Features

- Measures all important indoor air quality values: CO_2, T, RH, VOC
- Communicates via Modbus RTU (RS-485)
- Wide input voltage range 5 - 30V
- Indicates CO_2 (carbon dioxide) level using LED for quick air quality assesment
- Easy to setup using Raspberry Pi and open-source Veles Sensors python library
- Carbon dioxide measurement range 0 - 40000 ppm
- Temperature range -40 - 125 °C
- Relative humidity range 0 - 100 %
- VOC (volatile organic compounds) index range 1 - 500 VOC index points
- Fully opensource

Description

IAQ01 is a wired indoor air quality sensor measuring temperature, relative humidity, carbon dioxide, and volatile organic compounds. Communication over RS-485 using Modbus RTU protocol makes it easy to interface with the sensor using PLC or any PC with RS-485 to USB converter. Open-source Python libraries are available to ease sensor configuration and readout using PC and embedded computers (e.g. Raspberry Pi).

On-board RGB LED enables the user to quickly assess air quality with a single glance. Two quality-to-color schemes are available: continuous color change and tri-state (semaphore) mode. The thresholds for color change are user-configurable.

A wide input voltage range makes it possible to integrate the sensor with many different systems, ranging from house-wide 12V bus to 5V USB connected to a local computer.

The extended version of this sensor IAQ01-PM adds the option of particulate matter (dust) measurement.

Fully open-source ecosystem: sensor hardware, case, firmware, and connected Python libraries are open-sourced under permissive licensing.

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1 Specifications

1.1 Electrical Specifications

Parameter	Symbol	Min.	Typ.	Max.	Unit
Input voltage	V_{DD}	5	12	24	V
Average supply current	I_{DD}			50	mA
RS485 Single-Ended Output High	V_{OH}	2.2			V
RS485 Single-Ended Output Low	V_{OL}			0.8	V
RS485 Differential Output	V_{OD}	2.0			V
RS485 Receiver Differential Threshold Voltage	V_{TH}	-200	-105	-10	mV

Table 1: Electrical Specifications

1.2 Sensing Specifications

Parameter	Conditions	Value
CO_2 measurement range	-	0 ÷ 40000 ppm
CO_2 measurement accuracy	400 ppm – 2000 ppm	(±50 ppm + 5% of reading)
CO_2 measurement repeatability	Typical	±10 ppm
T measurement range	-	–40 ÷ +125 °C
T measurement accuracy	Typical	±0.2 °C
T measurement repeatability	Typical	±0.2 °C
RH measurement range	-	0 ÷ 100 %RH
RH measurement accuracy	Typical	±1.8 %RH
RH measurement repeatability	-	±0.08 %RH

Table 2: Sensing Specifications

1.3 Interface Specifications

Parameter	Value
Used Protocol	Modbus RTU
Default Baudrate	19200 Baud
Usable Baudrates	4800, 9600, 14400, 19200, 28800, 38400, 57600, 76800, 119200 Baud
Data Bytes	8
Parity	Even
Stop Bits	1

Table 3: Sensing Specifications

1.4 Connectors Pinout

1.4.1 Main Connector Pinout

The main connector is the Sullins Connector Solutions SWR204-NRTN-D02-RA-GA connector. The matching connector for the cable is SWH204-NULN-D02-UU-WH with SWT204-UPTN-S01-UU-UU crimping pins.
The pinout can be seen in figure 1 and table 4.

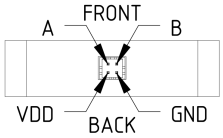


Figure 1: Main Connector Pinout

Pin	Name	Description
1	VDD	Supply Voltage
2	A	RS485 A+
3	B	RS485 B-
4	GND	Ground

Table 4: Main Connector Pinout

1.4.2 Programming Connector Pinout

The sensor can be programmed through the Serial Wire Debug (SWD) interface using an ST-Link. ST-Link can be connected to the sensor using pads for spring-loaded pins in the bottom layer of the PCB. The pinout can be seen in table 5. The first pin of the connector is marked with a square pad.

Pin	Name	Description
1	3V3	3.3V Sensing
2	GND	Ground
3	SWDIO	SWD Data
4	SWCLK	SWD Clock
5	NRST	MCU Reset

Table 5: Programming Connector Pinout

2 Communication Specification

For the physical layer, RS-485 is used. This allows the communication to be robust and resistant to EMI (electro-magnetic interference). On top of the physical layer, Modbus RTU is used as a data link layer. This protocol is widely supported by the number of PLCs and other devices. To interface with a PC (or any computer with a USB port), a USB to RS485 converter may be used in conjunction with the Veles Sensors python library.

2.1 Physical Layer - RS485

RS-485 is a full-duplex serial bus, ideally suited for low-speed, noise-resistant communication over long distances (up to 1200 m - more if repeaters are used). Linear bus topology is preferable over star or ring configurations. To prevent signal reflections, each sensor is equipped with a 120 Ω termination resistor. Therefore, the optimal cable for connecting sensors to each other and to the master node is a twisted pair cable with 120 Ω characteristic impedance.

