CO_2 Meter

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Abstract

A project for monitoring CO_2 levels, temperature, humidity, and pressure using the SCD30 and BMP280 sensors.

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While rummaging through my basement, I discovered a half-finished CO_2 Meter from the COVID-19 era. Back in the COVID-19 days, it was utterly important to ventilate the rooms when the air got bad (and avoid unnecessary ventilation in winter when it was freezing cold outside).

I remember leaving the project in a functional state that delivered plausible values. However, given that I didn't have much exposure to C languages I was not sure how reliable the measurements were. The original setup was a bit "basic". The necessity to air the room was indicated by a servo motor driven analog pointer.

I took this as an opportunity to upgrade the setup:

1. Get to know C++ and
2. Use a "real" digital display

And I learned even more along the way as we will see…

1 Hardware

I took inventory of the existing setup. I already had:

- NodeMCU Lua Lolin V3 Module ESP8266 ESP-12F
- BMP280
- SCD30

All nicely attached to two joined tiny breadboards.

I just needed a display. I chose a:

- SSD1306 OLED screen

As a power supply I use the spare power adapter from my decommissioned *Iomega Zip Drive*[1]. Any other 5V DC power supply should work just as well.

1.1 NodeMCU Lua Lolin V3 Module ESP8266 ESP-12F

The *NodeMCU Lua Lolin V3* (see Figure 1) is a versatile and beginner-friendly development board that combines the power of the *ESP8266 ESP-12F* module with additional hardware to simplify prototyping and development. It is widely used in IoT projects due to its affordability, ease of use, and flexibility[2].

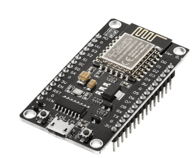

Figure 1: NodeMCU Lua Lolin V3 Module ESP8266 ESP-12F

Therefore, I used it in my project.

I assume other boards based on ESP8266 or ESP32 would work as well. Nevertheless, I encourage to use a development board if you want to streamline the build up of this project.

1.2 SDC30 Sensor

The *SCD30* is a high-accuracy sensor module developed by Sensirion for measuring *CO concentration*, *temperature*, and *humidity*. It is widely used in air quality monitoring, HVAC systems, and IoT applications due to its precision and ease of integration.

[1] The older folks might remember Iomega (2024)

[2] For more details see *AZ-Delivery NodeMCU Lolin V3 Documentation* (n.d.).

The SCD30 uses a *Non-Dispersive Infrared (NDIR)* sensor to measure CO concentration. It also includes temperature and humidity sensors to provide environmental data and compensate for temperature and humidity effects on CO measurements.

Figure 2: SCD30

The I²C wiring is shown in Table 1.

Table 1: SCD30 wiring

SCD30 Pin	ESP8266 Pin
VCC	3.3V
GND	GND
SCL	D1 (GPIO5)
SDA	D2 (GPIO4)

1.2.1 Key Features

- *CO Measurement*:
  - Measures carbon dioxide concentration with high accuracy.
  - Measurement range: 400 ppm to 10,000 ppm.
  - Accuracy: ±30 ppm + 3% of the measured value.
- *Temperature Measurement*:
  - Measures ambient temperature for environmental monitoring.
  - Temperature range: -40°C to +70°C.
  - Accuracy: ±0.8°C.
- *Humidity Measurement*:
  - Measures relative humidity for air quality applications.
  - Humidity range: 0% to 100% RH.
  - Accuracy: ±3% RH.
- *Interfaces*:
  - Supports *I²C* and *Modbus* communication protocols for easy integration with microcontrollers.
- *Compact Design*:
  - Small form factor (35 mm x 23 mm x 7 mm), making it suitable for compact devices.

1.3 BMP280 Sensor

The *BMP280* is a high-precision, low-power barometric pressure and temperature sensor developed by *Bosch Sensortec*. It is widely used in IoT, weather monitoring, and altitude measurement applications due to its small size, accuracy, and ease of integration.

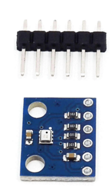

Figure 3: BMP280

The BMP280 uses a piezo-resistive sensor to measure pressure and a temperature sensor to compensate for temperature-related variations in pressure readings. It outputs raw data, which can be processed using libraries or formulas to calculate pressure, altitude, and temperature.

