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Assessment of the CU-1106 Series of CO_2 Sensors

I. Introduction

"[*There are a variety of carbon dioxide (CO_2) sensors that differ in important factors such as cost, power consumption, accuracy, and precision. Generally, highly accurate and more precise instruments consume more power and are expensive. Consequently, cheaper sensors have lower quality in their data measurements. The importance of each factor depends on the application. For example, if the device must operate from battery power, then power consumption has significance in determining which sensor to choose.*

The cost of CO_2 sensors spans anywhere from around $50 to thousands of dollars. Although expensive high-end analyzers are likely better, low-cost simple analyzers are still advantageous. A low-cost sensor's inexpensive and low power consumption can be comparable to a high-end instrument if used in the proper application.]." The above information is an excerpt from a similar document[1] written by the same author: "Assessment of the SCD30 Sensors."

The manufacturer known as GasLab sells a family of low-cost CO_2 analyzers called the Cubic CU-1106. These sensors have four variations[2]: the C, the H-NS, the SL-NS, and the SL-N. All four versions look physically identical but have slightly different configurations and features. The cost of the CU-1106 series range from $80 to $130, depending on the exact version. Generally, low-cost analyzers have simpler and limited technology, reducing the accuracy and precision of measurements.

On the other hand, expensive high-end analyzers have better technology that allows their data to have better quality. One such analyzer is the GasHound LI-800[3]. This assessment aims to compare the performances of the low-cost CU-1106 sensors with that of the GasHound LI-800.

II. Equipment

a. Low-cost sensor

The GasLab Cubic CU-1106 sensors use nondispersive infrared (NDIR) technology to measure CO_2. Any microcontroller, such as an Arduino board, can control these devices. Unlike high-end analyzers, these low-cost sensors function passively, not requiring any pumps to intake gas. As stated previously, each version of the CU-1106 series has slight variations. Table 1 shows the difference in specifications between the different sensor models.

Table 1: Specifications of the Cubic CU-1106 CO_2 sensors[2].

Sensor Model	CU-1106-C	CU-1106H-NS	CU-1106SL-N	CU-1106SL-NS
CO_2 range	0 – 5000 ppm	0 – 10000 ppm	0 – 5000 ppm	0 – 5000 ppm
	± (50ppm+5% of reading)	± (30ppm+3% of reading)	± (50ppm+5% of reading)	± (50ppm+5% of reading)
Frequency	1 second	1 second	4 seconds	4 seconds
Cost	N/A	$89	$129	$89

b. Sensor Data Logger

A data logger is an electronic circuit that records data from a sensor over time and stores it reliably. A prototype logger was built on a breadboard using various components to retrieve data from a CU-1106 sensor. An Arduino Mega controls the circuit by extracting CO_2 measurements and timestamps from a CU-1106 sensor and a time-keeping module. The Arduino stores the information into a microSD card.

The experiments performed in this assessment used four separate data loggers, where each one was dedicated for each CU-1106 sensor model. Figures 1 and 2 show the breadboard and schematic of the data logging circuit for the CU-1106H-NS model. The data loggers for the other models contain the same components but have slightly different wrings to account for the differences in pinout configurations of the CU-1106 models.

