

RRH47000

NDIR CO<sub>2</sub> Sensor

**Description**

The RRH47000 sensor module uses non-dispersive infrared (NDIR) technology to accurately measure CO<sub>2</sub> in a compact package size while ensuring competitive pricing.

An integrated relative humidity and temperature sensor enables calibration and compensation of the NDIR sensor for precise operation in different environments. The integrated sensor signal conditioning and an MCU allow algorithms to use the correlation between all built-in sensing elements to improve the accuracy of each measurement.

CO<sub>2</sub> level is a key parameter for indoor air quality. The sensor module enables active, real-time monitoring of CO<sub>2</sub> along with humidity and temperature, allowing automated demand-controlled ventilation and environment control for better air quality, energy efficiency, and wellbeing of occupants.

RRH47000 is configurable with selectable UART or I<sup>2</sup>C interface, with a 40.8 × 19.7 × 9.1 mm package.

**Features**

- Best-in-class NDIR CO<sub>2</sub> sensor technology
- Integrated temperature and humidity sensor
- CO<sub>2</sub> measurement range: 0 ppm to 5000 ppm
- CO<sub>2</sub> Accuracy: typical ±75ppm
- Current consumption: < 50mA at 1s sample time
- I<sup>2</sup>C and UART interface
- Package: 40.8 × 19.7 × 9.1 mm pin type
- Long term stability and long lifetime >15 years
- Supply Voltage: 4.5V to 5.5V
- Compliant with RESET<sup>®</sup>, California Title 24, UBA and WELL Building Standard<sup>™</sup>

**Applications**

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



Figure 1. Sensor Module

## Contents

|   |           |
|---|-----------|
| <b>1. Overview</b>  | <b>4</b>  |
| 1.1 Functional Overview   | 4         |
| 1.2 Block Diagram   | 5         |
| <b>2. Pin Information</b>   | <b>6</b>  |
| 2.1 Pin Assignments   | 6         |
| 2.2 Pin Descriptions  | 6         |
| <b>3. Specifications</b>  | <b>7</b>  |
| 3.1 Absolute Maximum Ratings  | 7         |
| 3.2 Recommended Operating Conditions  | 7         |
| <b>4. Sensor Module Specifications</b>                                      | <b>8</b>  |
| 4.1 CO <sub>2</sub> Sensor Specifications                                   | 8         |
| 4.2 Humidity and Temperature Sensor Specifications                          | 8         |
| <b>5. Sensor Placement</b>  | <b>9</b>  |
| <b>6. Sensor Correction</b>   | <b>10</b> |
| 6.1 Automatic Baseline Correction (ABC)                                     | 10        |
| 6.2 Manual Baseline Correction  | 10        |
| <b>7. Functional Description</b>  | <b>11</b> |
| 7.1 UART Interface  | 11        |
| 7.1.1 Typical Application Circuit for UART Interface                        | 11        |
| 7.1.2 UART Transmission Characteristics                                     | 11        |
| 7.1.3 Basic Data Transmission Format UART                                   | 12        |
| 7.1.4 UART Command Description  | 12        |
| 7.2 I <sup>2</sup> C Interface  | 16        |
| 7.2.1 Typical Application Circuit for I <sup>2</sup> C Interface            | 16        |
| 7.2.2 I <sup>2</sup> C Transmission Characteristics                         | 17        |
| 7.2.3 I <sup>2</sup> C Features and Timing                                  | 17        |
| 7.2.4 Basic Data Transmission Format I <sup>2</sup> C                       | 18        |
| 7.2.5 I <sup>2</sup> C Command Description                                  | 18        |
| 7.3 Calculating CO <sub>2</sub> , Temperature, and Relative Humidity Output | 21        |
| 7.4 Checksum Calculation  | 22        |
| <b>8. Storage and Handling</b>  | <b>22</b> |
| <b>9. Marking Diagram</b>   | <b>23</b> |
| <b>10. Quality and Reliability</b>  | <b>23</b> |
| <b>11. Package Outline Drawings</b>   | <b>23</b> |
| <b>12. Ordering Information</b>   | <b>23</b> |
| <b>13. Revision History</b>   | <b>24</b> |

## Figures

|  |    |
|--|----|
| Figure 1. Sensor Module .....  | 1  |
| Figure 2. Functional Overview of RRH47000 .....                          | 4  |
| Figure 3. Functional Block Diagram of RRH47000 .....                     | 5  |
| Figure 4. Pin Assignments – Top View .....                               | 6  |
| Figure 5. Sensor Placement Recommendation .....                          | 9  |
| Figure 6. Application Circuit for UART Communication .....               | 11 |
| Figure 7. Data Transmission Format UART Communication .....              | 12 |
| Figure 8. Application Circuit for I <sup>2</sup> C Communication .....   | 16 |
| Figure 9. I <sup>2</sup> C Timing Diagram .....                          | 17 |
| Figure 10. Data Transmission Format I <sup>2</sup> C Communication ..... | 18 |
| Figure 11. Sticker Label RRH47000 .....                                  | 23 |

## Tables

|  |    |
|--|----|
| Table 1. Pin Descriptions .....  | 6  |
| Table 2. Absolute Maximum Ratings .....  | 7  |
| Table 3. Electrical Specifications .....   | 7  |
| Table 4. CO <sub>2</sub> Sensor Specifications .....   | 8  |
| Table 5. Humidity and Temperature Sensor Specifications, T <sub>A</sub> = +25°C, V <sub>DD</sub> = 1.71V to 3.6V ..... | 8  |
| Table 6. UART Protocol Format Description .....  | 12 |
| Table 7. Overview of Available UART Commands .....   | 12 |
| Table 8. Example Request to Disable “Automatic Baseline Correction” .....  | 14 |
| Table 9. Example Request to Open ABC and Set Correction Cycle .....  | 14 |
| Table 10. Example Request to Change Correction Cycle .....   | 14 |
| Table 11. I <sup>2</sup> C Transmission Characteristics .....  | 17 |
| Table 12. I <sup>2</sup> C Timing Parameters .....   | 17 |
| Table 13. Overview of Available I <sup>2</sup> C Commands .....  | 18 |
| Table 14. Equations to Calculate the Measurement Outputs .....   | 21 |
| Table 15. Calculation Example for Measurement Outputs .....  | 21 |
| Table 16. Example Checksum Calculation for UART .....  | 22 |
| Table 17. Example Checksum Calculation for I <sup>2</sup> C .....  | 22 |

# 1. Overview

## 1.1 Functional Overview

This CO<sub>2</sub> sensor uses a non-dispersive infrared (NDIR) detection method. The sensor consists of four main components:

1. **Infrared Source:** Emits a beam of infrared light.
2. **Sample Chamber:** A chamber where the gas sample is introduced.
3. **Optical Filter:** An IR filter positioned in front of the detector, allowing only specific wavelengths of infrared light to pass through. This ensures that only the light absorbed by CO<sub>2</sub> reaches the detector.
4. **Infrared Detector:** Measures the intensity of the infrared light that passes through the filter and sample chamber