In this project the BMP280 is used to support the *altitude compensation* as explained in (*Interface Description Sensirion SCD30 Sensor Module*, n.d., p. 16).

The I²C wiring is shown in Table 2.

Table 2: BMP280 wiring

BMP280 Pin	ESP8266 Pin
VCC	3.3V
GND	GND
SCL	D1 (GPIO5)
SDA	D2 (GPIO4)

1.3.1 Key Features

- Pressure Measurement:
  - Measures barometric pressure with high accuracy.
  - Pressure range: 300 hPa to 1100 hPa (suitable for altitudes from -500 m to +9000 m).
- Temperature Measurement:
  - Measures ambient temperature as a secondary feature.
  - Temperature range: -40°C to +85°C.
- Low Power Consumption:
  - Ideal for battery-powered devices.
  - Power consumption: 2.7 µA in normal mode.
- Interfaces:
  - Supports both *I²C* and SPI communication protocols, making it versatile for different microcontroller setups.
- Compact Size:
  - Small form factor (2.0 mm x 2.5 mm x 0.95 mm), making it suitable for compact devices.

1.4 OLED SSD1306 display

The *OLED SSD1306* is a popular display module widely used in embedded systems and IoT projects. It features a compact design and high contrast, making it ideal for displaying text, graphics, and sensor data in small devices.

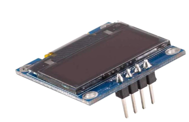

Figure 4: OLED SSD1306 display

The SSD1306 controller drives the OLED display. It communicates with the microcontroller via *I²C* or *SPI*, allowing the microcontroller to send commands and data to render text or graphics on the screen.

1.4.1 Key Features

- *Display Type*:
  - Monochrome OLED display with a resolution of 128x64 pixels.
  - High contrast and wide viewing angles.
- *Low Power Consumption*:
  - Consumes very little power, making it suitable for battery-powered devices.
- *Interfaces*:
  - Supports both *I²C* and *SPI* communication protocols, allowing easy integration with microcontrollers.
- *Compact Design*:
  - Small size (typically 0.96 inches), making it ideal for compact projects.

The I²C wiring is shown in Table 3.

Table 3: SSD1306 wiring

SSD1306 Pin	ESP8266 Pin
VCC	3.3V
GND	GND
SCL	D1 (GPIO5)
SDA	D2 (GPIO4)

1.5 Assembly

The wiring of the bread board prototype is shown in Figure 5.

The color code of the wiring:

- **red** - 5V
- **black** - Gnd
- **orange** - 3.3V
- **yellow** - SDA
- **green** - SCL

2 Software

For my initial microcontroller projects I used to use *Ardunio IDE*[3]. However, since I wanted to expose myself more to *C++* I looked for a more bare bone *C++* tooling.

[3]see *Arduino IDE | Arduino Documentation* (n.d.)

