Indoor CO2, relative humidity and temperature sensor UFS1107

with wired ModbusRTU (RS485) communication interface

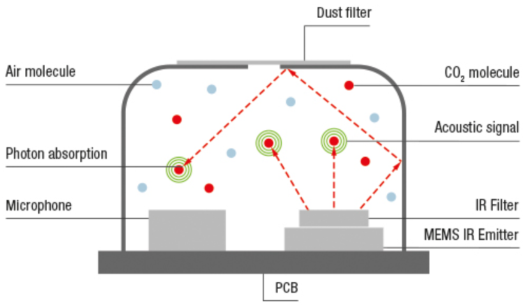
Based on Sensirion SCD41 multifunctional sensor element

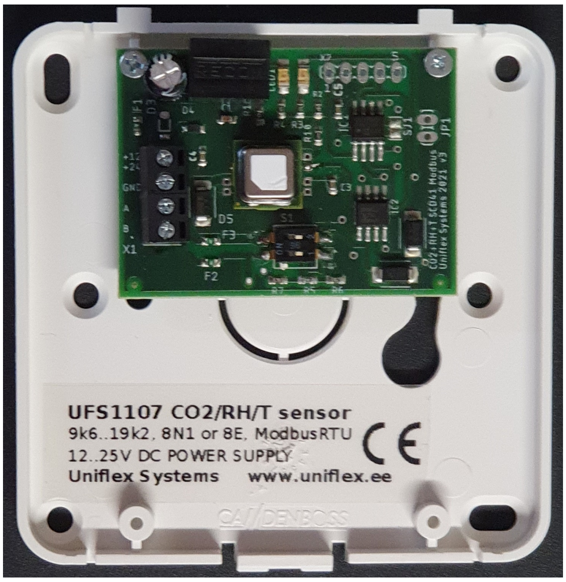
User Manual

1. Introduction

The UFS1107 sensor described in this document is a combined sensor to measure CO2 concentration, relative humidity and air temperature indoors, in living or office rooms. The readings are available via RS485 interface using ModbusRTU protocol. The sensor has calibration registers for 2-point calibration for maximum accuracy for every metered item. Readings are available both as raw data from the sensor element (SCD41 from Sensirion), or converted and calibrated to ppm, dC and d% values.

The novel sensor element in use (SCD41 from Sensirion) is based on the photoacoustic sensing principle for CO2 measuring. The photoacoustic sensing principle allows extreme miniaturization of the CO_2 sensor without compromising sensor performance due to the fact that the sensor sensitivity is independent of the optical cavity size.





The SCD41 sensor is mounted on a PCB with a microprocessor, taking care of protocol conversion and calibration data based linear conversions. The linear conversion is in use to convert the raw readings into actual (ppm, %, C) values while improving the actual accuracy for the measurement range (see below about the calibration).

The power consumption of the sensor is very low, minimizing the effect of self-heating to the temperature and relative humidity readings.

The cased sensor mounts on the wall and is suited to cover the recessed installation box (to bring in the UTP cable). Supply voltage range is from 10 to 25 V DC, consumed current is less than 20 mA on average (even 7 mA in default low-power mode).

The sensor orientation is important - the PCB should be located at the upper edge of the case, as shown on the image above. This way the self-heating effects of the components on the PCB on the measured value are minimal.

2. Technical specifications

Temperature range: -45..60 degC
Humidity range: 10..100 %
CO2 range: 400..4000 ppm
Measurements: 86 x 86 x 25 mm
Supply voltage: 10..25 V DC
Current consumption: less than 7 mA average in the default low-power mode (1 reading per 30 s),
less than 20 mA in normal mode (1 reading per 5 s), at 12 V supply voltage
Communication interface: RS485
Communication protocol: ModbusRTU
Communication speeds: 9600 or 19200 bps (factory default is 19200)
Communication parity: even or no parity, 8 data bits, 1 stop bit (factory default is 8E1)
Modbus address range: from 1 to 247 (factory default is 22)
Readings: raw (directly from the sensor SCD41) and converted (calibrated to ppm CO2, dC T, d% RH)
Accuracy: see SCD41 parameters by Sensirion in the Table1 below.

Table 1.

CO2 measurement accuracy	2 400 ppm – 5'000 ppm ± (40 ppm + 5% of reading)
	drift ± (5 ppm + 0.5 % of reading) / year
Humidity sensing accuracy	15 °C – 35 °C, 20 %RH – 65 %RH ± 6 % RH
	-10 °C – 60 °C, 0 %RH – 100 %RH ± 9 % RH
	drift < 0.25 %RH / year
Temperature sensing accuracy	15 °C – 35 °C ± 0.8 °C
	-10 °C – 60 °C ± 1.5 °C
	drift < 0.03 °C / year
Note: the best RH/T accuracy is realized when operating the SCD41 in low power periodic measurement mode, for minimal self-heating of the sensor.	