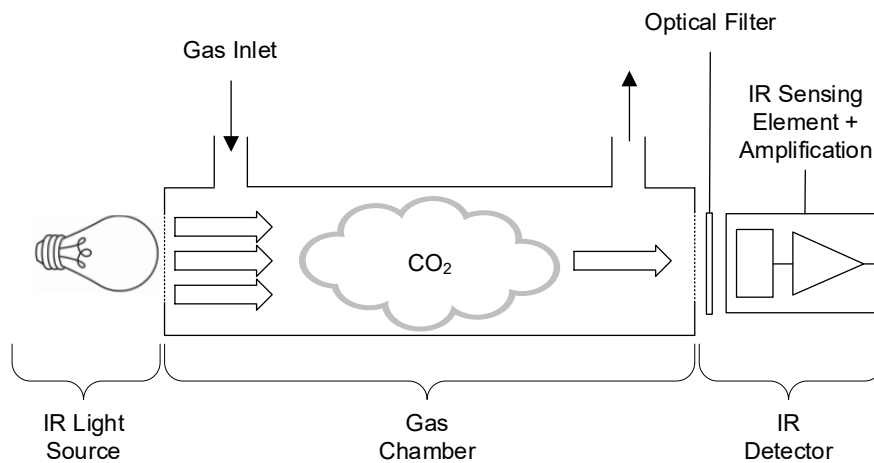


Figure 2. Functional Overview of RRH47000

Inside the sensor, an infrared light source emits a specific wavelength, in this case 4.26 $\mu$ m, that is absorbed by CO<sub>2</sub> molecules. A filter blocks all other wavelengths of light. The remaining light passes through the gas chamber and the sensor measures the intensity of light that reaches it. As CO<sub>2</sub> concentration increases, more light is absorbed, and the sensor output signal changes accordingly. This relationship between light absorption and gas concentration is described by the Lambert-Beer Law.

The Lambert-Beer Law, also known as Beer's Law, quantifies the relationship between the concentration of a gas and the absorption of light. The law is mathematically expressed as:

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

where:

- ( $A$ ) is the absorbance (no units)
- ( $\varepsilon$ ) is the molar absorptivity or extinction coefficient ( $L \cdot mol^{-1} \cdot cm^{-1}$ )
- ( $c$ ) is the concentration of the absorbing species in the sample ( $mol \cdot L^{-1}$ )
- ( $l$ ) is the path length through which the light passes in the sample (cm)

This law illustrates that absorbance is directly proportional to the concentration of the absorbing species and the path length the light travels through the sample.

## 1.2 Block Diagram

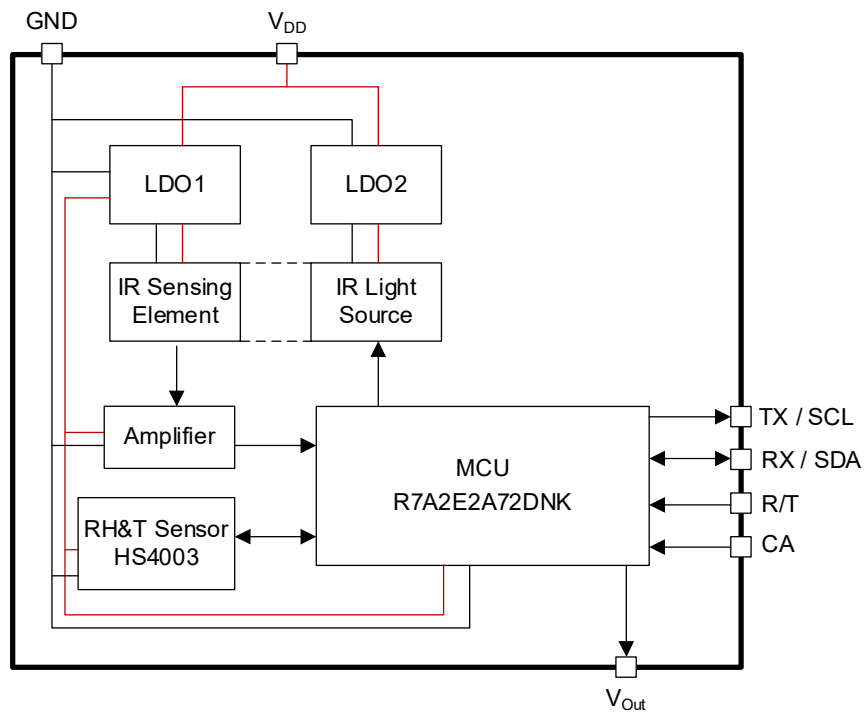


Figure 3. Functional Block Diagram of RRH47000

## 2. Pin Information

### 2.1 Pin Assignments

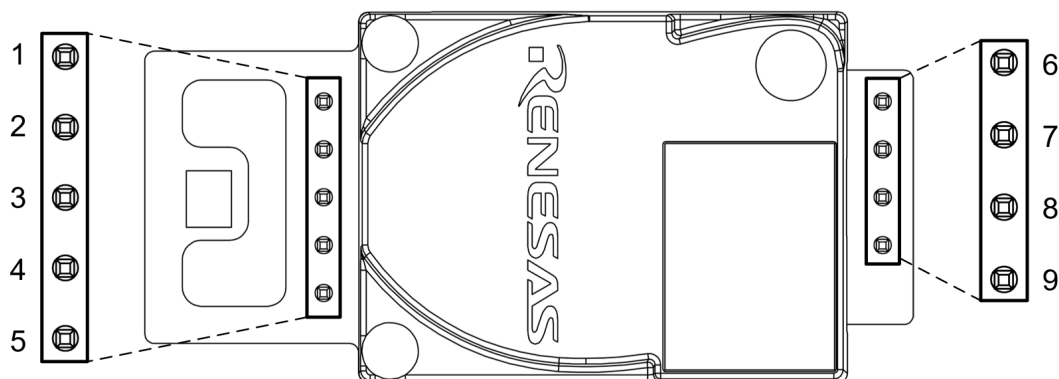


Figure 4. Pin Assignments – Top View

### 2.2 Pin Descriptions

Table 1. Pin Descriptions

| Pin Number | Pin Name         | Description   |
|------------|------------------|---|
| 1          | V <sub>Out</sub> | Power output (+3.3V/100mA).   |
| 2          | RX               | UART-RX (Receiving).  |
|            | SDA              | I <sup>2</sup> C data (slave address 0x31).   |
| 3          | TX               | UART-TX (Sending).  |
|            | SCL              | I <sup>2</sup> C clock.   |
| 4          | R/T              | Output mode selection, high level or floating for UART, low level for I <sup>2</sup> C. |
| 5          | CA               | Manual Correction.  |
| 6          | V <sub>DD</sub>  | Power supply input (+4.5V to +5.5V).  |
| 7          | GND              | Ground.   |
| 8          | DNC              | Do not connect. Leave floating.   |
| 9          | DNC              | Do not connect. Leave floating.   |

### 3. Specifications

#### 3.1 Absolute Maximum Ratings

**Caution:** Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions can adversely impact product reliability and result in failures not covered by warranty.

