DS-CO2-20

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Easy-to-build and accurate CO_2-meter with LCD

On this Arduino-forum we see projects with CO_2-sensors but the question is: how accurate are the measurements? As you know, within these Covid-days, accurate measurements are very important as they give an idea about the need of ventilation. When do we need to open windows and when can they be closed? And is the ventilation system working well? This is especially important during these cold days.

So we made measurements on 5 different types of CO_2-sensors (gas- and NDIR) that are used a lot in combination with Arduino. We compared the results with a very precise CO_2-meter (AirCO₂ntrol 5000). As a result we concluded that only one sensor passed our tests.

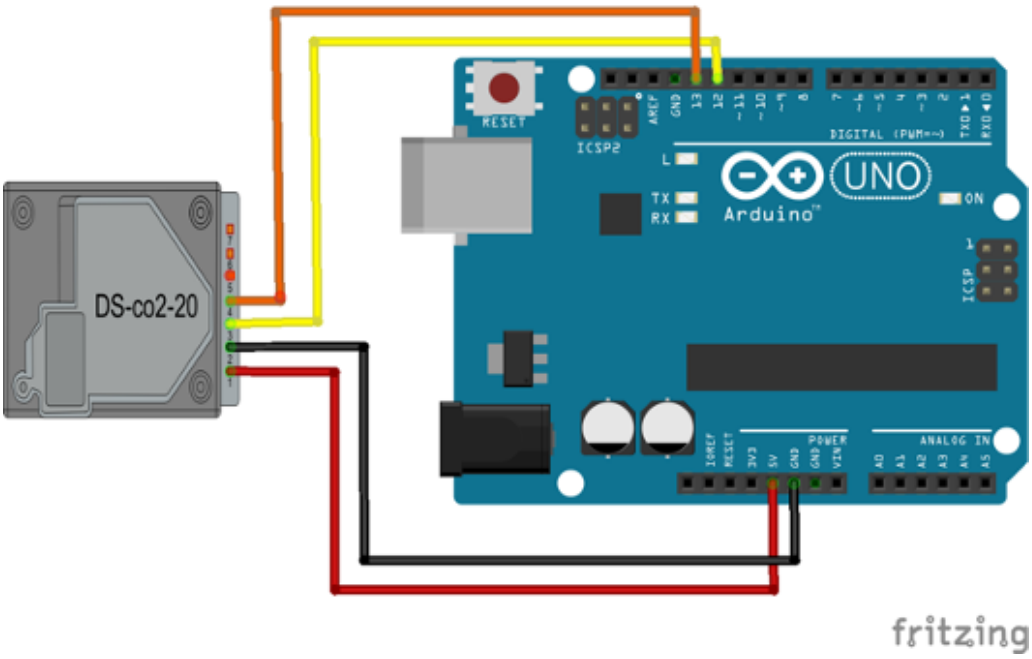
Based on this DS-CO2-20 sensor, we made an easy to build CO_2-meter that gives an indication about the air-quality. We worked in an Arduino UNO environment with LCD. The price is around € 70, all components included.

We are three students at the Energy Technology University college Odisee in Belgium (Ghent). We thought this was an exciting project to do and yes it turned out to be so ☺.

Hardware

Connection of the DS-CO2-20 sensor

- In our project we worked with the DS-CO2-20 NDIR-sensor (about €35)
- Plantower® ds-co2-20 co2 sensor dual channel gas accurate detection of carbon dioxide sensor module Sale - Banggood.com

