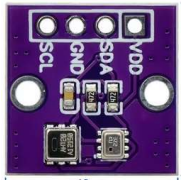
List of all the exact electronic modules used:

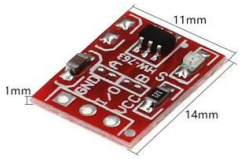
SCD41 CO^2 Sensor

AHT20 Temp+Humidity & BMP280 Pressure sensor

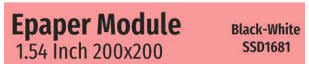


1.54” E-paper display

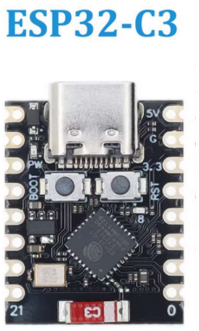
TTP223 Touch Sensor



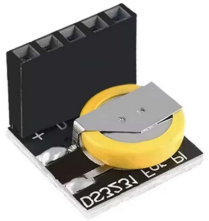
Mini 7x7mm 5-way Switch



ESP32-C3 Microcontroller



DS3231 Time-keeping module



TP4056 L-ion Battery Charger
+ DW01 Battery Protection Module

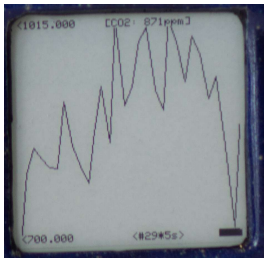
...and resistors, wiring, connectors, and a 2800mAh 18650 Lithium-ion battery. Feel free to pop open the back panel and take a look inside. If anything goes wrong and the device needs a reset, just pull and plug back in the battery cable inside. If there’s any bugs, contact me at joecsul@gmail.com and I can send you a software update. Feel free to take a look at the source code at https://github.com/joevial/CO2Monitor.

BATTERY-POWERED CO^2 MONITOR

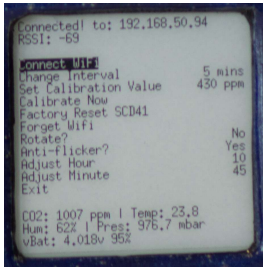
BY JOEVIAL INDUSTRIES

Congratulations! You are now the proud owner of a battery powered, e-paper display, carbon dioxide monitor.

- The main screen displays the CO^2 reading in parts-per-million on a small e-paper display, along with an analog clock indicating the time of the last sample, the air temperature, the relative humidity, the air pressure, and the battery level.
- Carbon dioxide, unlike carbon monoxide, isn’t very dangerous. We exhale it every time we breathe. But exposure to high concentrations for a long time can cause mild physical and psychological deficits in sensitive people.
- Thanks to the e-paper screen, the device can leave information on the display and then “go to sleep”, only waking to take a new sample every 5 minutes, resulting in a battery life of months.
- On the side is a 5-way switch. Pressing the switch in any of the 4 directions will show a chart of the most recently recorded samples of CO^2, temperature, humidity, or pressure depending on the direction pressed.



- The top of this chart will show the name and most recent sample, the top left and bottom left will show the maximum and minimum ranges for the y-axis, and the bottom of the chart will show the time range for the x-axis, given in number of samples multiplied by the sample interval.
- Pressing the center of the switch will take a new reading and return to the main screen.
- Pressing and *holding* the center button will launch the settings menu. From here, you can:
  - Connect to wifi to receive software updates
  - Change the sampling interval
  - Set the calibration target value (outdoor average CO^2)
  - Calibrate the CO^2 sensor based on the above value
  - Reset the CO^2 sensor
  - Rotate the screen
  - Toggle between anti-flicker mode vs anti-ghosting mode (In anti-flicker mode, sometimes the screen leaves a ghost of the previous image. In anti-ghost mode, the screen flashes white and black before each update.)
  - Adjust the time
  - Exit
  - View live updates of all sensors updated every 10 seconds



- The sensor’s accuracy drifts by +-5ppm roughly every 12 months. Once a year, it is recommended to take it outside in warm (5-30°C) fresh air, launch the settings menu, leave it running for 3 minutes, then select “Calibrate Now”. The average outside air CO^2 concentration is currently assumed to be roughly 430ppm, however this number is slowly increasing every year.

Health Canada recommendations:

Residential indoor air quality guidelines for Carbon Dioxide (CO_2)

Exposure limit	Concentration ~~mg/m³~~	ppm	Critical effect(s)
			As CO_2 increases, there may be an increased risk of:
Long-term (24 h)	~~1,800~~	1,000	• mucous membrane or respiratory symptoms (e.g., eye irritation, sore or dry throat, stuffy, congested or runny nose, sneezing, coughing, and rhinitis) • decreased test performance (e.g., decision-making, task performance, standardized test scores) • neurophysiological symptoms (such as headache, tiredness, fatigue, dizziness or difficulty concentrating)

The recommended long-term exposure limit for CO_2 is 1,000 ppm (based on a 24-hour average). The guidelines are based on effects observed in epidemiological studies in schools or offices and controlled exposure studies.