Table 2. Absolute Maximum Ratings

| Parameter                 | Minimum | Maximum | Unit |
|---------------------------|---------|---------|------|
| Supply Voltage            | 3.7     | 6       | V    |
| Storage Temperature Range | -40     | 85      | °C   |

#### 3.2 Recommended Operating Conditions

Table 3. Electrical Specifications

| Parameter                        | Condition             | Minimum | Typical | Maximum | Unit |
|----------------------------------|-----------------------|---------|---------|---------|------|
| Operating Supply Voltage         | -                     | 4.5     | 5       | 5.5     | V    |
| Operating/Storage Humidity Range | Non-condensing        | 0       | -       | 95      | %RH  |
| Operating Temperature Range      | -                     | -10     | -       | 50      | °C   |
| Storage Temperature Range        | -                     | -30     | -       | 70      | °C   |
| Sleep Current                    | -                     | -       | 5       | -       | mA   |
| Average Current                  | 1s sample time        | -       | 10      | -       | mA   |
| Peak Current <sup>[1]</sup>      | 1s sample time        | -       | -       | 220     | mA   |
| Sampling Interval                | -                     | -       | 1       | -       | s    |
| Preheating time                  | -                     | 30      | -       | -       | s    |
| Startup Time for Communication   | UART                  | 0.5     | -       | -       | s    |
|                                  | I <sup>2</sup> C      | 3       | -       | -       | s    |
| Signal Output Voltage Level      | UART/I <sup>2</sup> C | -       | 3.3     | -       | V    |

1. Describes the peak current when emitter is switched on.

## 4. Sensor Module Specifications

### 4.1 CO<sub>2</sub> Sensor Specifications

This sensor module is fully compliant with several well-established standards, ensuring its reliability and accuracy in various applications. It meets the requirements set by UBA<sup>1</sup> (Umweltbundesamt), WELL™ Building Standard<sup>2</sup>, RESET® Air Standard<sup>3</sup>, and California Title 24<sup>4</sup>. This allows the sensors to be used in residential, commercial, and industrial environments.

Table 4. CO<sub>2</sub> Sensor Specifications

| Parameter   | Conditions                            | Minimum | Typical | Maximum               | Unit    |
|---|---------------------------------------|---------|---------|-----------------------|---------|
| CO <sub>2</sub> Measurement range, default <sup>[1]</sup> | Fast ABC turned on                    | 400     | -       | 5000                  | ppm     |
| CO <sub>2</sub> Measurement range, extended               | Fast ABC turned off                   | 0       | -       | 5000                  | ppm     |
| Operating Temperature Range                               | -                                     | -10     | -       | 50                    | °C      |
| Accuracy <sup>[2][3]</sup>                                | 0 to 5000 ppm, -10°C~50°C and 0-85%RH | -       | ±75     | ± (30+ 3% of reading) | ppm     |
| Accuracy Drift  | Without regular ABC                   | -       | 3       | -                     | ppm/day |
| Life span   | -                                     | 15      | -       | -                     | years   |
| Response time   | $T_{90\%}$                            | -       | 80      | -                     | s       |

1. Sensor is designed to measure in the range 0~5000ppm; nevertheless, exposure to concentrations below 400ppm may result in incorrect operation of ABC algorithm and should be avoided for model with auto baseline correction (ABC) ON.
2. In normal IAQ applications, accuracy is defined after minimum three (3) ABC (automatic baseline correction) periods of continuous operation with ABC on.
3. Specification is referenced to certified calibration mixtures. Uncertainty of calibration gas mixtures (vendor dependent, typical ±2%) have to be added to the specified accuracy for absolute measurement.

### 4.2 Humidity and Temperature Sensor Specifications

Table 5. Humidity and Temperature Sensor Specifications, T<sub>A</sub> = +25°C, V<sub>DD</sub> = 1.71V to 3.6V

| Parameter               | Condition    | Minimum | Typical | Maximum | Unit |
|-------------------------|--------------|---------|---------|---------|------|
| <b>Humidity Sensor</b>  |              |         |         |         |      |
| Range                   | -            | 0       | -       | 100     | %RH  |
| Accuracy <sup>[1]</sup> | 20% to 80%RH | -       | ±3.5    | -       | %RH  |
| Resolution              | 14-bit       | -       | 0.04    | -       | %RH  |
| Hysteresis              | -            | -       | -       | ±1.0    | %RH  |

<sup>1</sup> Umweltbundesamt, Gesundheitliche Bewertung von Kohlendioxid in der Innenraumluft, (Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 2008).

<sup>2</sup> WELL v2 pilot, Q4 2022.

<sup>3</sup> RESET Air Standard v2.0 Grade B, 2018.

<sup>4</sup> California Building Energy Efficiency Standards for Residential and Nonresidential Buildings, 2022.



| Parameter  | Condition               | Minimum | Typical | Maximum | Unit   |
|--|-------------------------|---------|---------|---------|--------|
| Non-linearity from Response Curve                  | 20% to 80% RH           | -       | ±0.15   | ±0.25   | %RH    |
| Long-Term Stability                                | -                       | -       | ±0.1    | -       | %RH/Yr |
| Response Time Constant <sup>[2]</sup> ( $\tau_H$ ) | 20% to 80% RH Still Air | 3.0     | 4.0     | 6.0     | s      |
| <b>Temperature Sensor</b>                          |                         |         |         |         |        |
| Range  | -                       | -40     | -       | 125     | °C     |
| Accuracy   | -                       | -       | ±0.5    | -       | °C     |
| Resolution   | 14-bit                  | -       | 0.01    | -       | °C     |
| Response Time Constant <sup>[3]</sup> ( $\tau_T$ ) | -                       | -       | >2.0    | -       | s      |
| Long-Term Stability                                | -                       | -       | -       | 0.03    | °C/Yr  |

1. Monotonic increases from 20 to 80% RH after sensor has been stabilized at 50% RH.
2. Initial value to 63% of total variation. Response time depends on system airflow.
3. Initial value to 63% of total variation. Response time depends on system thermal mass and air flow.

## 5. Sensor Placement

To ensure a proper airflow to the CO<sub>2</sub> sensing path, a minimum distance of 1.5mm between the area of the waterproof filter and the other components must be considered. Not keeping the minimum distance will result in a slower sensor response time to environmental changes.

