ENS190

NDIR CO$_2$ Sensor

ENS190 Datasheet

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The ENS190 is a high-performance, non-dispersive infrared (NDIR) CO_2 sensor designed for precise and reliable carbon dioxide measurement. It complies with key regulatory standards such as California Title 24, RESET, WELL, and ASHRAE. It is an ideal solution for air quality monitoring in smart buildings, HVAC systems, and other indoor environments.

At the core of the ENS190 is its patented **"M-shaped" long optical path gas chamber**, a uniquely engineered design that maximizes the effective optical path within a compact air cavity. This innovation, combined with a self-developed fully automated high-precision calibration system, ensures exceptional accuracy, consistency, and a wide measurement range. With its advanced sensing capabilities and robust design, the ENS190 provides a solution for applications demanding high-precision CO_2 monitoring.

Key Features & Benefits

High Accuracy & Stability – Delivers precise CO_2 measurements with long-term stability for reliable air quality monitoring.

Compliance with Industry Standards – Meets regulatory requirements, including California Title 24, RESET, WELL, and ASHRAE.

Automatic High-Precision Calibration – Self-calibrating system ensures consistent performance over time without manual intervention.

Fast Response Time – Achieves rapid measurement updates thanks to a much larger air intake aperture.

Small Long-Term Drift – Maintains measurement accuracy with a typical drift below 50 ppm over 3 months when automatic baseline correction is off.

Wide Measurement Range of 400 to 10000 ppm – Suitable for diverse applications, from indoor air quality monitoring to industrial CO_2 detection.

Applications

- HVAC / industrial automation / building control
- Air quality monitors
- Home appliances / air purifiers
- IoT devices
- Agriculture / greenhouses

Properties

- 33 x 20 x 9.6 mm^3 package
- CO_2 Accuracy: typical ±75ppm
- Measurement range 400 - 10000 ppm
- Temperature operating range from –5 to +50 ˚C
- Alarm output
- Average current consumption < 15 mA
- Long term stability and long lifetime >15 years
- Supply Voltage: 4.5 V to 5.5 V
- UART, PWM, RS485 and Modbus communication interface

Table of Contents

1 Quick Start

A typical application circuit for the ENS190, along with pseudo-code for quickly reading CO_2 values, is provided in Figure 1. For more detailed application examples please refer to chapter 9.

Basic application circuit
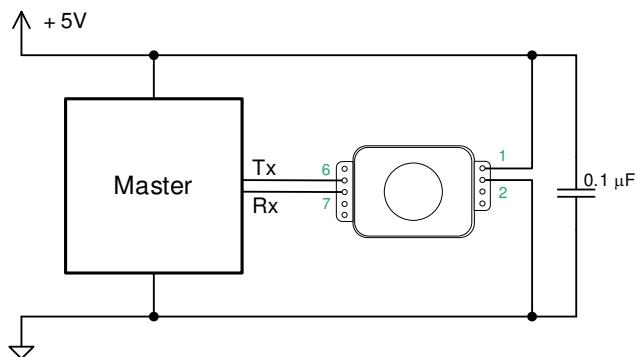
Pseudo code

```
Initialize UART with 9600 baud rate, 8N1 format
Repeat forever
    Write(0x1A, 0x01, 0x01, 0xE4) //Get CO2
    response = ReadBytes(8)       // Read response from the sensor into an array
    co2 = response[3] * 256 + response[4]
    Print("CO2 (ppm) = ", co2)
```

Figure 1: Typical application circuit (top) and pseudo code (bottom) for easy starting. For details on the sensor configuration see section 7.

Find code resources and drivers on:
- Arduino: https://github.com/sciosense/ens190-arduino

2   Pin assignment
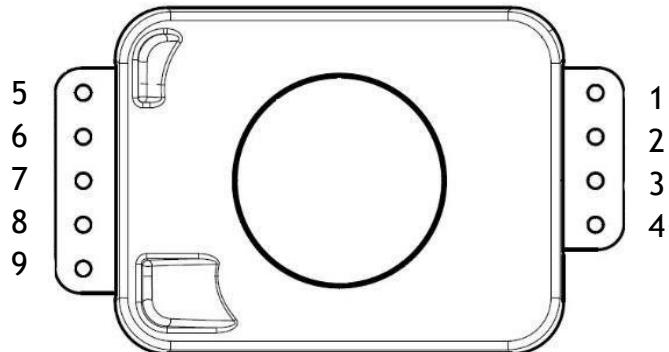
Figure 2: Pin diagram

Pins	Pin Name	Pin Type	Description
1	VDD	Supply	Positive supply voltage
2	GND	Supply	Ground supply voltage
3	ALM	Output	Alarm output
4	PWM	Output	CO_2 concentration
5	VO	Output	Power output (+3.3 V / 10 mA)[1]
6	RXD	Input	UART receive input
7	TXD	Output	UART transmit output
8	RT	Output	RS485 transmission direction control
9	CAL	Input	Calibration enable

Table 1: Pin description

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[1] Suitable for logic level conversion with 5 V MCU supply. Inductive noise or high current can affect sensor accuracy; use an external series resistor. No internal protection.