Read more about this sensor at
https://www.sensirion.com/en/environmental-sensors/carbon-dioxide-sensors/carbon-dioxide-sensor-scd4x/

3. Cabling and powering

The suggested way of cabling is to use 4-pair CAT5 or CAT6 twisted pair shielded or unshielded cable, commonly used in local area computer networks. One pair is needed for RS485 bus, the rest of the pairs can be used tor power the device. Suggested connections:

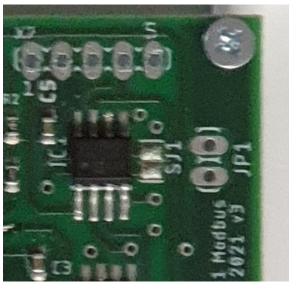
- green pair for RS485, connect green wire to A and green/white to B
- orange pair (both wires in parallel) for positive supply voltage
- blue pair (both wires in parallel) for negative supply voltage (GND)

All devices connected to the same Modbus master should share the same cable in a daisy-chain (sequential) manner, star-topology should be avoided if possible. Line end must be terminated (the devices on the line end should have termination switches ON, all the rest OFF). About a hundred devices can share the same line. Each of them must have an unique Modbus address, but the same communication parameters (speed and parity).

Note: it may take up to 1 minute after powering up to get the valid readings from the sensor (in the default low-power mode).

4. Communication

The default modbus address of the device is 22, serial line parameters 19200, 8 bits, EVEN parity, 1 stop bit. It is possible to change the speed to 9600 bps and parity to None. To change this data, write the new configuration word into the holding register with address 7. See table 1 for the register details (bit meanings) at the end of this document.



To reset the parameters to the factory default value, disconnect power, short-circuit the contacts of JP1 on the PCB (with tweezers for example) and apply the power. Both the RX and TX LEDs will flash once. Remove the short-circuit from JP1. The communication parameters are now 19k2 8E1, modbus address 22.

5. Power modes

The device can be used in a normal or low-power mode (default). The mode is controlled by the bit1 value in the register 7. Active value of this bit disabes low-power mode and the new readings will be available every 5 seconds, instead of 30 s intervals in low-power mode (which is default after factory reset). In normal mode, the new readings are available every 5 seconds.

From the accuracy point of view, to keep the low-power mode is suggested, as the self-heating of the sensor element (affecting the temperature and humidity measurements) is lower. To compensate for the effect of self-heating, the calibration process should be carried on AFTER the desired power mode is selected (bit1 in register 7).

The supply current and power consumed by the sensor depends on the power mode as follows:

- Low-power mode: less than 7 mA, less than 85 mW in average at 12V supply voltage
- Normal mode: less than 20 mA, less than 240 mW in average at 12V supply voltage

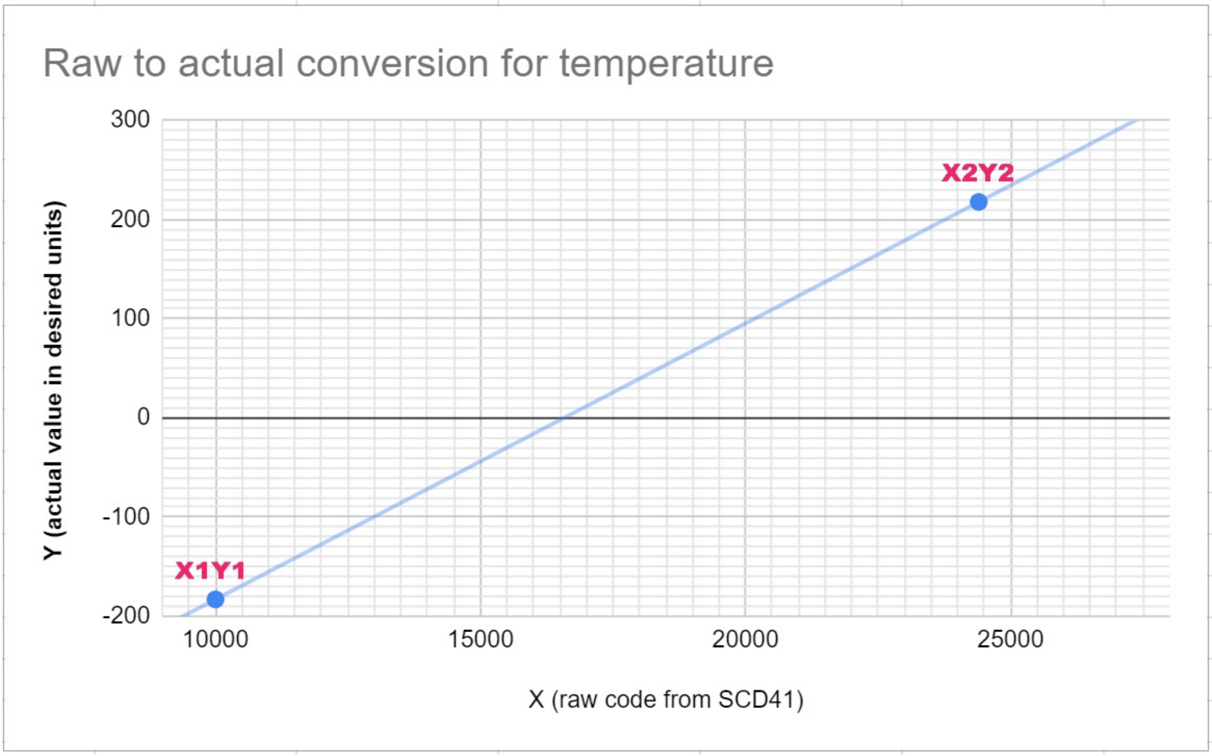
6. Reading the values

The measured data is accessible in two ways:

- in raw format (as presented by SCD41 sensor element) from the registers 0..2, or
- as converted to true values in the desired units from the registers 3..5.