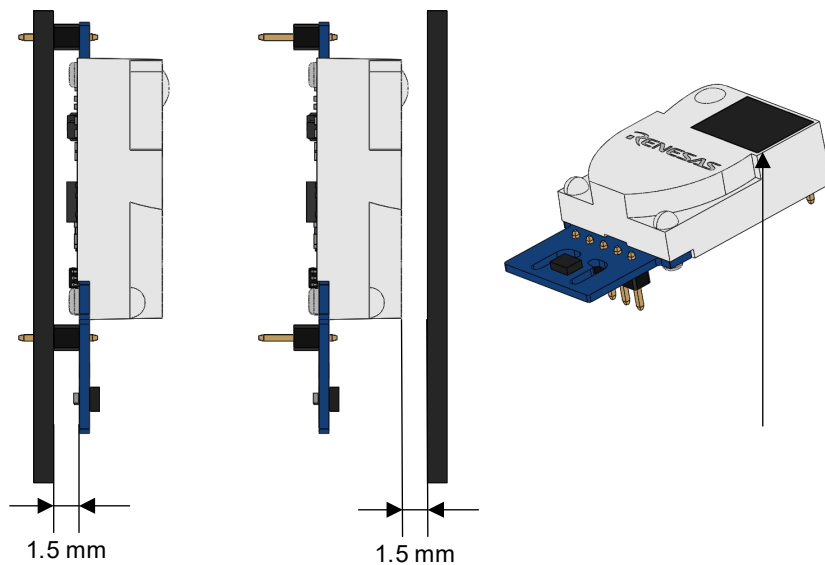


Figure 5. Sensor Placement Recommendation

## 6. Sensor Correction

### 6.1 Automatic Baseline Correction (ABC)

To ensure optimal performance, handle the CO<sub>2</sub> sensor with care during transport and installation. Rough handling, sensor aging, and drastic environmental changes may cause a reduction in accuracy.

The sensor incorporates an auto-baseline correction (ABC) feature to automatically compensate for drift. This feature operates as follows:

- **Initial Baseline Correction:** After the sensor is powered on, it continuously monitors the CO<sub>2</sub> levels for 24 hours. The lowest measured concentration during this period is established as the new baseline.
- **Periodic Baseline Correction:** Following the initial 24-hour period, the sensor automatically performs baseline correction every 7 days. The time interval for the periodic baseline correction can be adjusted.

For the ABC feature to function correctly, the sensor must be exposed to fresh air (approximately 400ppm CO<sub>2</sub>) during both the initial 24-hour period and subsequent 7-day correction cycles. Ensure the sensor's locations allows for such exposure.

### 6.2 Manual Baseline Correction

To quickly restore sensor accuracy after installation or some special event, perform a manual baseline correction. To do this, place the sensor in an environment with a stable CO<sub>2</sub> concentration of approximately fresh, clean air (400 ppm). Connect the CA pin of the sensor to GND for at least 3 seconds. The total duration of the manual baseline correction is determined by the distance in ppm between the current ppm level and the set baseline level. The sensor requires 1 additional second for every 25 ppm.

Example calculation for a 400ppm baseline and 500ppm current CO<sub>2</sub> reading:

3s (trigger) + 1s (calc/storage) + 4s ((500ppm – 400ppm) / 25ppm) = 8s (total)

Manual correction can also be performed by sending a command to the sensor. Refer to the communication protocol documentation ([7.1.4.7](#) and [7.2.5.4](#)) for details on how to send this command.

## 7. Functional Description

### 7.1 UART Interface

#### 7.1.1 Typical Application Circuit for UART Interface

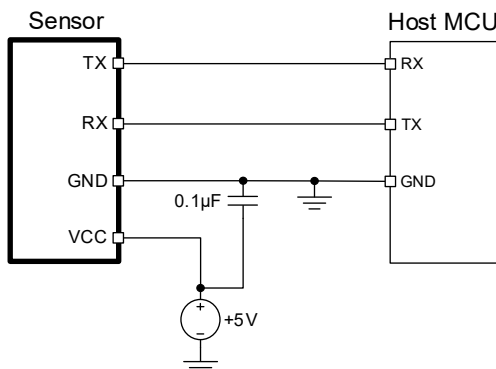


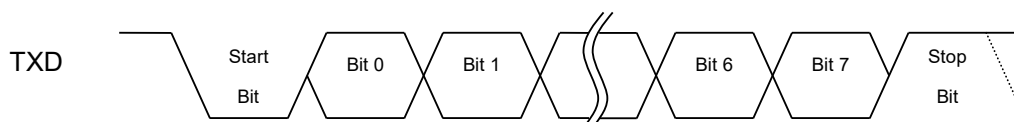
Figure 6. Application Circuit for UART Communication

#### 7.1.2 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 (for example: "46" for decimal [70]). After power-on, the sensor needs at least 0.5s to start communication via UART.

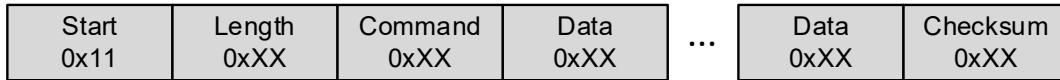
[x x] is for single-byte data (unsigned, 0-255); for double data, high byte is in front of low byte.

| Parameter      | Value    |
|----------------|----------|
| Baud Rate      | 9600 bps |
| Data Bite Size | 8-bit    |
| Stop Bit Size  | 1-bit    |
| Parity         | No       |
| Flow Control   | No       |



### 7.1.3 Basic Data Transmission Format UART

#### Command Request



#### Command Response

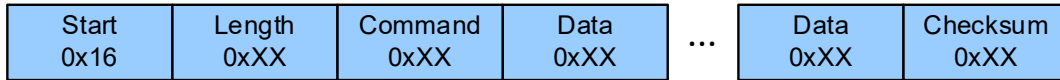


Figure 7. Data Transmission Format UART Communication

Table 6. UART Protocol Format Description

| Protocol Format | Description   |
|-----------------|---|
| Start           | Master to slave is fixed to [0x11], slave to master is fixed to [0x16]. |
| Length          | Length of frame bytes = data length +1 (including Command + Data).      |
| Command         | See <a href="#">Table 7</a> .   |
| Data            | Data of writing or reading, length is not fixed.                        |
| Check Sum       | See <a href="#">Checksum Calculation</a> .                              |

### 7.1.4 UART Command Description

#### 7.1.4.1 Overview of UART Commands

Table 7. Overview of Available UART Commands

| Code | Action                                 | Request Bytes | Response Bytes |
|------|--|---------------|----------------|
| 0x0B | Set Measurement Range.                 | 5             | 4              |
|      | Get Measurement Range.                 | 4             | 5              |
| 0x31 | Get Measurement Results.               | 4             | 12             |
| 0x10 | Set ABC Parameters.                    | 10            | 4              |
| 0x0F | Get ABC Parameters.                    | 4             | 10             |
| 0x03 | Set CO <sub>2</sub> Baseline Manually. | 6             | 4              |
| 0x1F | Get Serial Number.                     | 4             | 20             |
| 0x1E | Get Firmware Version Number.           | 4             | 15             |

### 7.1.4.2 Set Measurement Range

Read the current measurement range setting.

|                       | Value | Bytes [Hex]                    | Description                                     |
|-----------------------|-------|--------------------------------|---|
| <b>Command</b>        | 0x0B  | -                              | -   |
| <b>Request bytes</b>  | 5     | [0x11] [0x02] [0x0B] [D1] [CS] | -   |
| <b>Response bytes</b> | 4     | [0x16] [0x02] [0x0B] [DE]      | [D1]:<br>0 = 0 – 5000 ppm<br>1 = 400 – 5000 ppm |

### 7.1.4.3 Get Measurement Range

Read the current measurement range setting.