3 CO_2 Sensor Specifications

This sensor module complies with multiple well-established standards, ensuring high reliability and accuracy across various applications. It meets the requirements of UBA1 (Umweltbundesamt), WELL™ Building Standard, RESET® Air Standard, California Title 24, and ASHRAE. Compliance with these standards makes the sensor suitable for use in residential, commercial, and industrial environments. All CO_2 sensor specifications are summarized in Table 2. For a detailed visualization of the accuracy specifications, refer to Figure 4.

Table 2: CO_2 sensor specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
C_{RANGE}	Measurement range[2]		400		10000	ppm
C_{ACC}	Accuracy [3,4]	400-2500 ppm, 25 °C [5]		±75		ppm
		400-3000 ppm [3,6]		±(30 ppm+3 % of reading)		ppm
		3001-10000 ppm [3,6]		±5 % of reading		ppm
C_{RES}	Resolution			1		ppm
C_{TSTAB}	Temperature stability			±2.5		ppm / °C
t_{WARM}	Warm-up time				10	s
t_{RESP}	Response time ($τ_{63}$)	Step: 400 to 5000ppm			20	s
t_{MINT}	Measurement interval			4		s
t_{LS}	Life span		15			years

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[2] Sensor is designed to measure in the range 400–10000 ppm. Exposure to concentrations below 400 ppm may result in incorrect operation of ABC algorithm and should be avoided.

[3] Accuracy is specified with default operating conditions of –5…+50 °C, 0…90 %RH (non-condensing, dew point ≤ 35 °C), 1013 hPa, ABC on.

[4] The specified accuracy is referenced to certified calibration gas mixtures. For absolute measurements, the uncertainty of the calibration gas mixtures (±2 % at present) must be added to the stated accuracy. The sensor accuracy is calibrated during production; however, slight deviations may occur due to transportation and assembly after leaving the factory. To ensure optimal accuracy, it is recommended to perform a manual calibration or allow the sensor to remain powered on until it completes an Automatic Baseline Calibration (ABC) cycle.

[5] ANSI/ASHREA Addendum ab to ANSI/ASHRAE Standard 62.1-2022 specifies sensor to be accurate within ±75 ppm at concentrations of 600, 1000 and 2500 ppm, when measured at sea level at 77 °F (25 °C). See Figure 4.

[6] C_{TSTAB} should be taken into account for temperatures deviating from 25°C.
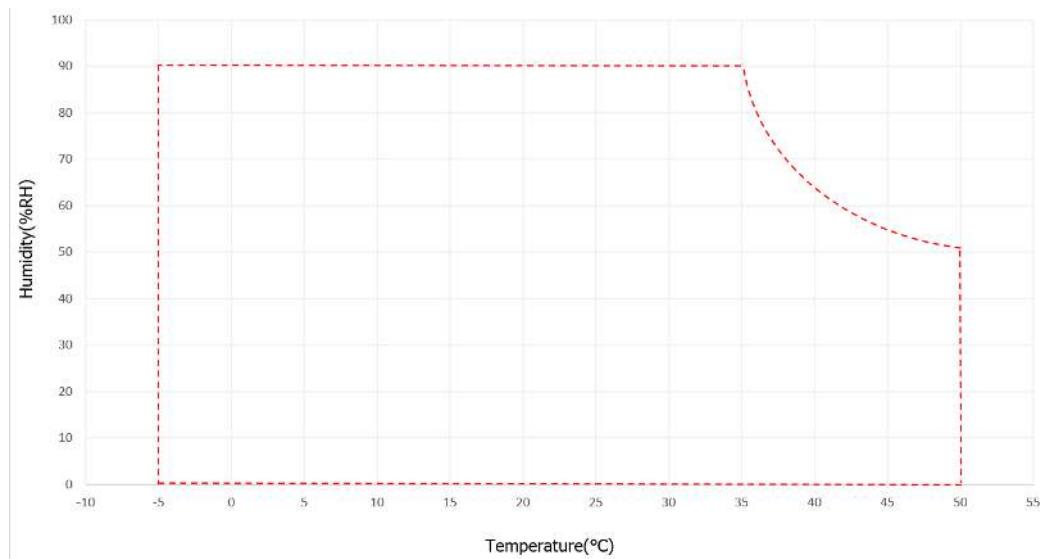
Figure 3: Sensor operating range
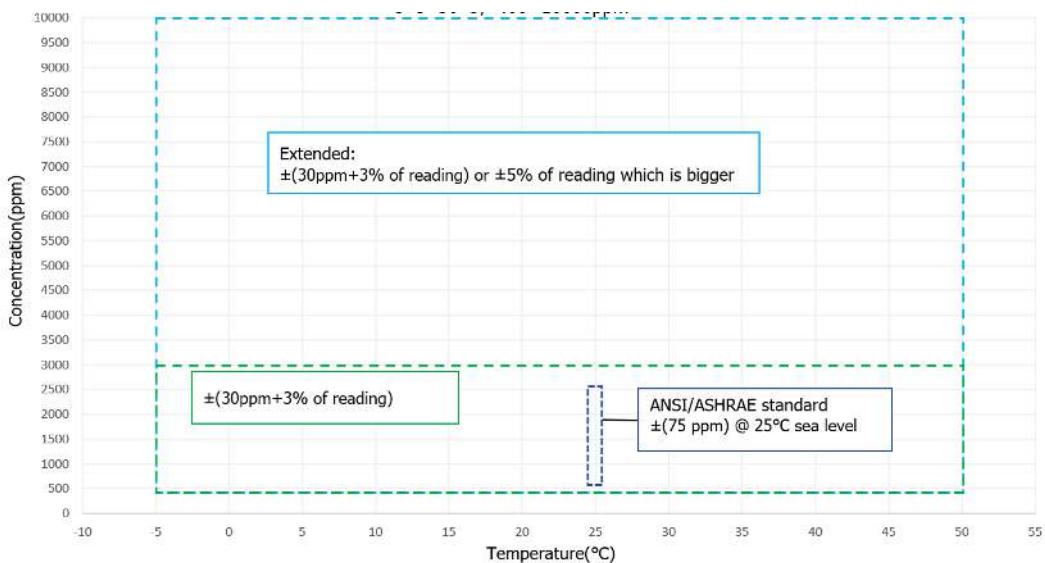
Figure 4: Typical CO_2 accuracy specifications

