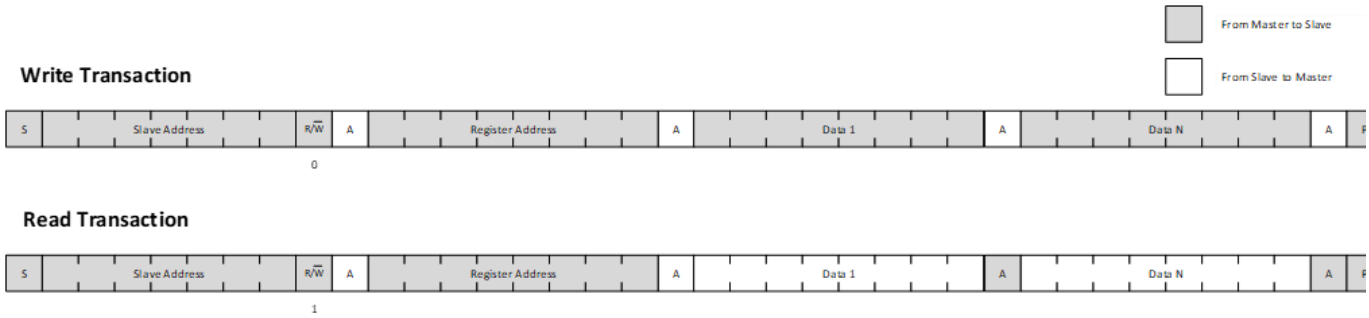

Figure 10 I2C write and read transaction

Table 12 I2C transaction

Byte	Description	Value	Comments
	Start condition		
1	Header	(Slave Address << 1) | R/W	
2	First data-byte	As per user request/register value	Read: data provided by the slave Write: data provided by the user
N+2	Data byte N	As per user request/register value	Read: data provided by the slave Write: data provided by the user
	End condition		

4.6.3 UART Interface

When UART is selected as a serial communication interface, the device acts as a UART slave. The device operates via UART for point-to-point communication. Bus operation is not supported. As a result, it is recommended that the master uses a time-out mechanism. The basic format of a valid UART frame is 1 start bit, 8 data bits, no parity bit, and 1 stop bit. The master combines several UART frames into a message (read or write). The combination of master request and salve answer defines a transaction. The main characteristics of the interface are described below:

- Point to point operation – no bus support.
- Slave operation only.
- UART clock frequency = 9.6 kHz
- Format: 1 start bit, 8 Data bits, no parity bit, 1 stop bit. Supports direct connection with a terminal program.

For further details on UART communication, please have a look into our relevant application note titled as ‘Programing guide for XENSIV™ PAS CO2’ in the application note section on the product website.

4.7 Register map

Name	Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset
PROD_ID	0x00	PROD r			REV r					0x4F
SENS_STS	0x01	SEN_RDY rh	PWM_DIS_ST rh	ORTMP rhs	ORVS rhs	ICCER rhs	ORTMP_CLR w	ORVS_CLR w	ICCER_CLR w	0xC0
MEAS_RATE_H	0x02	VAL rwh								0x00
MEAS_RATE_L	0x03	VAL rwh								0x3C
MEAS_CFG	0x04	0 rw		PWM_OUTEN rw	PWM_MODE rw	BOC_CFG rwh		OP_MODE rwh		0x24
CO2PPM_H	0x05	VAL r								0x00
CO2PPM_L	0x06	VAL r								0x00
MEAS_STS	0x07	0 rw		Res rh	DRDY rhs	INT_STS rhs	ALARM rhs	INT_STS_CLR w	ALARM_CLR w	0x00
INT_CFG	0x08	0 rw			INT_TYP rw	INT_FUNC rw			ALARM_TYP rw	0x11
ALARM_TH_H	0x09	VAL rw								0x00
ALARM_TH_L	0x0A	VAL rw								0x00
PRESS_REF_H	0x0B	VAL rwh								0x03
PRESS_REF_L	0x0C	VAL rwh								0xF7
CALIB_REF_H	0x0D	VAL rwh								0x01
CALIB_REF_L	0x0E	VAL rwh								0x90
SCRATCH_PAD	0x0F	VAL rw								0x00
SENS_RST	0x10	SRTRG w								0x00
Reserved	0x11 ... 0x14	Reserved registers Read & Write access to those registers generate a communication error								
Reserved	0x15 ... 0xFF	Reserved registers Read & Write access to those registers generate a non-acknowledge condition.								

Complete 'Register-map description' has been covered in a separate application note titled as ‘Register-map description of XENSIV™ PAS CO2’ in the product webpage.

5 Assembly instruction

XENSIV™ PAS CO2 module is classified as Moisture-Sensitivity Level 3 (MSL 3). The maximum reflow temperature during board assembly must not exceed 245°C according to IPC/JEDEC J-STD-020E. As shown in the figure 11, Pad 1 to 14 need to be soldered. Pad 1 to 10 need to be assembled as per functionality. Pad 11 and 13 need to be connected to the GND. Pad 12 and 14 are not internally connected but must be soldered to maintain mechanical stability. Pad 12 and 14 can be left open or connected to GND. Non-marked smaller pads should be kept open.