|                       | Value | Bytes [Hex]                    | Description                                     |
|-----------------------|-------|--------------------------------|---|
| <b>Command</b>        | 0x0B  | -                              | -   |
| <b>Request bytes</b>  | 4     | [0x11] [0x01] [0x0B] [0xE3]    | -   |
| <b>Response bytes</b> | 5     | [0x16] [0x02] [0x0B] [D1] [CS] | [D1]:<br>0 = 0 – 5000 ppm<br>1 = 400 – 5000 ppm |

### 7.1.4.4 Get Measurement Results

Read all measurement results of the RRH47000. Returns CO<sub>2</sub> (ppm), temperature (°C), and humidity (%RH) bytes. For more information on how to convert these bytes into the respective measure, see section 7.3.

|                       | Value | Bytes [Hex]                             | Description  |
|-----------------------|-------|---|--|
| <b>Command</b>        | 0x31  | -                                       | -  |
| <b>Request bytes</b>  | 4     | [0x11] [0x01] [0x31] [0xBD]             | -  |
| <b>Response bytes</b> | 12    | [0x16] [0x09] [0x31] [D1] ... [D8] [CS] | [D1] and [D2]: CO <sub>2</sub> Results<br>[D3] and [D4]: Reserved<br>[D5] and [D6]: Temperature Results<br>[D7] and [D8]: Humidity Results |

### 7.1.4.5 Set ABC parameters

This function is used to set the automatic baseline correction (ABC) parameters. The ABC function is crucial for maintaining the accuracy and reliability of the sensor's long-term CO<sub>2</sub> measurements. By periodically recalibrating the sensor to a baseline CO<sub>2</sub> concentration, typically representing fresh outdoor air, the ABC function compensates for sensor drift and ensures consistent performance.

A fast automatic baseline correction (fast ABC) occurs when the sensor undergoes a correction process outside the set correction period (default 24 h/7 days). This correction is typically triggered during periods of exceptionally low CO<sub>2</sub> concentrations that are unrealistic for fresh air (below 400ppm). The fast ABC ensures that the sensor quickly adapts to new baseline CO<sub>2</sub> concentrations, thereby maintaining its accuracy and reliability in dynamic conditions.

The CO<sub>2</sub> baseline value is used to set the lowest expected CO<sub>2</sub> concentrations to what the ABC references. This feature can be utilized to ensure accuracy in environments where fresh air is higher or lower than 400ppm, ensuring accuracy in different environments.

|                       | Value | Bytes [Hex]                             | Description  |
|-----------------------|-------|---|--|
| <b>Command</b>        | 0x10  | -                                       | -  |
| <b>Request bytes</b>  | 10    | [0x11] [0x07] [0x10] [D1] ... [D6] [CS] | [D1]: Reserved, default 0x64<br>[D2]: Enable/disable auto correction<br>(0: enable all (default), 1: enable only ABC,<br>2: enable only fast ABC, 3: disable all)<br>[D3]: Correction cycle period<br>(1-30 days, default is 7 days)<br>[D4]: High byte CO <sub>2</sub> baseline value,<br>default 0x01 (400)<br>[D5]: Low byte CO <sub>2</sub> baseline value ,<br>default 0x90 (400)<br>[D6]: Reserved, default 0x64 |
| <b>Response bytes</b> | 4     | [0x16] [0x01] [0x10] [0xD9]             | -  |

**7.1.4.5.1 Disable all ABC**

The automatic baseline correction functions are enabled by default. To disable this function, set [2] = 3.

**Table 8. Example Request to Disable “Automatic Baseline Correction”**

|                       | Value | Bytes [Hex]   |
|-----------------------|-------|---|
| <b>Request bytes</b>  | 10    | [0x11] [0x07] [0x10] [0x64] [0x03] [0x07] [0x01] [0x90] [0x64] [0x76] |
| <b>Response bytes</b> | 4     | [0x16] [0x01] [0x10] [0xD9]   |

**7.1.4.5.2 Enable ABC and Set Correction Cycle**

To turn the automatic baseline correction (ABC) function back on after disabling it, set [D2] to 0. Additionally, set the correction cycle period to 7 days.

**Table 9. Example Request to Open ABC and Set Correction Cycle**

|                       | Value | Bytes [Hex]   |
|-----------------------|-------|---|
| <b>Request bytes</b>  | 10    | [0x11] [0x07] [0x10] [0x64] [0x00] [0x07] [0x01] [0x90] [0x64] [0x78] |
| <b>Response bytes</b> | 4     | [0x16] [0x01] [0x10] [0xD9]   |

**7.1.4.5.3 Change the Correction Cycle Period**

The correction cycle is 7 days by default. For example, if want to change the correction cycle to 10 days, the user should set the [D3] = 0A.

**Table 10. Example Request to Change Correction Cycle**

|                       | Value | Bytes [Hex]   |
|-----------------------|-------|---|
| <b>Request bytes</b>  | 10    | [0x11] [0x07] [0x10] [0x64] [0x00] [0x0A] [0x01] [0x90] [0x64] [0x75] |
| <b>Response bytes</b> | 4     | [0x16] [0x01] [0x10] [0xD9]   |

### 7.1.4.6 Get ABC Parameters

Read the current ABC parameter set.

|                       | Value | Bytes [Hex]                             | Description   |
|-----------------------|-------|---|---|
| <b>Command</b>        | 0x0F  | -                                       | -   |
| <b>Request bytes</b>  | 4     | [0x11] [0x01] [0x0F] [0xDF]             | -   |
| <b>Response bytes</b> | 10    | [0x16] [0x07] [0x0F] [D1] ... [D6] [CS] | [D1]: Reserved, default 0x64<br>[D2]: Enabled/disabled auto correction<br>(0: enabled all (default), 1: enabled only ABC,<br>2: enabled only fast ABC, 3: disabled all)<br>[D3]: Correction cycle period<br>(1-30 days optional, default is 7 days)<br>[D4]: High byte CO <sub>2</sub> baseline value,<br>default 0x01 (400)<br>[D5]: Low byte CO <sub>2</sub> baseline value ,<br>[D6]: Reserved, default 0x64 |

### 7.1.4.7 Set CO<sub>2</sub> Baseline Manually

Correct current CO<sub>2</sub> reading to a target concentration. Use the following equation to calculate D1 and D2. The correction range is 400 to 1500 ppm. Convert the decimal values to hexadecimal before writing them to the sensor.

$$CO_2 = [D1] \cdot 256 + [D2]$$

Before correction, make sure that the CO<sub>2</sub> concentration in the current environment is in the correction target range. Let the RRH47000 stabilize in the environment for at least 2 minutes before beginning the correction.

|                       | Value | Bytes [Hex]                         | Description   |
|-----------------------|-------|-------------------------------------|---|
| <b>Command</b>        | 0x03  | -                                   | -   |
| <b>Request bytes</b>  | 6     | [0x11] [0x03] [0x03] [D1] [D2] [CS] | [D1] and [D2]: CO <sub>2</sub> concentration in ppm |
| <b>Response bytes</b> | 4     | [0x16] [0x01] [0x03] [0xE6]         | -   |

#### Example:

For a CO<sub>2</sub> concentration of 600ppm, the bytes D1 and D2 need to represent this value in hexadecimal form. The value 600 in decimal is 0x258 in hexadecimal. Therefore, D1 would be 0x02 and D2 would be 0x58.