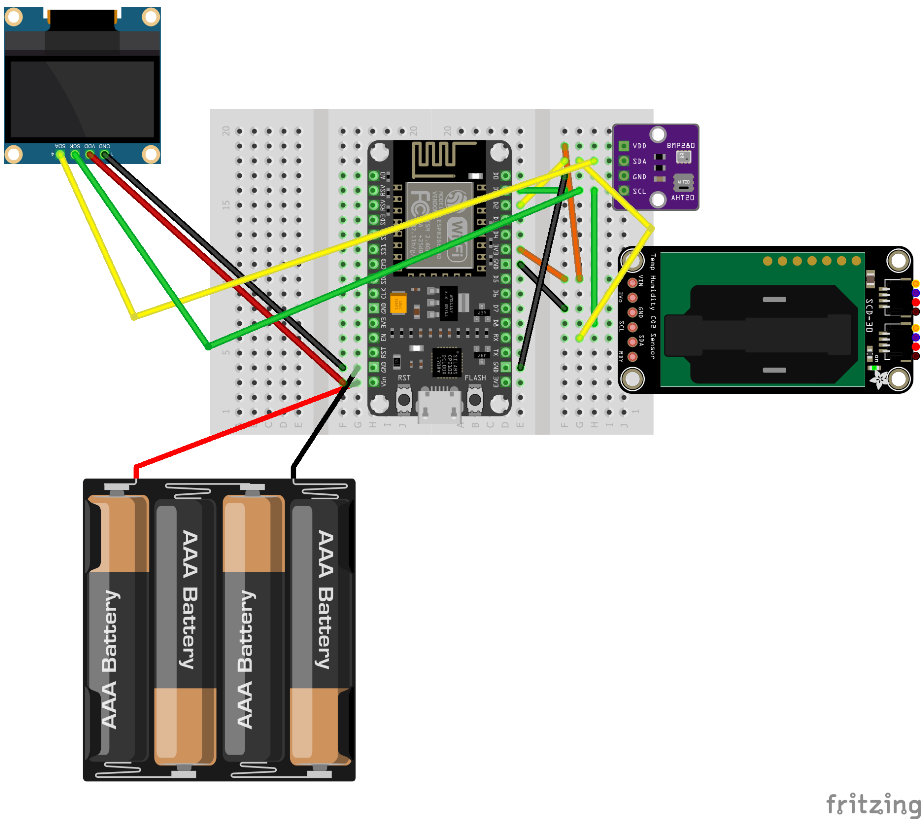

Figure 5: Bread board prototype

The complete source code, including all classes and configuration files, is available in the GitHub repository:

CO Meter GitHub Repository

2.1 Tooling

After some research I found *PlatformIO*[4] and the corresponding plugin for *Visual Studio Code*[5].

https://www.youtube.com/watch?v=JmvMvIphMnY

Figure 6: PlatformIO Beginner's Tutorial - Learn how to get started with PlatformIO.

I selected *Make*[6] as a build and deployment tool for its simplicity and direct control over the build process. In addition, I use it for additional housekeeping tasks such as resolving I²C device addresses.

2.2 Design

A high level Class diagram is depicted in Figure 7. The white boxes show the classes (here: the corresponding header files) developed and the gray boxes show libraries used.

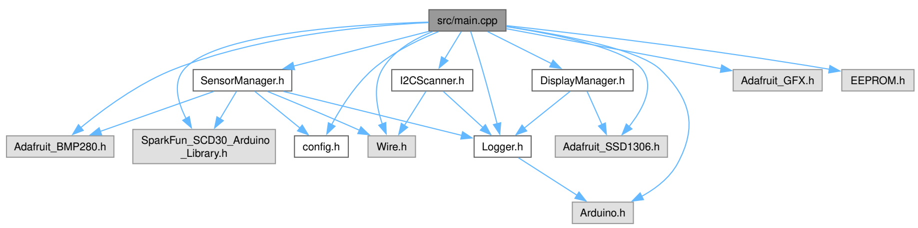

Figure 7: Classes in CO2 meter

The developed classes are:

- **main** serves as an entry point
- **SensorManager** encapsulates communication from and to the sensors
- **DisplayManager** encapsulates communication from and to the display
- **Logger** provides as logging facility to

3 Conclusion

A working prototype is shown in Figure 8 below. You will notice the SDC30 looks quite different compared to the schematic representation in Figure 5. This is a variant of the sensor (SEK-SCD30) with an additional PCB for a RJ47-socket

[4] see PlatformIO (n.d.)
[5] see *Visual Studio Code - Code Editing. Redefined* (n.d.)
[6] see *Make - GNU Project - Free Software Foundation* (n.d.)

to plug in an SEK-Sensor Bridge from the manufacturer *Sensirion*. I retained this variant because it allowed easy access to the pins required for I²C wiring through the existing female connection points.