Further details such as footprint drawing, board assembly guidelines, stencil recommendation can be found into CO2 product page under Infineon package name 'LG-MLGA-14'.

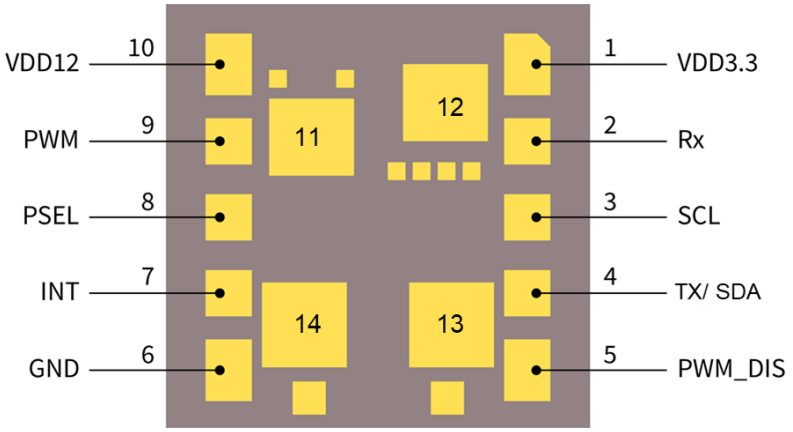

Figure 11 XENSIV™ PAS CO2 pads need to be connected to an application board.

Note: 1) One-time reflow is permitted and after assembly rework is not recommended.
2) Vapor phase soldering may damage the sensor irreversibly.

For the customer, the allocated floor time (Out of bag) is 168 hours (at ≤30°C and 60% r.H.) according to IPC/JEDEC J-STD-020. If floor time exceeds, then the parts (Out of moisture barrier bag) need to be baked according to the following table:

Table 13 Baking condition of the XENSIV™ PASCO2

Package condition	Bake temperature	Bake time	Condition
Sensors outside of tape	125°C	24 hours	r.H. < 5%
Sensors within the tape	40°C	8 days	r.H. < 5%

6 Package information

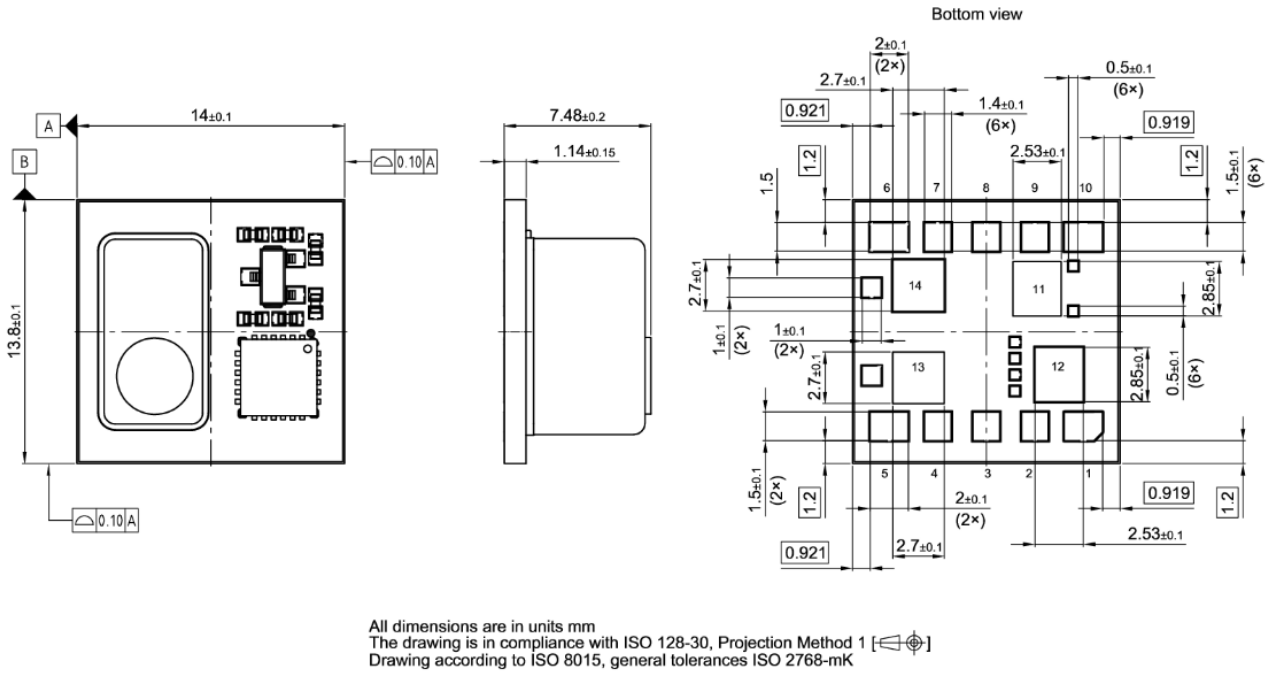

Figure 12 Package dimensions of XENSIV™ PAS CO2.