### 7.1.4.8 Get Serial Number

Returns the serial number of the sensor. The serial number received needs to be converted to ASCII.

|                       | Value | Bytes [Hex]                              | Description                                 |
|-----------------------|-------|--|---|
| <b>Command</b>        | 0x1F  | -  | -   |
| <b>Request bytes</b>  | 4     | [0x11] [0x01] [0x1F] [0xCF]              | -   |
| <b>Response bytes</b> | 20    | [0x16] [0x11] [0x1F] [D1] ... [D16] [CS] | [D1] to [D16]: Serial number as hexadecimal |

**Example:**

Serial number in hex: 35 31 39 32 34 31 30 44 30 31 31 31 30 38 36 39

Corresponding serial number in ASCII: 5192410D01110869

**7.1.4.9 Get Firmware Version Number**

Returns the firmware version of the RRH47000. The received firmware version number needs to be converted to ASCII.

|                       | Value | Bytes [Hex]                              | Description   |
|-----------------------|-------|--|---|
| <b>Command</b>        | 0x1E  | -  | -   |
| <b>Request bytes</b>  | 4     | [0x11] [0x01] [0x1E] [0xD0]              | -   |
| <b>Response bytes</b> | 15    | [0x16] [0x0C] [0x1E] [D1] ... [D11] [CS] | [D1] to [D11]: Firmware version number as hexadecimal |

**Example:**

Serial number in hex: 56 35 2E 30 35 5F 36 42 52 30 32

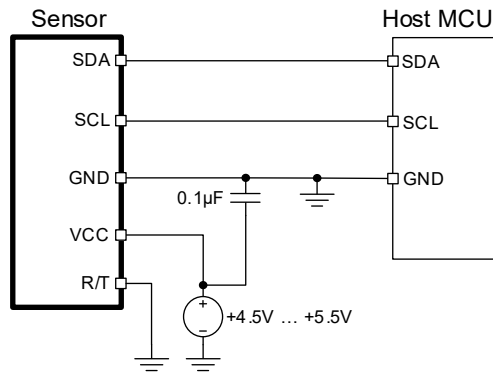
Corresponding serial number in ASCII: V5.05\_6BR02

*Note:* ASCII code 20 represents a blank space.

**7.2 I<sup>2</sup>C Interface**

This protocol follows the standard I<sup>2</sup>C timing sequence, with a clock frequency ranging from 10kHz to 100kHz. Communication utilizes the big-endian format, where the most significant bit is transmitted first. After power-on, the sensor requires a minimum of 3 seconds to initiate communication via I<sup>2</sup>C.

**7.2.1 Typical Application Circuit for I<sup>2</sup>C Interface**



**Figure 8. Application Circuit for I<sup>2</sup>C Communication**



## 7.2.2 I<sup>2</sup>C Transmission Characteristics

Table 11. I<sup>2</sup>C Transmission Characteristics

|                          |                      |
|--------------------------|----------------------|
| Slave Address            | 0x31                 |
| Clock Frequency          | Typical 100kHz       |
| General Call Address     | Unsupported          |
| Logic Voltage Level High | > 2.64V (0.8 * 3.3V) |
| Logic Voltage Level Low  | < 0.66V (0.2 * 3.3V) |

## 7.2.3 I<sup>2</sup>C Features and Timing

Table 12. I<sup>2</sup>C Timing Parameters

| Parameter                     | Symbol       | Minimum | Typical | Maximum | Unit    |
|-------------------------------|--------------|---------|---------|---------|---------|
| SCL clock frequency           | $f_{SCL}$    | 10      | -       | 100     | kHz     |
| Hold time START condition     | $t_{HD,STA}$ | -       | 0.6     | -       | $\mu$ s |
| Setup time START condition    | $t_{SU,STA}$ | -       | 0.6     | -       | $\mu$ s |
| Data setup time               | $t_{SU,DAT}$ | -       | 250     | -       | ns      |
| Data hold time                | $t_{HD,DAT}$ | -       | 0       | -       | $\mu$ s |
| Setup time for STOP condition | $t_{SU,STO}$ | -       | 4       | -       | $\mu$ s |

Note: SCL clock frequency is generated by the master device with the range 10kHz to 100kHz.

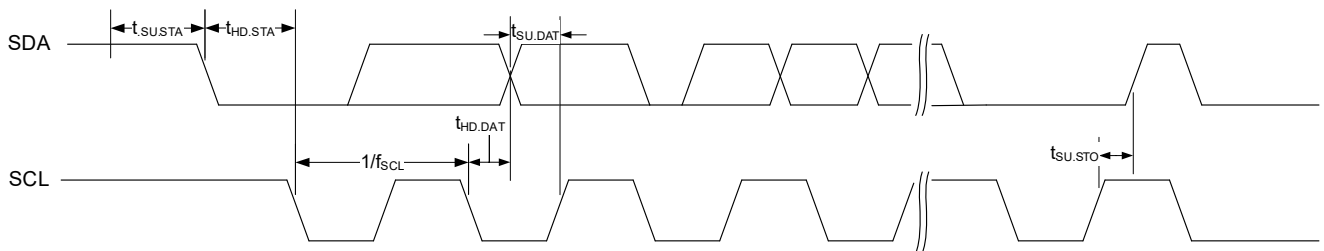


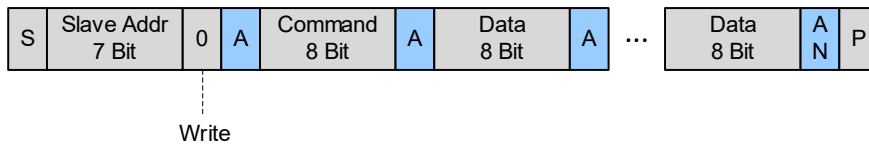
Figure 9. I<sup>2</sup>C Timing Diagram

If an I/O port is used to simulate an I<sup>2</sup>C master device, it is suggested to reserve a period before and after ACK signal (such as 100 $\mu$ s), after sending every byte (8 bit) to leave enough time for the MCU to process the data. Within requirements of speed, it is recommended to lower the reading speed as much as possible.

Using a delay of 300ms between request and response is recommended. Always verify the checksum to ensure data integrity.