4 Electrical Specifications

Table 3: ENS190 electrical specifications

Symbol	Parameter	Min	Typ	Max	Unit	Note
V_{DD}	Power supply	4.5	5	5.5	V	
I_{AVG}	Average current consumption		15		mA	
I_{PEAK}	Peak current consumption			350	mA	<10 ms
V_{VO}	Reference voltage output	3.23	3.3	3.37	V	
I_{VO}	Reference output current			10	mA	
V_{IH}	High-level input voltage	$0.7 \times V_{VO}$			V	
V_{IL}	Low-level input voltage			$0.3 \times V_{VO}$	V	
V_{OH}	High-level output voltage	$V_{VO} - 0.6$			V	
V_{OL}	Low-level output voltage			0.4	V	
I_O	Output current	-10		10	mA	

5 Absolute maximum ratings

Table 4: Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Units	Comments
Electrical parameters					
V_{DD}	Supply voltage	-0.3	6.5	V	
V_{IO}	Interface voltage	-0.3	$V_{VO} + 0.3$	V	
Electrostatic discharge					
ESD_{HBM}	Electrostatic Discharge HBM	± 6000		V	IEC-61000-4-2 Grade 4
Operating and storage conditions					
T_{OP}	Operating Temperature	-5	50	°C	
T_{STRG}	Temperature at storage	-30	70	°C	
RH_{OP}	Operating Relative Humidity	0	95	%	Non-condensing
RH_{STRG}	Humidity at storage	0	95	%	Non-condensing

Stresses beyond those listed under Table 4: Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only including the operating and storage conditions. Functional operation of the device at these or any other conditions beyond those indicated under Table 3: ENS190 electrical specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability and lifetime.

Note: The ENS190 is not designed for use in safety-critical or life-protecting applications.

6 Functional description

6.1 Operational principle

The ENS190 CO_2 sensor utilizes a Non-Dispersive Infrared (NDIR) detection method to measure CO_2 concentration. This method relies on the absorption of infrared light by CO_2 molecules at a specific wavelength, providing a reliable and selective gas measurement. The sensor comprises four key components:

1. **Infrared Source**: Emits a beam of infrared (IR) light at a broad spectrum.

2. **Optical Cavity**: A controlled environment where the gas sample interacts with the IR light.

3. **Optical Filter**: Positioned before the detector, this filter selectively allows only the wavelength absorbed by CO_2 (4.26 µm) to pass through.