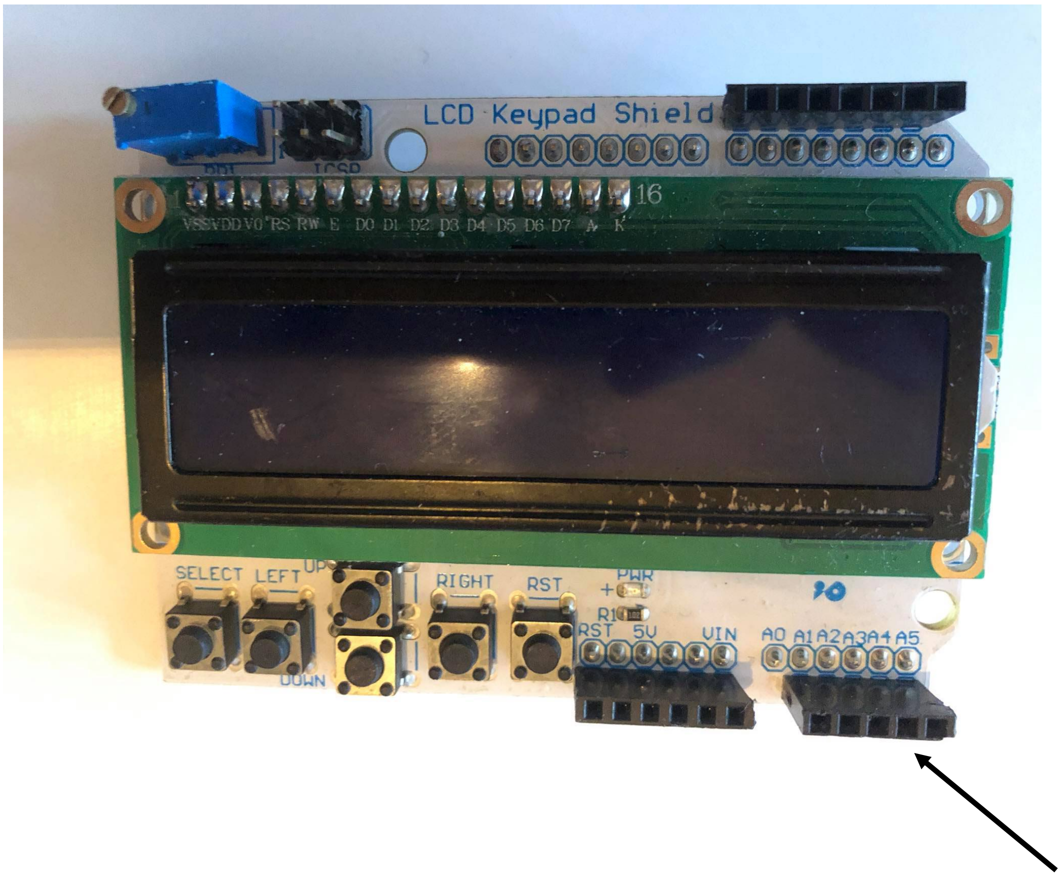


Connection of the LCD

We worked with this LCD shield: LCD & KEYPAD SHIELD FOR ARDUINO® (VMA203) from Velleman. (about €15)

https://www.velleman.eu/products/view/?id=435510

Thanks to the LCD Keypad shield, we can easily place the shield on the Arduino.

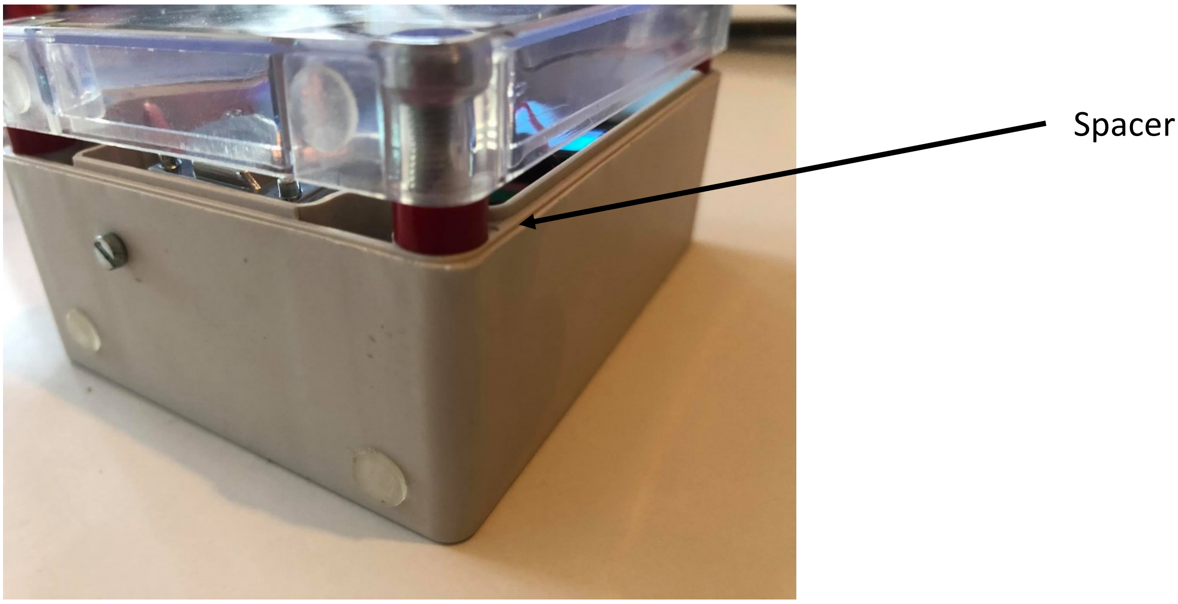


Headers

On our shield we placed multiple headers which allow us to connect other components without the need of soldering. These were especially useful when testing the different pins for the sensors. For the DS-CO2-20 we didn't have headers for digital pin 12&13, so it needed to be soldered. We used the headers for the 5V-supply and the GND-pin.