## 7.2.4 Basic Data Transmission Format I<sup>2</sup>C

### Command Request



### Command Response

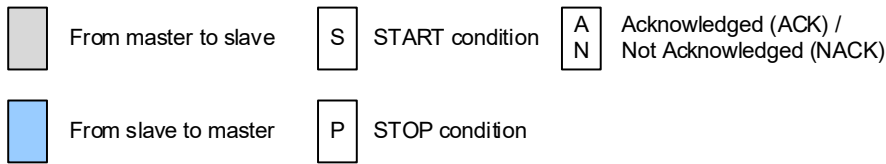
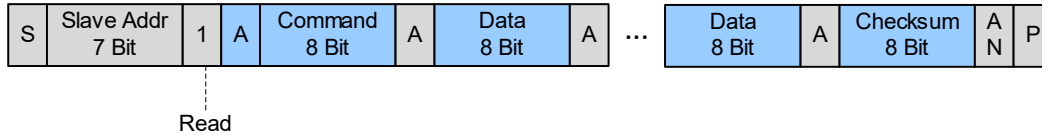


Figure 10. Data Transmission Format I<sup>2</sup>C Communication

## 7.2.5 I<sup>2</sup>C Command Description

### 7.2.5.1 Overview of I<sup>2</sup>C Commands

The slave address is 0x31; the data command of the slave device is listed in the following table.

Table 13. Overview of Available I<sup>2</sup>C Commands

| Code | Action                                 | Request bytes | Response Bytes |
|------|--|---------------|----------------|
| 0x31 | Get Measurement Results.               | 1             | 10             |
| 0x10 | Set ABC Parameters.                    | 7             | 8              |
| 0x03 | Set CO <sub>2</sub> Baseline Manually. | 3             | 4              |
| 0x1F | Get Serial Number.                     | 1             | 18             |
| 0x1E | Get Firmware Version Number.           | 1             | 13             |

Every response includes a request command as a first byte and the checksum as last byte.

### 7.2.5.2 Get Measurement Results

Returns the measurement results for CO<sub>2</sub>, temperature, and relative humidity. For more information on how to calculate the output values, see section 7.3.

|                | Value | Bytes [Hex]               | Description  |
|----------------|-------|---------------------------|--|
| Command        | 0x31  | -                         | -  |
| Request bytes  | 1     | [0x31]                    | -  |
| Response bytes | 10    | [0x31] [D1] ... [D8] [CS] | [D1] and [D2]: CO <sub>2</sub> Results<br>[D3] and [D4]: Reserved<br>[D5] and [D6]: Temperature Results<br>[D7] and [D8]: Humidity Results |

**7.2.5.3 Set ABC Parameters**

This function is used to set the automatic baseline correction (ABC) parameters. The ABC function is crucial for maintaining the accuracy and reliability of the sensor's long-term CO<sub>2</sub> measurements. By periodically recalibrating the sensor to a baseline CO<sub>2</sub> concentration, typically representing fresh outdoor air, the ABC function compensates for sensor drift and ensures consistent performance.

A fast automatic baseline correction (fast ABC) occurs when the sensor undergoes a correction process outside the set correction period (default 24 h/7 days). This correction is typically triggered during periods of exceptionally low CO<sub>2</sub> concentrations that are unrealistic for fresh air (below 400ppm). The fast ABC ensures that the sensor quickly adapts to new baseline CO<sub>2</sub> concentrations, thereby maintaining its accuracy and reliability in dynamic conditions.

The CO<sub>2</sub> baseline value is used to set the lowest expected CO<sub>2</sub> concentrations to what the ABC references. This feature can be utilized to ensure accuracy in environments where fresh air is higher or lower than 400ppm, ensuring accuracy in different environments.

|                       | Value | Bytes [Hex]               | Description  |
|-----------------------|-------|---------------------------|--|
| <b>Command</b>        | 0x10  | -                         | -  |
| <b>Request bytes</b>  | 7     | [0x10] [D1] ... [D6]      | [D1]: Reserved, default 0x64<br>[D2]: Enable/disable auto correction<br>(0: enable all (default), 1: enable only ABC, 2: enable only fast ABC, 3: disable all)<br>[D3]: Correction cycle period<br>(1-30 days, default is 7 days)<br>[D4]: High byte CO <sub>2</sub> baseline value,<br>default 0x01 (400)<br>[D5]: Low byte CO <sub>2</sub> baseline value ,<br>[D6]: Reserved, default 0x64                |
| <b>Response bytes</b> | 8     | [0x10] [D1] ... [D6] [CS] | [D1]: Reserved, default 0x64<br>[D2]: Enabled/disabled auto correction<br>(0: enabled all (default), 1: enabled only ABC, 2: enabled only fast ABC, 3: disabled all)<br>[D3]: Correction cycle period<br>(1-30 days optional, default is 7 days)<br>[D4]: High byte CO <sub>2</sub> baseline value,<br>default 0x01 (400)<br>[D5]: Low byte CO <sub>2</sub> baseline value ,<br>[D6]: Reserved, default 0x64 |

**7.2.5.4 Set CO<sub>2</sub> Baseline Manually**

Correct current CO<sub>2</sub> reading to a target concentration. Use the following equation to calculate D1 and D2. The correction range is 400 to 1500 ppm. Convert the decimal values to hexadecimal before writing them to the sensor.

$$CO_2 = [D1] \cdot 256 + [D2]$$

Before correction, make sure that the CO<sub>2</sub> concentration in the current environment is in the correction target range. Let the RRH47000 stabilize in the environment for at least 2 minutes before beginning the correction.

|                       | Value | Bytes [Hex]           | Description   |
|-----------------------|-------|-----------------------|---|
| <b>Command</b>        | 0x03  | -                     | -   |
| <b>Request bytes</b>  | 3     | [0x3] [D1] [D2]       | [D1] and [D2]: CO <sub>2</sub> concentration in ppm |
| <b>Response bytes</b> | 4     | [0x03] [D1] [D2] [CS] | [D1] and [D2]: CO <sub>2</sub> concentration in ppm |

**Example:**

For a CO<sub>2</sub> concentration of 600 ppm, the bytes D1 and D2 need to represent this value in hexadecimal form. The value 600 in decimal is 0x258 in hexadecimal. Therefore, D1 would be 0x02 and D2 would be 0x58.

**7.2.5.5 Get Serial Number**

Returns the serial number of the sensor. The serial number received needs to be converted to ASCII.

*Note:* Use a 160ms delay between making the request and reading the response.

|                       | Value | Bytes [Hex]               | Description                                 |
|-----------------------|-------|---------------------------|---|
| <b>Command</b>        | 0x1F  | -                         | -   |
| <b>Request bytes</b>  | 1     | [0x1F]                    | -   |
| <b>Response bytes</b> | 18    | [0x1F] [D1] to [D16] [CS] | [D1] to [D16]: Serial number in hexadecimal |

**Example:**

Serial number in hex: 35 31 39 32 34 31 30 44 30 31 31 31 30 38 36 39

Corresponding serial number in ASCII: 5192410D01110869

**7.2.5.6 Get Firmware Version Number**

Returns the firmware version of the RRH47000. The received firmware version number needs to be converted to ASCII.

|                       | Value | Bytes [Hex]            | Description   |
|-----------------------|-------|------------------------|---|
| <b>Command</b>        | 0x1E  | -                      | -   |
| <b>Request bytes</b>  | 1     | [0x1E]                 | -   |
| <b>Response bytes</b> | 13    | [0x1E] [D1] [D11] [CS] | [D1] to [D11]: Firmware version number as hexadecimal |

**Example:**

Serial number in hex: 56 35 2E 30 35 5F 36 42 52 30 32

Corresponding serial number in ASCII: V5.05\_6BR02

*Note:* ASCII code 20 represents a blank space.