4. **Infrared Detector**: Measures the intensity of IR light after passing through the gas chamber, detecting the level of absorption caused by CO_2 molecules.
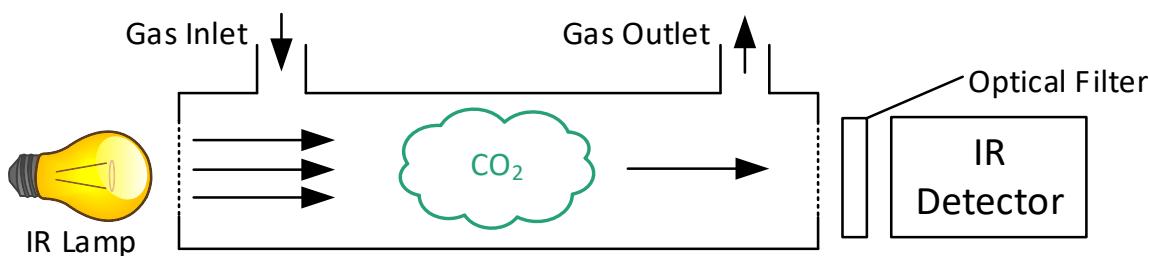

Figure 5: ENS190 measurement principle

The sensor operates by emitting infrared light from the IR source, which passes through the optical cavity containing the gas. CO_2 molecules absorb a specific portion of this light at a wavelength of 4.26 µm. The optical filter ensures that only this specific wavelength reaches the detector, which then measures the remaining light intensity. As CO_2 concentration increases, more infrared light is absorbed, reducing the signal detected by the sensor.

This absorption behavior follows **Lambert-Beer's Law**, which defines the relationship between light absorption and gas concentration:

$$A = \varepsilon \cdot c \cdot l$$

where:
- A = Absorbance
- ϵ = Molar absorptivity or extinction coefficient
- c = Concentration of CO_2 in the sample
- l = Optical path length through the optical cavity

According to this equation, absorbance is directly proportional to the CO_2 concentration and the optical path length. By continuously measuring the intensity of transmitted infrared light, the sensor calculates CO_2 levels with high precision.

6.2 Block diagram
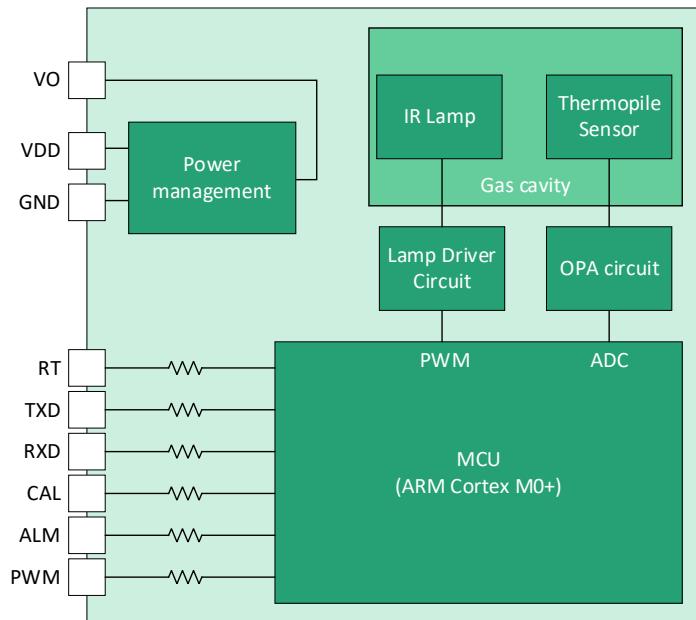
Figure 6: ENS190 block diagram

6.3 Sensor correction

6.3.1 Automatic Baseline Correction (ABC)

The sensor incorporates an Automatic Baseline Correction (ABC) feature to automatically compensate for sensor drift over time. ABC operates by periodically adjusting the sensor's baseline to account for long-term drift, ensuring accurate CO_2 measurements without manual calibration. By default, the sensor performs a baseline correction every 7 days (168 hours), but this interval can be adjusted if needed (see section 7.3.3). For the ABC feature to function correctly, the sensor must be exposed to fresh air (approximately 400 ppm CO_2) at least once during each 7-day cycle. In environments where CO_2 levels remain consistently elevated, manual calibration or user-defined baseline adjustments may be required to maintain accuracy.

6.3.2 Manual baseline correction

To quickly restore sensor accuracy after installation or a special event, a manual baseline correction can be performed. The procedure is as follows:

1. Place the sensor in an environment with a stable CO_2 concentration of approximately 400 ppm (fresh, clean air) for at least three minutes.

2. Connect the CAL pin (see chapter 2) of the sensor to GND for at least 4 seconds and maximum 8 seconds to trigger the correction process.

Manual baseline correction can also be executed via a command sent to the sensor. Please refer to section 7.3.5 for details on how to issue this command.

6.4 Alarm output

The sensor features a digital alarm output (pin ALM, see chapter 2) that provides a high or low signal based on the detected CO_2 concentration. This output can be used for triggering external devices such as ventilation systems, alarms, or controllers. It follows the following logic:

- High-Level Output: When the CO_2 concentration exceeds 1000 ppm (default threshold).

- Low-Level Output: When the CO_2 concentration falls below 800 ppm.

The alarm threshold is configurable via the communication protocol. Users can modify the threshold settings to meet specific application requirements. For detailed configuration instructions, refer to section 7.3.4.

7 UART Interface description

7.1 Transmission Characteristics

Table 5 details the UART Transmission Characteristics. Each data frame consists of a start bit, data, and stop bit. Data is sent asynchronously within each data frame. The data is all hexadecimal data.