7 Packing for shipment

The device will be shipped in tape and reel. Each tape and reel consist of 300 parts.

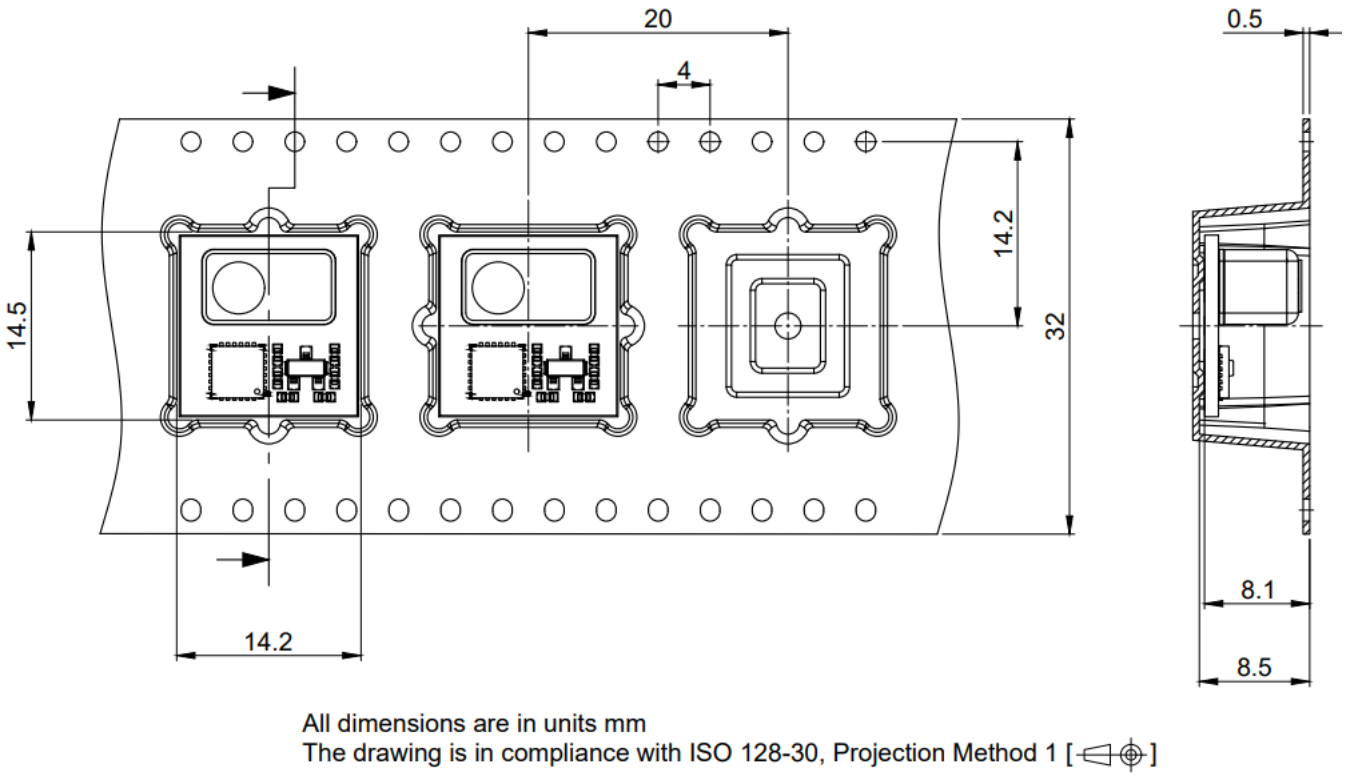

Figure 13 Tape and reel packing of XENSIV™ PAS CO2

8 Revision history

Table 14 Datasheet versions tracking

Reference	Description	Date
0.1	First copy of the preliminary datasheet	13.10.2020
0.2	Second copy of the preliminary datasheet	25.06.2021
1.0	First release of the datasheet	17.01.2022
1.1	Updated Storage condition, assembly instruction and minor cosmetic changes	13.06.2022
1.2	Storage during transportation, resolved ambiguity before paragraph 4.1.5, updated the baking time in assembly instruction and minor cosmetic changes	21.09.2022
1.3	Correction made in Storage condition section (non-evacuated instead of evacuated dry-pack). Note on typical sampling rate and sensor performance added. Parameter resolution added	21.11.2022
1.4	Halogen-free and RoHS symbol and storage time added/updated	06.03.2024
1.5	New OPN and SP#	09.04.2024
1.6	Typ. Accuracy spec for high CO2 concentration introduced, features list updated, footnote on uncertainty of calibration gas mixtures added.	26.08.2024

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