The latter values are converted from the raw values based on the calibration points X1Y1 and X1X2.

The following chart illustrates the linear conversion in use, to get actual values based on raw values (for temperature readings in this example).



The linear conversion in use enables to convert the raw values into any of the possible actual value units. The example is for 0.1 C as the temperature unit (minimal step of the actual value). It is well possible to get the reading in full or fractional degrees of Kelvin or Fahrenheit scale as well.

6. Calibration

As the previous chart illustrates, the linear conversion is dependent on the calibration points X1Y1 and X2Y2, with their values stored at registers 10..21. The received raw values from the sensor element will be converted to the actual values in desired units using the linear relation between raw input X and actual value Y, defined by the calibration points X1Y1 and X2Y2.

For building automation needs it is usually acceptable to leave the calibration point X1Y1 to factory default values and only adjust the upper calibration point X2Y2, using some precision meter as a source of etalon readings. For that

- Locate the precision meter nearby the UFS1107 in its final location (mounted on the wall)
- Let the meters settle for a few minutes, avoiding breathing on them (keep away)
- Take the readings of registers 0..3 (the raw values of CO_2, temperature and humidity)
- Write the value into register 11, 15 or 19 (for CO_2, temperature or humidity accordingly)
- Write the actual reading shown by the etalon meter into the register 13, 17 or 21 (for CO_2, temperature or humidity accordingly). Multiply the value in C or % by 10, if the desired unit is 0.1 C or 0.1 % for temperature and humidity. There is no need to multiply the value of CO_2 reading in ppm, unless you want to present it in some other unit than ppm.

For the scientific measurements it is strongly suggested that the calibration will be carried through in two calibration points. The points selection depends on what kind of actual environment conditions are possible to create for the sensor for the time of calibration. It is suggested however, that the calibration points are close to the lower and upper end of the possible range of the actual values during the scientific experiment. Keep in mind that the values for point X1Y1 should be smaller than the values for X2Y2.

Note: if for temperature calibration it is needed to save a negative actual value, convert the value into a 16 bit signed integer before saving. An example: the negative value of -183 (-18.3C) is represented 65353 as a signed 16-bit integer.

In order to maximize the precision for CO_2 measurements, it is suggested that the value of sensor height from the sea level in meters is stored into the register 9. The default value for this register is 10 (m), replace this with the actual height of the final sensor location.

It is strongly suggested that the (final) calibration for CO_2 is done at least a week after the sensor has been constantly powered. During this time before the calibration, the sensor has to be surrounded by clean air at least once. That can be achieved by simply opening the windows.

One of the many possible handheld meters (usable for calibration) for CO_2, humidity and temperature is DeltaOhm HD21ABE17.

Table 3.

The (holding) registers of CO2+RH+T sensor US1107		
Register Address	R (readable) W (writeable)	Description
0	R	Raw value of CO2 in ppm (directly from the SCD41 sensor)
1	R	Raw value of temperature (directly from the SCD41 sensor)
2	R	Raw value of relative humidity (directly from the SCD41 sensor)
3	R	True (converted) value of CO2 in ppm, format INT16
4	R	True (converted) value of temperature in dC (0.1C), format INT16 (signed)
5	R	True (converted) value of relative humidity in d% (0.1%), format UINT16
6	R	Firmware version
7	RW	**serial communication configuration:** bit 0 - speed, bit 7 - (1=none, 0=even). A few example values: 0 for 19k2 8e1, 129 for 9k6 8N1.
8	RW	Modbus address (from 1 to 247, default 22)
9	RW	Height in meters from sea level (default 10, correct value suggested for precise CO2 reading)
10	RW	Calibration value X1 for CO2
11	RW	Calibration value X2 for CO2
12	RW	Calibration value Y1 for CO2
13	RW	Calibration value Y2 for CO2
14	RW	Calibration value X1 for temperature
15	RW	Calibration value X2 for temperature
16	RW	Calibration value Y1 for temperature
17	RW	Calibration value Y2 for temperature
18	RW	Calibration value X1 for relative humidity
19	RW	Calibration value X2 for relative humidity
20	RW	Calibration value Y1 for relative humidity
21	RW	Calibration value Y2 for relative humidity

Remarks:
1. Writable registers content is permanently stored into the flash memory of the device
2. Calibration values are used for linear conversion of raw values to to true readings
3. Calibration points X1Y1 and X2Y2 should be selected in the ends of actual measuring range
4. The calibration point X1Y1 must have lower values than the upper point X1Y2