Table 5: UART Transmission Characteristics (baud rate can be adapted, please refer to section 7.3.6)

Parameter	Value
Baud Rate	9600 Bd
Data Bit Size	8-bit
Start bit size	1
Stop Bit Size	1
Parity	None / disabled

7.2 Frame Format

The sensor operates as a slave device and only responds to commands issued by the master. It does not initiate communication autonomously. All transactions, including reading the CO_2 concentration and executing additional functions, must be initiated by the host system.

Host Command

Start (0x1A)	Length	Command	Data *D1*		Data *Dx*	Checksum

Device Answer

Start (0x1A)	Length	Command	Data *D1*		Data *Dx*	Checksum

Figure 7: UART Frame Format

Table 6: UART Protocol Format Description

Protocol Format	Description
Start	Fixed to 0x1A for both master and slave
Length	Length of frame bytes = data length + 1
Command	See Table 7
Data	Data of writing or reading, length is not fixed
Check Sum (CS)	See section 7.4

7.3 Command description

7.3.1 Overview

Table 7: UART command overview

Code	Action	Request Bytes	Response Bytes
0x01	Get CO_2 value	0	4
0x10	Set ABC parameters	2	2
0x13	Set alarm thresholds	4	4
0x18	Set CO_2 baseline manually	2	0
0x19	Set baud rate	1	1
0x0E	Get serial number	0	7
0x0F	Get firmware version number	0	11

7.3.2   Get CO₂ value

Read the current CO_2 concentration. Use the following equation to calculate D1 and D2:

$$CO_2 \, / \, [\text{ppm}] = [D1] \cdot 256 + [D2]$$

Table 8: Command Get CO₂ value

Command 0x01	Bytes	Description
Host command	0x1A 0x01 **0x01** 0xE4	
Device answer	0x1A 0x05 **0x01** [D1] … [D4] [CS]	[D1] and [D2]: CO₂ concentration in ppm [D3] and [D4]: Reserved

7.3.3   Set ABC parameters

This function configures the Automatic Baseline Correction (ABC) parameters, which are essential for maintaining long-term measurement accuracy and reliability. The ABC function periodically recalibrates the sensor to a baseline CO_2 concentration of 400 ppm, which is corresponding to fresh outdoor air, to compensate for sensor drift and ensure consistent performance.

To enable the ABC function, set the ABC period to any value other than 0. The ABC function is enabled by default with a period of 7 days (168 hours).

Use the following equation to calculate [D1] and [D2]:

$$ABC \; period \, / \, [\text{hours}] = [D1] \cdot 256 + [D2]$$

Table 9: Command Set ABC parameters

Command 0x10	Bytes	Description
Host command	0x1A 0x03 **0x10** [D1] [D2] [CS]	[D1] and [D2]: ABC period in hours
Device answer	0x1A 0x03 **0x10** [D1] [D2] [CS]	[D1] and [D2]: ABC period in hours

7.3.4   Set alarm thresholds

This function sets the high and low thresholds for the alarm output. Refer to section 6.4 for additional details. The threshold values are calculated using the following equations:

$$High \; alarm \; threshold \, / \, [ppm] = [D1] \cdot 256 + [D2]$$

$$Low \; alarm \; threshold \, / \, [ppm] = [D3] \cdot 256 + [D4]$$

By default, the high alarm threshold is set to 1000 ppm, and the low alarm threshold is set to 800 ppm. To read the currently programmed threshold values without modifying them, set [D1] to [D4] to 0xFF in the host command.

Table 10: Command Set alarm thresholds

Command 0x13	Bytes	Description
Host command	0x1A 0x05 **0x13** [D1] … [D4] [CS]	[D1] and [D2]: High alarm threshold [D3] and [D4]: Low alarm threshold Set [D1] to [D4] to 0xFF to read the currently programmed thresholds
Device answer	0x1A 0x05 **0x13** [D1] … [D4] [CS]	[D1] and [D2]: High alarm threshold [D3] and [D4]: Low alarm threshold

7.3.5   Set CO$_2$ baseline manually

Correct current CO$_2$ reading to a target concentration. Use the following equation to calculate D1 and D2:

$$CO_2 \,/\, [\text{ppm}] = [D1] \cdot 256 + [D2]$$

Table 11: Command Set CO$_2$ baseline manually

Command 0x18	Bytes	Description
Host command	0x1A 0x03 **0x18** [D1] [D2] [CS]	[D1] and [D2]: CO$_2$ concentration in ppm
Device answer	0x1A 0x01 **0x18** 0xD3	

Before performing the baseline correction, ensure that the CO$_2$ concentration in the environment is within the target correction range. Allow the sensor to stabilize in this environment for at least 5 minutes before initiating the correction process.

7.3.6 Set baud rate

The default baud rate is 9600 bps. It can be changed according to Table 12.