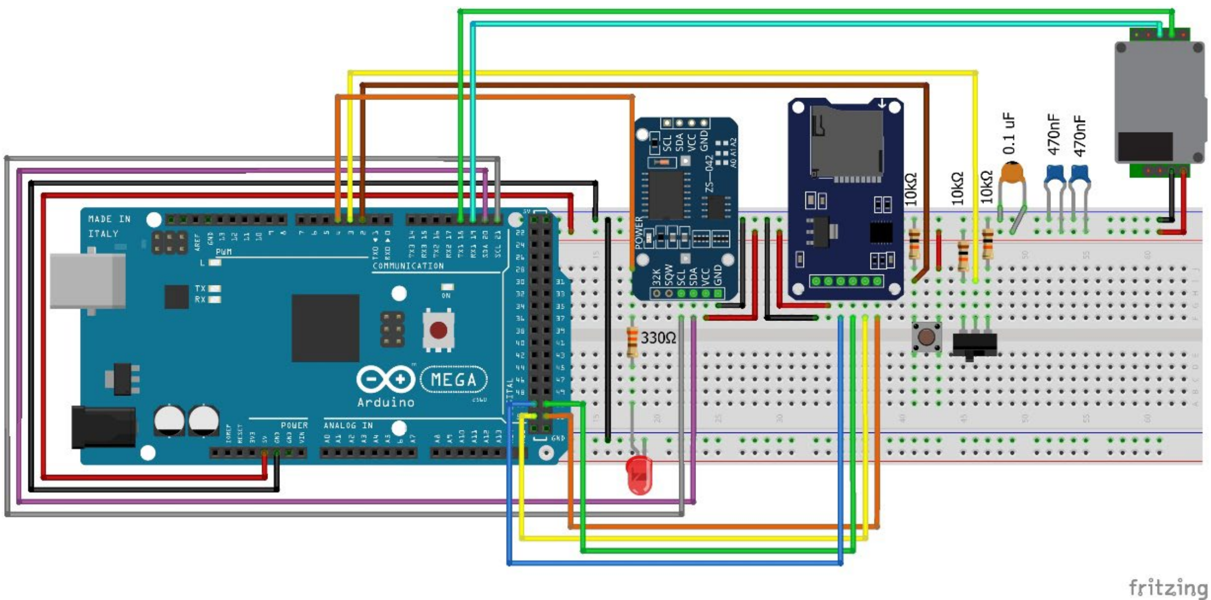

Figure 1. Breadboard diagram of the CU-1106H-NS DataLogger[4].

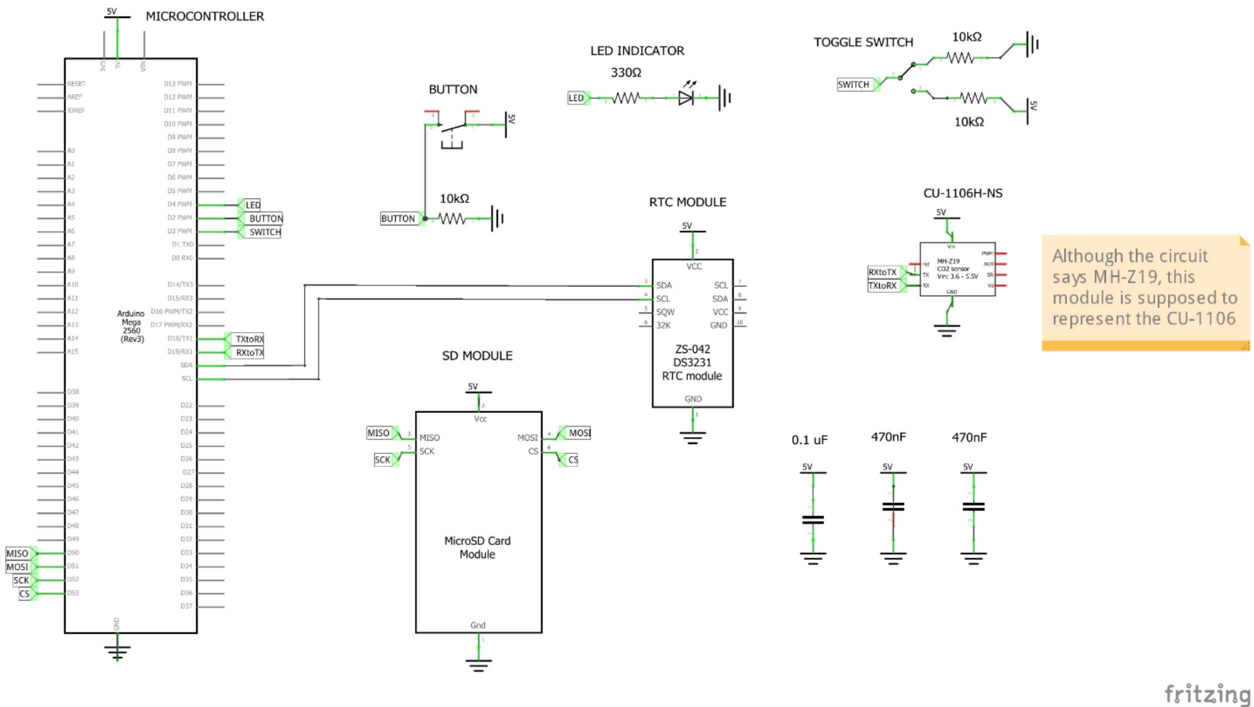

Figure 2. Electrical schematic of the CU-1106H-NS DataLogger[4].

c. High-end sensor

"[*An expensive CO_2 gas analyzer is the GasHound LI-800, which uses NDIR technology. Typically, a computer is connected to the instrument to control it and extract data from it. However, an Arduino Uno is capable of retrieving measurements from the device. The LI-800's measurement range is limited to only 0 to 2,000 ppm, but the sampling rate can be as fast as 0.5 seconds. Because of its complexity and the requirement of a pump to intake gas, the current draw is generally 300 mA at a voltage between 12 V and 30 V.*