If you don't want to use a Keypad shield, it is also possible to use a regular LCD (with breadboard) with slight adjustments in the code.

Case of the CO2-meter



Spacers are placed between the lid and the case. This ensures that enough ambient air enters the housing where the sensor is located. So a good air flow between the lid and the box is important.

Measurements on our prototype and the Aircontrol 5000

The "Air CO_2ntrol 5000" is used as reference meter. It works on the same principle (NDIR) as the sensor we use.

Calibration

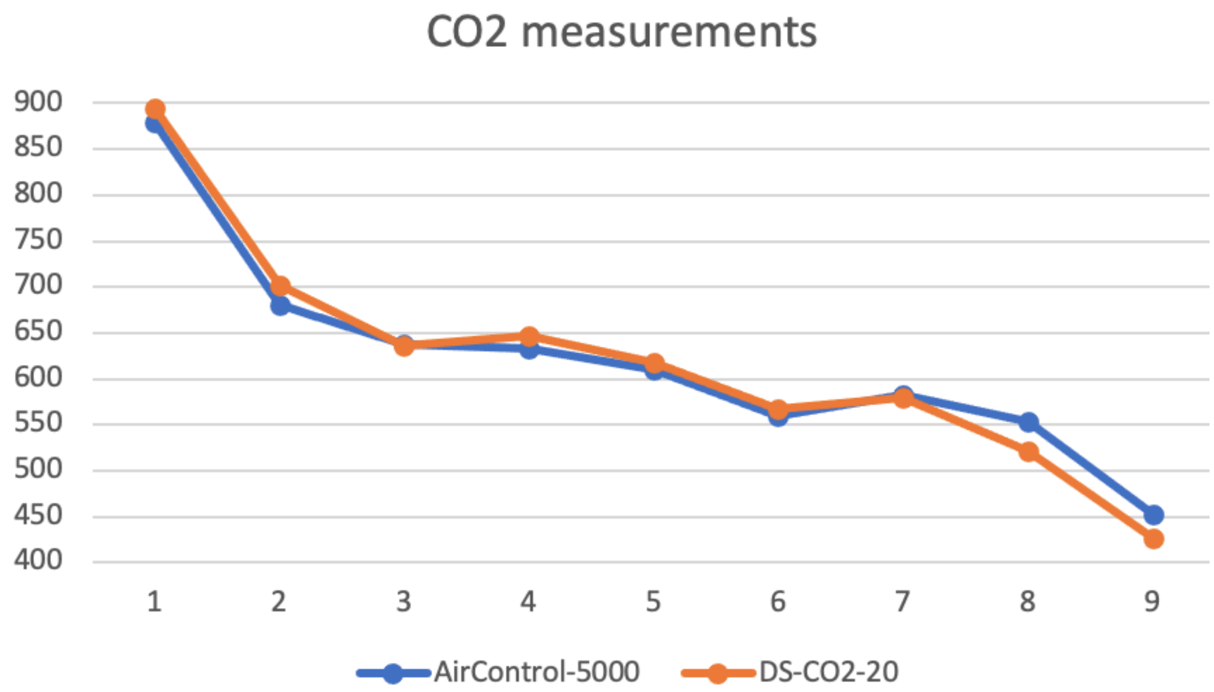
The calibration of the Aircontol 5000 and DS-CO2-20 is performed in a room that is ventilated very well (all windows open for an hour and no people in it). After calibration, the ppm value is 400, which is approxmately the value of open air.

The Aircontol 5000 has a calibration function.

With our DS-CO2-20 we do a correction with a software constant.