Table 12: Command Set baud rate

Command 0x19	Bytes	Description
Host command	0x1A 0x02 **0x19** [D1] [CS]	[D1]: Baud rate 0x00: 9600 bps 0x01: 2400 bps 0x02: 4800 bps 0x03: 19200 bps 0x04: 38400 bps 0x05: 115200 bps
Device answer	0x1A 0x02 **0x19** [D1] [CS]	[D1]: Baud rate

7.3.7 Get serial number

Table 13: Command Get serial number

Command 0x0E	Bytes	Description
Host command	0x1A 0x01 **0x0E** 0xD7	
Device answer	0x1A 0x08 **0x0E** [D1] … [D7] [CS]	[D1], [D2], [D3]: Production date, YYMMDD [D4] and [D5]: Serial number [D6] and [D7]: Reserved

7.3.8 Get firmware version

Table 14: Command Get firmware version

Command 0x0F	Bytes	Description
Host command	0x1A 0x01 **0x0F** 0xD6	
Device answer	0x1A 0x0C **0x0F** [D1] … [D11] [CS]	[D1] - [D11]: Firmware version

7.4   Checksum Calculation

To calculate the checksum, use the following equation:

$$CS = \left(n \times 256 - \sum_n \text{Bytes} \right) \% \ 256 = \left(- \sum \text{Bytes} \right) \bmod 256$$

Table 15 shows an example checksum calculation for reading the CO_2 concentration value.

Table 15: Example Checksum Calculation

Byte	1	2	3	4	5	6	7
Byte description	Start	Length	Command	Data D1	Data D2	Data D3	Data D4
Hexadecimal Value	0x1A	0x05	0x01	0x03	0x5C	0x00	0x00
Decimal Value	26	5	1	3	92	0	0
Equation	$CS = (8 \times 256 - (26 + 5 + 1 + 3 + 92 + 0 + 0)) \% \ 256$						
Result	$CS = (2048 - 127) \% \ 256 = 129 = 0x81$						

8   PWM Interface description

The PWM (Pulse Width Modulation) output encodes the measured CO_2 concentration linearly by its duty cycle. The following equation relates the duty cycle $t_{\text{high}}/t_{\text{period}}$ to the CO_2 concentration:

$$CO_2 \, / \, [\text{ppm}] = \frac{t_{\text{high}} \, / \, [\mu s]}{t_{\text{period}} \, / \, [\mu s]} \times 10000 \, [\text{ppm}]$$

In Table 16 the technical specifications of the PWM protocol are provided. The output signal can be converted by either directly measuring the pulse-duration or alternatively by employing a low-pass filter and measuring the output voltage.

Table 16: PWM characteristics

Parameter	Value
Base frequency	1 kHz
Duty cycle	1000 µs[7] Linear from 4 % to 100 % (400 to 10000 ppm)
Minimal step size of duty cycle	<1ppm (step size: 41.67 ns)
Output	3.3 V Push/Pull driver

If a low-pass filter is used to convert the PWM signal into an analog voltage for concentration measurement, the trade-offs between settling time, ripple, voltage accuracy deviation at the high level, and current consumption need to be considered in the design of the circuit. The following equation relates the analog voltage V_{meas} to the CO_2 concentration:

$$CO_2 \, / \, [\text{ppm}] = \frac{V_{\text{meas}}}{V_{\text{VO}}} \times 10000 \, [\text{ppm}]$$

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[7] The error of the MCU crystal oscillator is:+2 % / -4 %(T_j:-40~85 °C); ±0.7 % (T_A=25 °C)

9 Application information and use case examples

9.1 UART operation

9.1.1 Basic circuitry
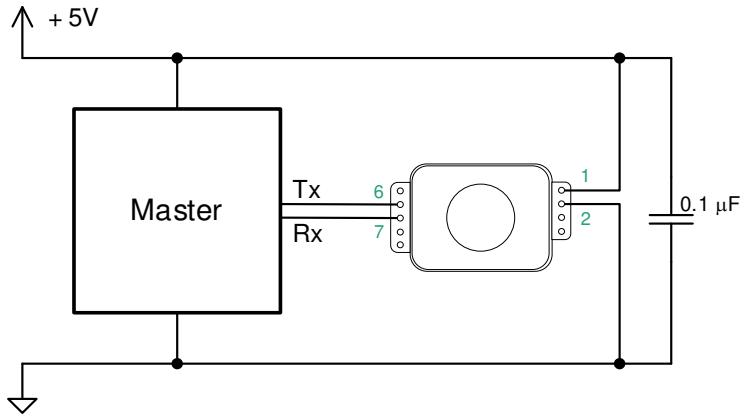
Figure 8: Recommended application circuit for UART operation

Note(s):

- Both the TXD and RXD pin of the ENS190 are connected internally through a 270 Ω series resistor
- The RXD pin additionally has an internal pull-up resistor of 27 kΩ