2.2 Data Link Layer - Modbus RTU

Modbus is a well-tested, openly-published, and royalty-free data communications protocol. Developed for industrial applications, it aims to be simple and robust. It is a client/server (master/slave) type protocol. The maximum number of client nodes on a Modbus bus is 247.

A limitation of Modbus-based buses is that there is no arbitration in case of address conflict. This means that nodes should be either added one by one or node addresses should be configured beforehand.

Address 0 can be used as a broadcast message (e.g. instructing all sensors to turn off LED). No slave response is generated.

2.2.1 Modbus register space

Modbus supports four types of registers:

Object type	Access	Size	Address space
Coil	read / write	1 bit	00001 - 09999
Discrete input	read	1 bit	10001 - 19999
Input register	read	16 bits	30001 - 39999
Holding register	read / write	16-bits	40001 - 49999

Table 6: Modbus register space

2.3 IAQ01 Modbus registers

2.3.1 Input registers

Input registers contain measured values. They are read-only and 16-bit in size.

Register name	Register address	Unit	Note
Serial Number HI	30001	-	
Serial Number LO	30002	-	
Temperature	30003	°C	
Temperature	30004	°F	
Relative humidity	30005	%	
CO_2 concentration	30006	ppm	
VOC index	30007	VOC index	see Note 1
VOC ticks	30008	raw VOC ticks	raw value from VOC sensor
PMC Mass 1.0	30009	TODO	if connected
PMC Mass 2.5	30010	TODO	if connected
PMC Mass 4.0	30011	TODO	if connected
PMC Mass 10.0	30012	TODO	if connected
PMC Number 0.5	30013	TODO	if connected
PMC Number 1.0	30014	TODO	if connected
PMC Number 2.5	30015	TODO	if connected
PMC Number 4.0	30016	TODO	if connected
PMC Number 10.0	30017	TODO	if connected
Temperature from CO_2 sensor	30019	°C	
Temperature from CO_2 sensor	30020	°F	
RH from CO_2 sensor	30021	%	

Table 7: Modbus input registers for IAQ01

Note 1 The VOC index has a range of 1-500 with 100 being the average. After sensor start-up, the VOC index is 0 until a sufficient amount of data has been measured.

2.3.2 Holding registers

The holding registers can be written to by the master node. Sensor IAQ01 offers the following configuration registers:

Register name	Address	Note
Device Modbus address	40001	see Note 4
Modbus baudrate	40002	see Note 5
LED on	40003	set to 0 to turn off LED; set to 1 to turn LED on
LED brightness	40004	range from 0 (off) to 100 (full intensity)
LED smooth	40005	see Note 1
CO_2 alert limit 1	40006	see Note 2
CO_2 alert limit 2	40007	see Note 2
CO_2 temperature offset	40008	see Note 3
Reset device	49999	see Note 6

Table 8: Modbus holding registers for IAQ01

Note 1 Setting LED smooth register to 1 will turn on LED color interpolation, meaning the LED will have color in a continuous spectrum from green to red according to the CO_2 level. Setting this register to 0 will turn off interpolation and set the LED to semaphore (tri-state) mode. Depending on CO_2 level, the LED color will then be either green, yellow, or red.

Note 2 Registers CO_2 alert the limit 1 and 2 set thresholds for LED color change (see Note 1). Limit 1 is the threshold between green and yellow color; limit 2 is the threshold between yellow and red color.

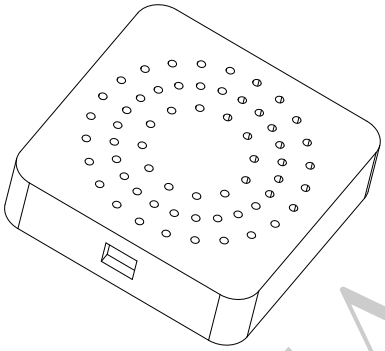
Note 3 SCD41 is the CO_2 sensing device used in the IAQ01 sensor. It is also able to measure temperature, however it may be subject to offset due to internal heating of SCD41. This register allows the user to compensate for this offset.

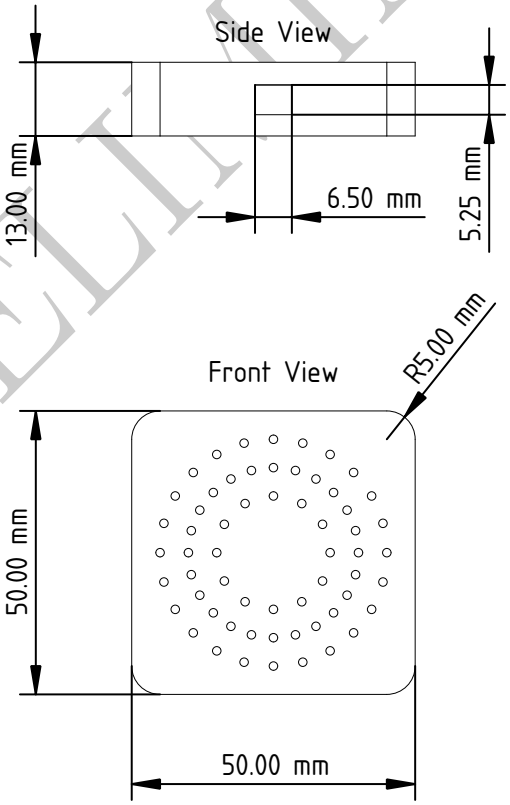
Note 4 Device Modbus address may be changed by writing to this register. The allowed values are in the range of 1 to 247. The device will start using a new address immediately and cease to respond at the previous address. Reset is not needed. It is the responsibility of the user to prevent address collisions on a bus.