Studies in humans in school or office settings have found associations between CO_2 exposure and mucous membrane or respiratory symptoms, rhinitis, neurophysiological symptoms, a lack of concentration, headaches, dizziness, heavy-headedness, tiredness, and decreased performance on tests or tasks. Studies in laboratory animals were generally at high concentrations of CO_2; however, the results from studies investigating the neurological effects of CO_2 exposure or its effects on the developing brain support the observations from human studies.

Individuals with pre-existing health conditions (such as allergies and asthma) were found to be more susceptible to the mucous membrane and respiratory effects of CO_2 than those without these conditions. Patients suffering from panic disorder were found to be more susceptible to the anxiogenic effects of CO_2 compared to healthy subjects. Due to the physiological and metabolic actions of CO_2 in the body, it is expected that individuals with cardiovascular conditions may also be more susceptible to the health effects of elevated CO_2 exposure.

As CO_2 levels are strongly correlated with occupant density and ventilation, achieving a CO_2 level in the home that is below the recommended exposure limit should be feasible with uncrowded housing and adequate ventilation. These strategies include the following:

- increasing natural ventilation by opening windows (taking into consideration ambient air quality);
- ensuring fuel-burning appliances are in good working order and properly vented;
- setting the mechanical ventilation system to a higher setting or letting it run longer;
- running the kitchen range hood exhaust fan when cooking;
- using the furnace fan or, if necessary, a separate fan or air supply to make sure air is distributed throughout the home;
- avoiding the use of unvented fuel-burning appliances (e.g., gas space heaters) indoors;
- not smoking indoors; and
- avoiding crowded living situations, if possible.

(https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guidelines-carbon-dioxide.html)

Swiss Sensirion SCD41 CO^2 Sensor info:

The SCD4x is Sensirion's second generation series of optical CO^2 sensors. The sensor series builds on the photoacoustic NDIR sensing principle and Sensirion's patented PASens® and CMOSens® technology to offer high accuracy at an attractive price and small form factor. On-chip signal compensation is realized with the built-in SHT4x humidity and temperature sensor.

SCD41: Improved accuracy, specified measurement range 400 – 5'000 ppm, additionally compatible with California Title 24 2 and RESET® 3, features single-shot operation mode

SCD41 CO^2 measurement accuracy:

400 ppm – 1'000 ppm ±(50 ppm + 2.5% of reading)

1'001 ppm – 2'000 ppm ±(50 ppm + 3% of reading)

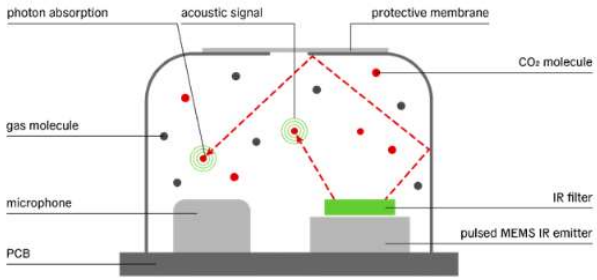
2'001 ppm – 5'000 ppm ±(40 ppm + 5% of reading)

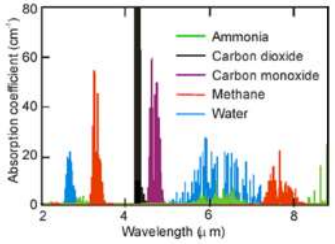
Temperature operating conditions: (-10°C to 60 °C)

Sensor lifetime Typical operating conditions >10 years

Photoacoustic NDIR (PA)

PA uses a pulsed IR light source that emits wavelengths absorbed by CO_2. Absorption of light by CO_2 molecules leads to additional molecular vibration, increasing the pressure in the measurement cell. As the light source is pulsed, this pressure increase occurs periodically, creating an acoustic wave. The more CO_2 molecules present, the larger the amplitude of the acoustic wave. This is measured by a microphone to calculate the CO_2 concentration.





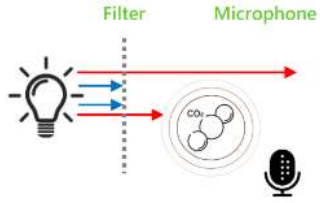


Illustration of a Photoacoustic NDIR setup

(https://sensirion.com/products/catalog/SCD41)