9.1.2 Example code

The following code is a functional example and does not include error checking, so it is not suited for production.

```
Initialize UART with 9600 baud rate, 8N1 format
Repeat forever
    Write(0x1A, 0x01, 0x01, 0xE4);    // Get CO2

    if (AvailableBytesOnUART2 >= 8)
        response = ReadBytes(8);        // Read response from the sensor into an array
        for(i = 0; i < length(response); ++i) {
            sum += response[i];          // Sum all bytes including the CRC byte
        }
        if ((sum & 0xff) == 0) { // & 0xff = % 256
            co2 = (response[3] << 8) | response[4]; //=response[3]*256 + response[4]
            Print("CO2 (ppm) = ", co2);
        } else {
            Print("Warning: Data transaction fault");
        }
    Wait(4 s);
```

9.2 RS485 operation circuitry
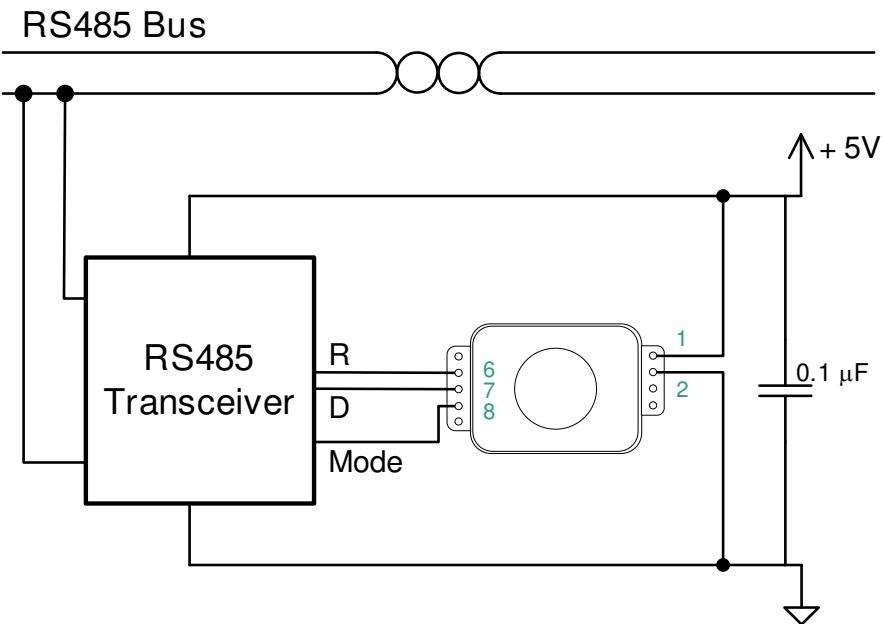
Figure 9: Recommended application circuit for RS485 operation

10   Soldering information

ScioSense recommends hand soldering to ensure better process control and minimize stress on the sensor.

For hand soldering, use a soldering iron with a temperature of 380 ˚C, applying heat for 2 seconds per pin. If selective soldering using the drag soldering method is required, maintain a soldering temperature of 295 ˚C for a duration of 3 seconds.

11 Mechanical dimensions

The ENS190 is delivered with two pin header strips attached, featuring a 2.54 mm (0.1 inch) pitch, which can be used to establish a connection between the device and the PCB. Figure 10 provides the mechanical dimensions of the ENS190 sensor without pin headers.
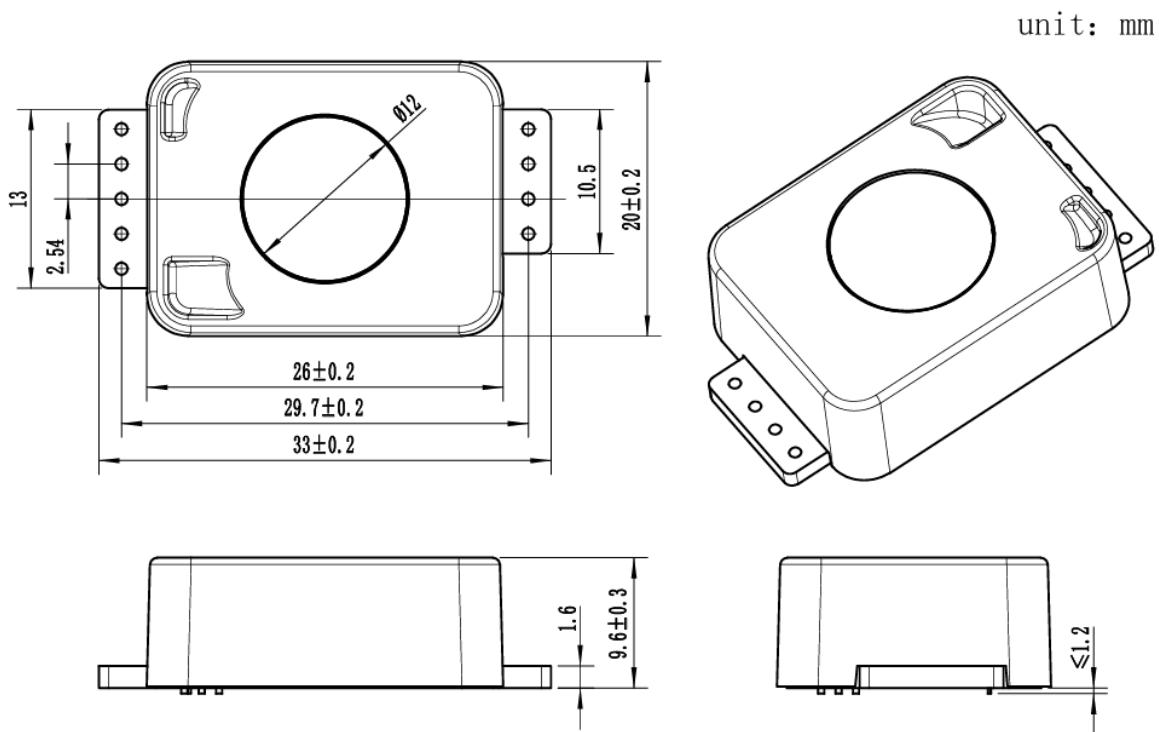