The GasHound was calibrated using gas cylinders with known concentrations before the experiments. Therefore, the measurements given by this high-end gas analyzer are assumed to be the correct readings, thereby granting the LI-800 100% accuracy. The purpose of this is so that the low-cost CU-1106 sensors have a baseline to compare their measurements with]" The above information is another excerpt from the similar document[1]: "Assessment of the SCD30 Sensors".

d. CO_2 Gas Cylinder

A stable supply of carbon is needed to assess the performance of the low-cost sensors and the expensive sensor. The following laboratory-based experiment uses three gas cylinders containing 0 ppm, 500 ppm, and 1500 ppm of CO_2. A pressure regulator attaches to each cylinder controlled by a valve to release gas through connected tubing. It is reasonably assumed that any gas released from a cylinder is the precise concentration it is rated to be.

III. Experiment 1: Laboratory Setting

This experiment aims to observe how well each CU-1106 device responds to a sudden decrease in concentration and then a sudden increase in concentration. The measurements from the GasHound LI-800 act as the baseline for comparing the CU-1106 devices. Below is the experimental procedure for a laboratory-based setting involving CO_2 gas cylinders.

a. Procedure

1. Hook up each CU-1106 sensor to a data-logging circuit where external batteries power the Arduino microcontrollers.
2. Connect the LI-800 to an Arduino board powered by a local computer. The LI-800 itself, however, is powered by a nearby wall outlet to deliver the high voltage required to operate it.
3. Place all five sensors in the same open container.
4. Connect a tube from the container to a gas cylinder containing 0 ppm of CO_2 (air). Leave the cylinder valve closed.
5. Boot up all sensors and ensure that each one is functioning correctly.
6. Allow 5 minutes for the sensors to record ambient concentrations.
7. Then, open the cylinder valve and leave it open for about 5 minutes to continuously inject air into the system.
8. Close the valve and transfer the pressure regulator to the cylinder containing 500 ppm gas.
9. Open the pressure regulator to allow a continuous injection of 500 ppm gas lasting about 10 minutes.
10. Close the valve and transfer the pressure regulator to the cylinder containing 1500 ppm gas.
11. Open the regulator to allow a continuous injection of 1500 gas lasting a few minutes.
12. Close the valve, and shut down the sensors.

b. Results

Because the experiments were performed before the calibration method was coded, ppm offset values were applied for each sensor's values to compare the results better. Figure 3 displays the results without offset values, whereas Figure 4 has the offset values applied to the results.

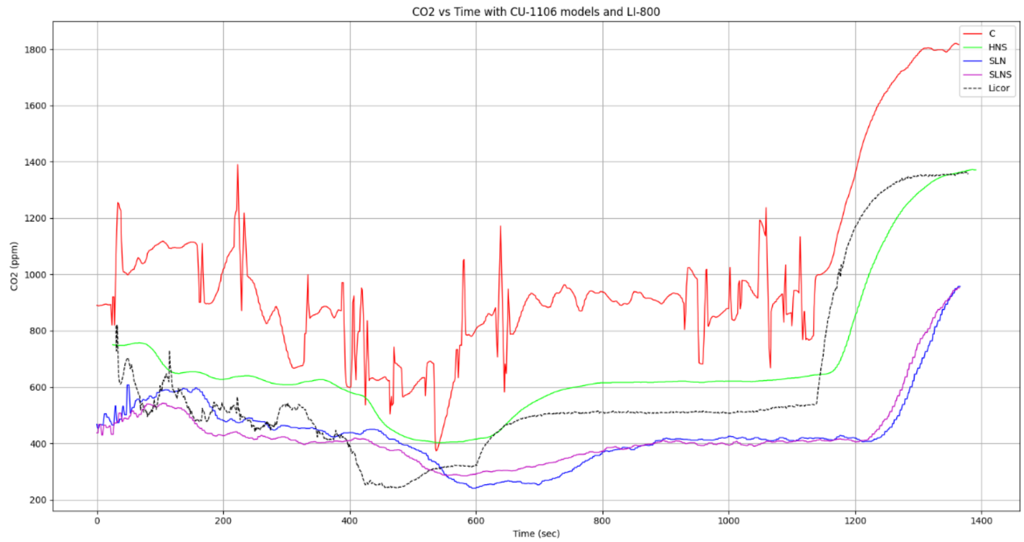

Figure 3: Raw Concentration versus Time plot of the Laboratory-based experiment.