Note 5 Modbus baudrate in bits/s. May be one of: 4800, 9600, 14400, 19200, 28800, 38400, 57600, 76800, 115200. Please be aware that lower baudrates are more reliable for long distance communication.

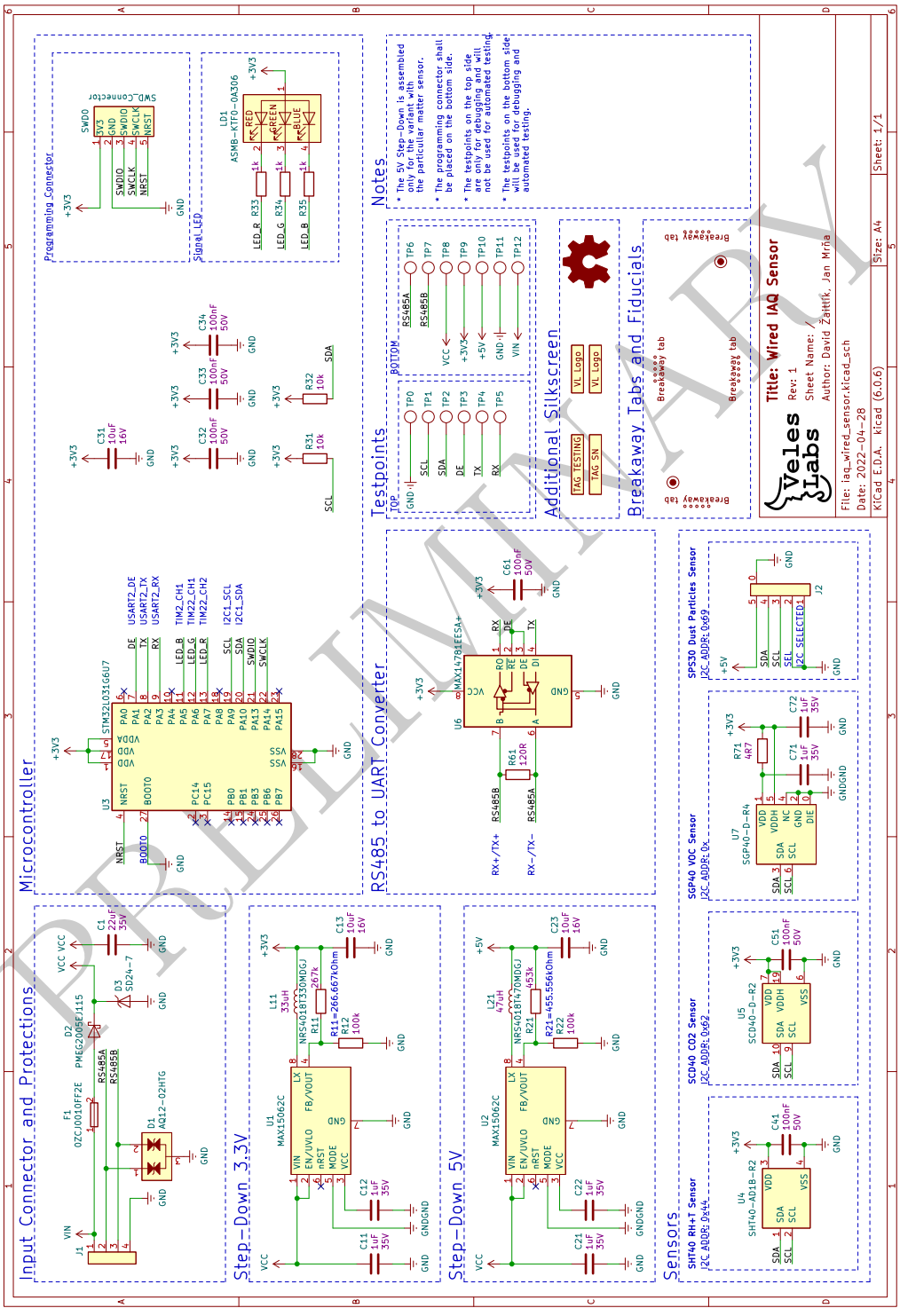
Note 6 Writing the magic constant 0xABCD to this device will instruct the device to soft-reset.

3 Mechanical Dimesions





4 Schematic


Input Connector and Protections
Step-Down 3.3V
Step-Down 5V
Microcontroller
RS485 to UART Converter
Sensors
Testpoints
Notes
Additional Silkscreen
Breakaway Tabs and Fiducials
Programming Connector
Signal_LED
Title: Wired IAQ Sensor
Rev: 1
Author: David Zaitlík, Jan Mrňa
Date: 2022-04-28
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