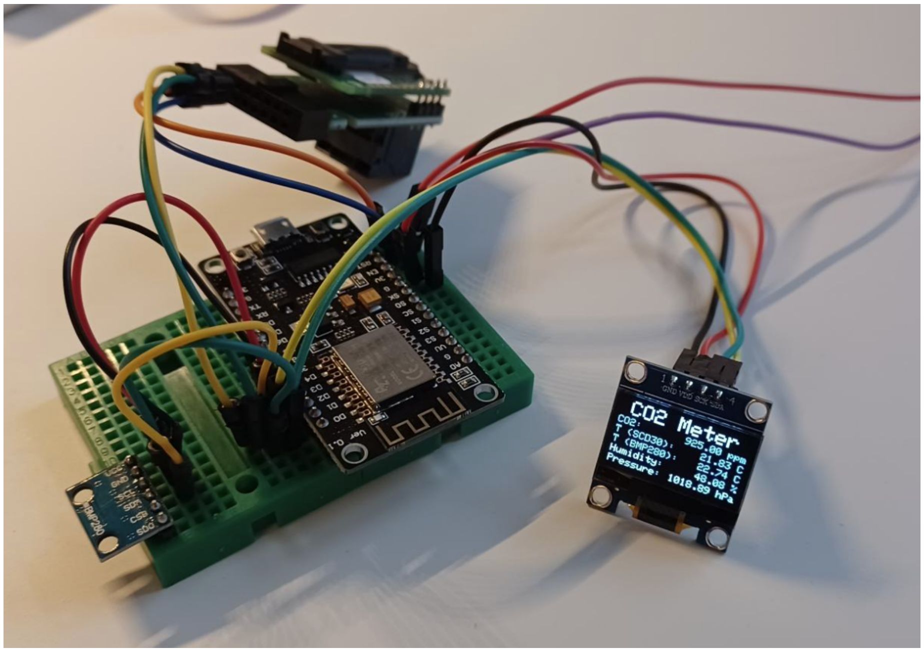

Figure 8: Photo of the running prototype

3.1 Features

The completed project combines hardware and software components to create a functional CO meter with these key features:

- *CO_2 Monitoring*: Measures CO_2 levels using the SCD30 sensor.
- *Environmental Data*: Reads temperature, humidity, and pressure from the SCD30 and BMP280 sensors.
- *OLED Display*: Displays sensor readings and warnings on an SSD1306 OLED screen.
- *Logging*: Logs sensor data and system messages using the Logger class.
- *Calibration*: Automatically calibrates the SCD30 sensor and stores the calibration flag in EEPROM.
- *I²C Scanner*: Scans the I2C bus for connected devices.

4 Next Steps

I already started to look into document *Doxygen*[7]. However, I didn't manage to get its working together with *GitHub pages*[8] so far. I plan to explore CMake as I read it might be the wiser choice looking forward[9]. In addition, unit-testing and run-time debugging sound interesting as well. Hardware-wise the next step could be a PCB version of the prototype outlined here. In addition, I would like to explore the *Low Power Mode for SCD30* mentioned in (*Low Power Mode for SCD30*, n.d.).

Once refined, this CO meter could be deployed in classrooms, offices, or homes to help maintain healthy indoor air quality and optimize ventilation.

Please drop me a note for any helpful hints.

5 References

Arduino IDE | arduino documentation. (n.d.). https://docs.arduino.cc/software/ide/

AZ-delivery NodeMCU lolin V3 documentation. (n.d.). https://cdn.shopify.com/s/files/1/1509/1638/files/AZ196_A_6-8_EN_B06Y1ZPNMS_75603c75-b499-4052-9d38-609562f9fd57.pdf?v=1721119260

CMake - upgrade your software build system. (n.d.). https://cmake.org/

Doxygen homepage. (n.d.). https://www.doxygen.nl/index.html

GitHub Pages documentation. (n.d.). https://docs-internal.github.com/_next/data/uSuKQAxygQnnUD9JQCJms/en/free-pro-team%40latest/pages.json?versionId=free-pro-team%40latest&productId=pages

Interface description sensirion SCD30 sensor module. (n.d.). https://eu.mouser.com/pdfDocs/CD_AN_SCD30_Interface_Description_D1.pdf

Iomega. (2024). *Iomega zip drive*. https://theiomega.com/iomega-zip-drive/

Low power mode for SCD30. (n.d.). https://eu.mouser.com/pdfdocs/CD_AN_SCD30_Low_Power_Mode_D2.pdf

Make - GNU project - free software foundation. (n.d.). https://www.gnu.org/software/make/

PlatformIO. (n.d.). *PlatformIO: Your Gateway to Embedded Software Development Excellence*. https://platformio.org

Visual Studio Code - Code Editing. Redefined. (n.d.). https://code.visualstudio.com/

[7]see *Doxygen Homepage* (n.d.)

[8]see *GitHub Pages Documentation* (n.d.)

[9]While Make gives you raw control, CMake provides higher-level abstractions and dependency management. In short, if you're after modern flexibility and scalability, CMake might be your forward-thinking ally; if you love the simplicity and directness of the old-school approach, Make still holds its charm. See *CMake - Upgrade Your Software Build System* (n.d.)