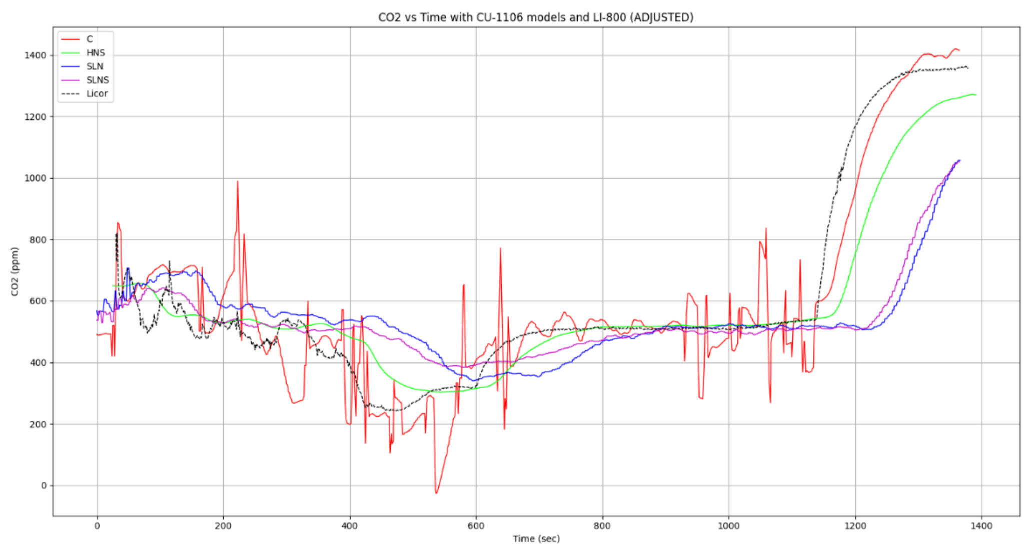

Figure 4. Adjusted Concentration versus Time plot of the Laboratory-based experiment.

c. Analysis

The results from the laboratory-based experiment reveal helpful information. From Figures 3 and 4, the following observations are made:

1. Models C and HNS have a delay to changes in ppm when compared with the Licor. However, models SLN and SLNS have a much longer delay. These delays are seen around time t = 1150 sec. The SLN and SLNS sensors are designed for low-power applications, which means their power draw is very low, likely causing a much longer

response time. If this is the case, it may indicate that low-cost sensors that **draw very low power have limitations in response time**.

2. Model C is the standard version but has very high signal noises. However, despite the noise, the general behavior of its graph resembles those of the other sensors. Therefore, **sensors with significant noise may still be able to detect the general trend of the gas concentrations**.

3. Although the CU-1106 sensors were not calibrated, the behavior of the plots for each sensor resembles the Licor's plot. The resemblance supports that these **low-cost sensors work reasonably well to detect significant concentration changes**.

IV. Experiment 2: Outdoor Setting

In this experiment, the CU-1106 devices are placed in an outdoor setting to assess their performance in the field. The procedure for the outdoor-based setting is as follows:

a. Procedure

1. Hook up each CU-1106 sensor to a data-logging circuit where external batteries power the Arduino microcontrollers.
2. Connect the LI-800 to an Arduino board powered by a local computer. The LI-800 itself, however, is powered by a nearby wall outlet to deliver the high voltage required to operate it.
3. Place all five sensors in the same area, with about 1 foot of spacing from one another.
4. Boot up all sensors and ensure that each one is functioning correctly.
5. Allow the sensors to record data.
6. Occasionally introduce gas spikes onto the sensors by blowing air over them.

b. Results

Similar to Experiment 1, the sensors were not also not calibrated before the experiment. However, no ppm offset values were applied to the dataset shown in Figure 5. The sensors SLN and SLNS did not have very high absolute values, making it difficult to see their behaviors when plotted alongside the other sensors. Therefore, Figure 6 shows the results from only these two sensors.