Figure 10: Mechanical dimensions (without pin-headers)

12 Ordering information

Table 17: Ordering information

Ordering Code	Material ID	Delivery Form	Delivery Quantity	Description
ENS190	510540001	Box	200 pcs	Sensor part
ENS190_EK V1	510540000	Box	1 pc	Evaluation Kit

13   Shipment & Packaging

The ENS190 sensors are shipped in boxes of 200 pieces containing 10+1 trays. The top layer tray serves as a protective limit function and does not contain any sensors. Each of the subsequent 10 trays holds 20 ENS190 sensors. Refer to Figure 11 for the box outline and packaging details.


H : 169mm

L : 234mm   W : 194mm
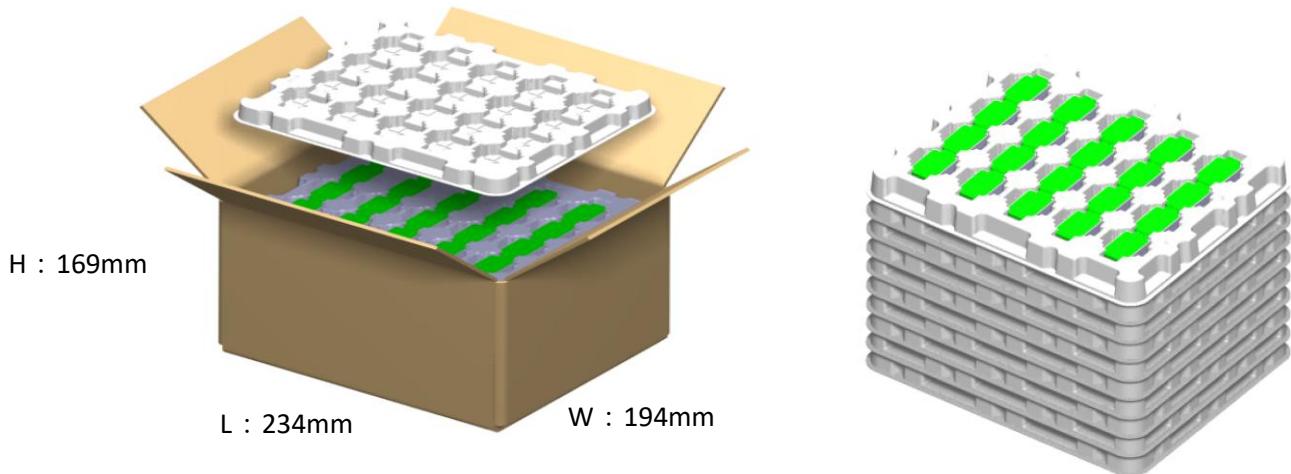
Figure 11: Packaging details

14   RoHS Compliance & ScioSense Green Statement

RoHS: The term RoHS compliant means that Sciosense B.V. products fully comply with current RoHS directives. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead does not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes.

ScioSense Green (RoHS compliant and no Sb/Br): ScioSense Green defines that in addition to RoHS compliance, our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

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16 Document status

Table 18: Document status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice.
Preliminary Datasheet	Pre-Production	Information in this datasheet is based on products in the design, validation or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice.
Datasheet	**Production**	**Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade.**
Datasheet (Discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of ScioSense B.V. standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs.

17 Revision information

Table 19: Revision history

Revision	Date	Comment	Page
1.0	2025-05-05	Final version	All
0.8	2025-03-27	Correct mistake in ABC period calculation	16
0.8	2025-03-26	Second version	All
0.7	2024-05-13	Initial Preliminary version	All

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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