Measurements on prototype

Our measuring procedure starts at a high CO_2 level. This can be achieved by closing all doors and windows of the bedroom before you go to sleep. This increases the CO_2 level because the produced CO_2 cannot escape. In the morning both sensors will be activated and both will have to heat up for a certain period of time. After this a window can be opened to ventilate the room. the CO_2 level will drop to around 400 ppm. We made measurements at regular intervals so that we obtain the curve below. Give the unit approx. 5 to 20 minutes to have a really accurate value.



Conclusion:

in the above measurements, we can see that our homemade prototype matches the reference. This means that we can use this meter to give us a good indication of the air quality.

Measurements on 9 units

After the good results with the prototype we built 9 meters in total.

We noticed that the values of all meters (including our AirControl 5000) were not stable concerning temperature and humidity change. E.g. an outside 400 ppm value in the evening at 20 °C turned out to be another value in the morning at 5 °C (also after giving the unit enough time to adapt to the new weather conditions).

After some experimenting, we noticed that we had accurate results when calibration of 400 ppm is done in the room where the meter is used. Of coarse with all windows open for some time and no people in the room.

This table gives an idea about the calibration-correction for our 9 meters:

	open windows without calibration	correction	end value open windows
aircontrol 5000	405		405
prototype	568	160	408
unit 2	514	110	404
unit 3	408	0	408
unit 4	908	500	408
unit 5	506	100	406
unit 6	673	270	403
unit 7	676	270	406
unit 8	766	360	406
unit 9	606	200	406

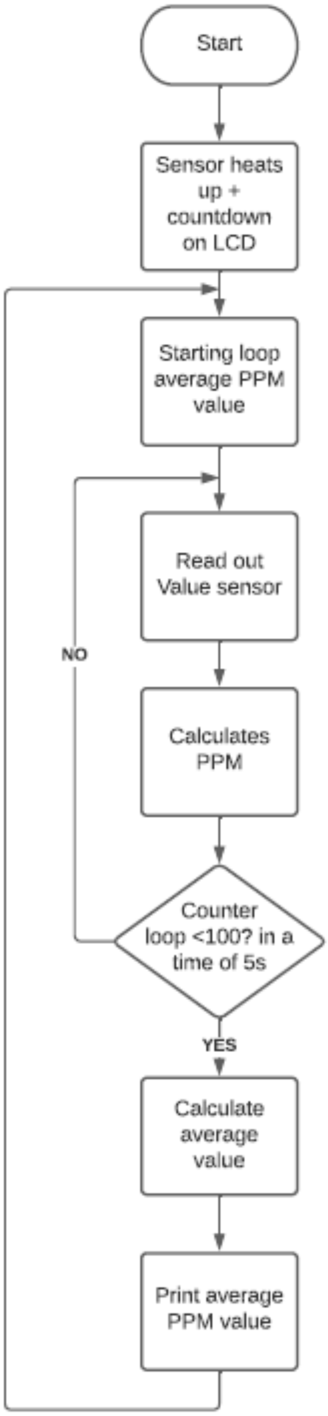
After calibration, these 400 ppm values were very stable for 8 of the 9 units in this room, also after a few days.

Foor higher CO2 values, 7 of the 9 units gave an accurate measurement. The 2 others gave values that were 100 ppm to high. E.g. they indicated 800 ppm when the real values was 700 ppm. The other did the opposite. In fact these meters also can be used as they also give an indication about the air quality.

Conclusion

If you are in search for a meter that indicates the air quality, this meter can be used very well. For 100% accurate values, you can not use it. However, our reference airControl 5000 is also not a 100% accurate meter. These 200€ meters only give an indication of the air quality.

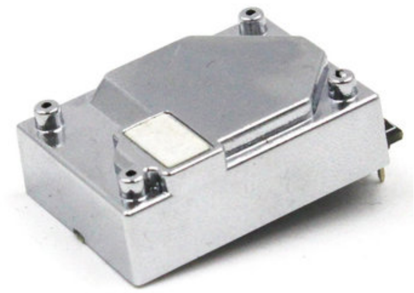
Flowchart


Start
Sensor heats up + countdown on LCD
Starting loop average PPM value
Read out Value sensor
NO
Calculates PPM
Counter loop <100? in a time of 5s
YES
Calculate average value
Print average PPM value