### 7.3 Calculating CO<sub>2</sub>, Temperature, and Relative Humidity Output

The following table contains all the necessary equations to calculate CO<sub>2</sub> levels, temperature, and relative humidity from the sensor output bytes. To calculate the measurement results of the RRH47000, the hexadecimal values must be transformed into decimal first. Use the decimal values in the equations of Table 14 to calculate the corresponding measurement outputs.

**Table 14. Equations to Calculate the Measurement Outputs**

|                   | Condition                              | Equation  | Unit |
|-------------------|--|---|------|
| CO <sub>2</sub>   | -                                      | $CO_2 = [D1] \cdot 256 + [D2]$                  | ppm  |
| Temperature       | $\{[D5] \cdot 256 + [D6]\} < 32768$    | $T = \frac{[D5] \cdot 256 + [D6]}{100}$         | °C   |
|                   | $\{[D5] \cdot 256 + [D6]\} \geq 32768$ | $T = \frac{[D5] \cdot 256 + [D6] - 65536}{100}$ |      |
| Relative Humidity | -                                      | $RH = \frac{[D7] \cdot 256 + [D8]}{100}$        | %RH  |

The following is an example of how to calculate output for the RRH47000.

**Table 15. Calculation Example for Measurement Outputs**

|                         | CO <sub>2</sub>     |      | Ignore |      | Temperature                      |      | Rel. Humidity                    |      |
|-------------------------|---------------------|------|--------|------|----------------------------------|------|----------------------------------|------|
| Data Byte               | 1                   | 2    | 3      | 4    | 5                                | 6    | 7                                | 8    |
| Hexadecimal             | 0x02                | 0x29 | 0x00   | 0xF7 | 0x0B                             | 0x72 | 0x12                             | 0xAD |
| Decimal                 | 2                   | 41   | Ignore |      | 11                               | 114  | 18                               | 173  |
| Equation <sup>[1]</sup> | $02 \cdot 256 + 41$ |      |        |      | $\frac{11 \cdot 256 + 114}{100}$ |      | $\frac{18 \cdot 256 + 173}{100}$ |      |
| Result                  | 553ppm              |      |        |      | 29.3°C                           |      | 47.81%RH                         |      |

1. The equations can be found in Table 14.

## 7.4 Checksum Calculation

To calculate the checksum, use the following equation:

$$CS = 256 - \sum Bytes \% 256$$

Table 16 provides an example of a checksum calculation. The bytes and hexadecimal values have been taken from Table 9.

**Table 16. Example Checksum Calculation for UART**

| Byte              | 1   | 2      | 3       | 4    | 5    | 6    | 7    | 8    | 9    |
|-------------------|---|--------|---------|------|------|------|------|------|------|
| Byte Description  | Start   | Length | Command | Data | Data | Data | Data | Data | Data |
| Hexadecimal Value | 0x11  | 0x07   | 0x10    | 0x64 | 0x00 | 0x07 | 0x01 | 0x90 | 0x64 |
| Decimal Value     | 17  | 7      | 16      | 100  | 0    | 7    | 1    | 144  | 100  |
| Equation          | $CS = 256 - (17 + 7 + 16 + 100 + 0 + 7 + 1 + 144 + 100)\%256$ |        |         |      |      |      |      |      |      |
| Result            | $CS = 256 - 392\%256 = 256 - 136 = 120 = \mathbf{0x78}$       |        |         |      |      |      |      |      |      |

**Table 17. Example Checksum Calculation for I<sup>2</sup>C**

| Byte              | 1   | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|-------------------|---|------|------|------|------|------|------|------|------|
| Byte Description  | Command   | Data | Data | Data | Data | Data | Data | Data | Data |
| Hexadecimal Value | 0x31  | 0x02 | 0x29 | 0x00 | 0xF7 | 0x0B | 0x72 | 0x12 | 0xAD |
| Decimal Value     | 49  | 2    | 41   | 0    | 247  | 11   | 114  | 18   | 173  |
| Equation          | $CS = 256 - (49 + 2 + 41 + 0 + 247 + 11 + 114 + 18 + 173)\%256$ |      |      |      |      |      |      |      |      |
| Result            | $CS = 256 - 655\%256 = 256 - 143 = 113 = \mathbf{0x71}$         |      |      |      |      |      |      |      |      |

## 8. Storage and Handling

**Recommendation:** Once the sensors are removed from their original packaging, store them in metal-in antistatic bags.

Avoid using polyethylene antistatic bags as they may affect the RHT sensors accuracy.

The nominal storage conditions are 10°C to 50°C and humidity levels within 20% to 60%RH. If stored outside of these conditions for extended periods of time, the RHT sensor readings may exhibit an offset. The RHT sensor can be reconditioned and returned to its calibration state by applying the following recondition procedure:

1. Bake at a temperature of 85°C with a humidity < 10% RH for 24 hours.
2. Rehydrate the sensor at a humidity of 75% RH and a temperature between 20°C to 30°C for 12 to 14 hours.

## 9. Marking Diagram



Figure 11. Sticker Label RRH47000

| Code Component                              | Description  | Example  |
|---|--|----------|
| Product Code (Char 1 – 3)                   | Code representing the product  | '519'    |
| Date Code (Char 4 – 7)                      | Production date in the format YYWW\$ (where \$ = location code)                      | '2410'   |
| Location Code (Char 8)                      | Code indicating the site of production   | 'D'      |
| Lot# in Production Week (Char 9 – 10)       | Number indicating the lot produced within the production week (ranges from 01 to 99) | '01'     |
| Internal Traceability Number (Char 11 – 16) | Internal tracking number for traceability  | '110869' |

## 10. Quality and Reliability

The RRH47000 series is available as a qualified product for consumer and industrial market applications. All data specified parameters are guaranteed if not stated otherwise.

## 11. Package Outline Drawings

The package outline drawings are located at the end of this document and are accessible from the [Renesas website](#). The package information is the most current data available and is subject to change without revision of this document.

## 12. Ordering Information

| Part Number     | Package Description  | Description  | MOQ (pcs) |
|-----------------|--|--|-----------|
| RRH47000-A1V    | 40.8 × 19.7 × 9.1 mm<br><a href="#">MN0009AA</a> Module  | NDIR CO <sub>2</sub> sensor module with RHT sensor | 540       |
| RRH47000-EVK    | RRH47000 Evaluation Kit including the RRH47000 Sensor Board, ECom Communication Board (USB Interface), and Micro-USB Cable. (The Environmental Sensors Evaluation Software is available for download free of charge on the <a href="#">RRH47000-EVK</a> product page.) |  |           |
| RRH47000-EVK-DB | RRH47000 Sensor Board as spare part for RRH47000 Evaluation Kit.   |  |           |

### 13. Revision History

| Revision | Date         | Description      |
|----------|--------------|------------------|
| 1.00     | Nov 11, 2024 | Initial release. |