Measurement principles of CO_2 sensors

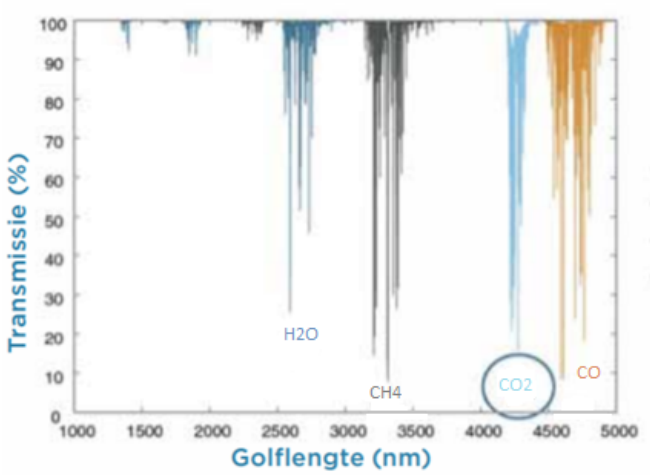
NDIR-working principle

<u>Plantower DS-CO2-20</u>



<u>Working principle</u>

Carbon dioxide and other gases consisting of two or more unequal atoms absorb a certain amount of infrared radiation. In picture 1 you can see that each gas absorbs infrared radiation at a unique wavelength. Based on the amount of infrared radiation that is absorbed, gases such as CO_2 can be detected.



Transmission represents the permeability of infrared radiation. At a high transmission, little infrared radiation is absorbed and at a low transmission, a lot of infrared radiation is absorbed. Wavelength represents the decay between two points with the same phase.

An infrared sensor consists of an infrared lamp, a tube or a measuring chamber, an optical filter and also an infrared detector. The infrared lamp emits light waves through the tube filled with gas from the environment. The absorption band of CO_2 is around 4260 nm. As a result, the CO_2 molecules will only absorb the specific band around 4260 nm, while allowing the other wavelengths to pass

through. At the end of the tube, all the remaining infrared light hits the optical filter which will absorb everything except the wavelength at which absorption took place by the CO2 molecules. Then the detector measures the remaining infrared light passing through the filter. On the basis of this measurement, the amount of CO2 present can then be determined.

Pros & Cons

Infrared sensors have many advantages over chemical sensors. They are stable and very selective regarding the measured gas. They have a long lifespan (4 - 5 j) and because the measured gas is not in direct contact with the sensor, IR sensors are resistant to high humidity, dust, dirt and other harsh conditions. They are a lot more expensive than the chemical sensors.

Why we didn't use the cheaper gas sensors?

Before we started working with NDIR-sensors we tried for three weeks to make an operating CO_2-meter using multiple gas sensors. Unfortunately we did not succeed. We specifically worked with two gas sensors. These were the **MQ135 (€5)** and the **SparkFun Enviromental Combo CCS811 / BME280**. **(€ 8)** When testing these sensors, there were some problems. For example, the CO2 values did not remain stable and did not match the reference-meter (Air CO_2ntrol 5000).

An attempt was made to work with correction factors and correction formulas after the first tests. These attempts did not lead to a solution for these sensors. Therefore, these two sensors are not recommended to be used in similar projects and we decided to switch to NDIR-sensors.

Working principle

A chemical sensor will produce a corresponding output voltage based on the gas present, by changing the resistance of the material in the sensor. This makes it possible to determine the type and concentration of the gas present.

A chemical sensor consists of a gas detecting layer and a heating coil that will burn in the detecting layer to increase its efficiency. Between these 2 elements there is a tubular ceramic that will promote the burning in of the detecting layer. Finally, there are also electrodes that are connected to the output of the detecting layer through which the output current will flow.

The gas detecting layer is in fact a variable resistance that will change based on the concentration of a gas in the environment. This layer consists of tin dioxide which generally has an excess of electrons. When no CO2 is present, the oxygen particles in the environment will attract the free electrons in SnO2. This will push the electrons to the surface of SnO2. Because then no more electrons can flow through the electrodes, the output current is 0 A.

When the sensor is placed in a CO2 rich environment, the chemical bond between the oxygen particles and the free electrodes is broken. As a result, electrons are released again and go back to their original position. As a result, a current can flow back through the electrodes that is proportional to the amount of available electrons in SnO2. The more CO2 is present, the higher the output current will become.

Pros & Cons

Chemical sensors have the advantage that they have a lower energy consumption, have a linear output and are usually a lot cheaper. However, they have a lower lifespan (1-3 years) which makes the sensor require more maintenance. Another problem with chemical sensors is that they measure different types of gases, which makes it difficult for them to distinguish between the gases that are present. This causes unstable and inaccurate measurements.