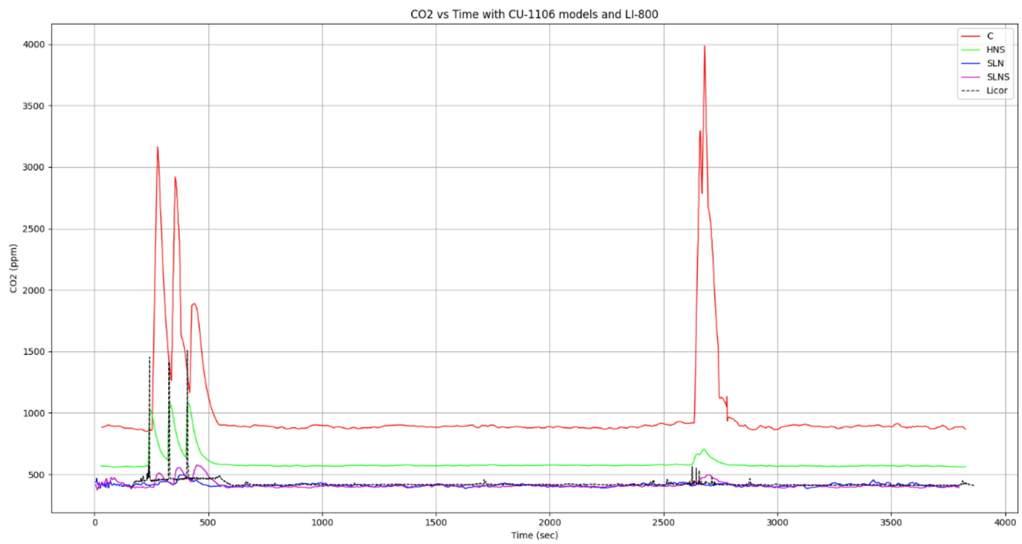

Figure 5. Concentration versus time plot of the Field-based experiment with all the sensors involved.

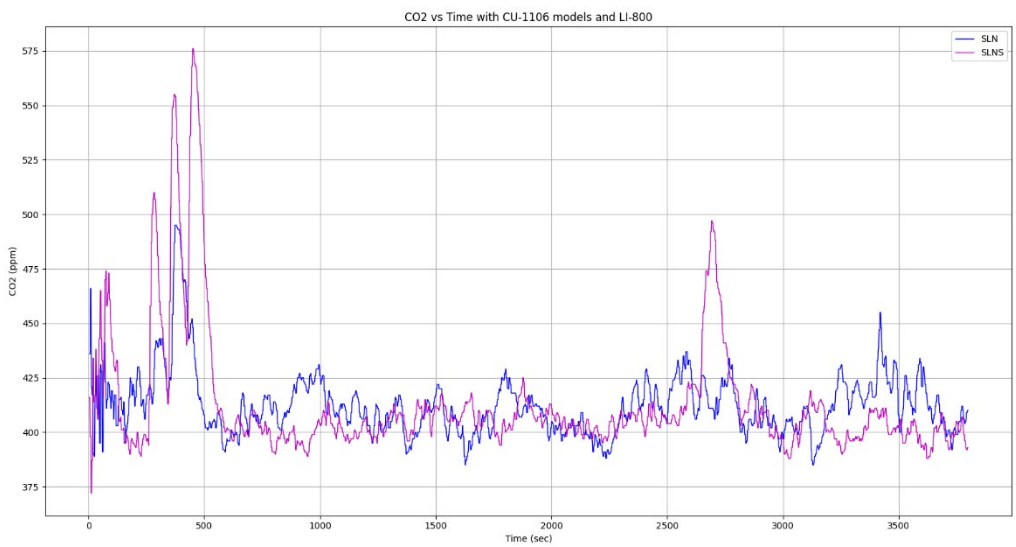

Figure 6. Concentration versus time plot of the Field-based experiment with only the SLN and SLNS models.

c. Analysis

The results from the field-based experiment reveal additional information regarding the reliability and performance of the CU-1106 series of sensors. From Figures 5 and 6, the following observations are made:

1. Model HNS reported changes in concentration that were similar to that from the Licor sensor between times t = 250 and t = 400. However, Model C reported extreme changes in concentration, especially at time t = 2700. In contrast, models SLN and SLNS reported minimal changes. Although low-cost sensors can detect significant changes in concentration, **the reported changes may sometimes be either too high or too low, thereby limiting the reliability of their data.**

2. In addition, sometimes changes in concentration may not even be detected at all. For example, in Figure 5, at about time t = 2700, sensors C, HNS, and the Licor detect a spike in concentration. In Figure 66, sensor SLNS also detects it at the same time. However, sensor SLN does not reflect the concentration change. Two possible explanations are:
    - 1. The plume of gas did not enter the vicinity of this specific sensor; therefore, it could never have detected it.
    - 2. The sensor, being limited by its low-power functionality, was not powerful enough to register the concentration change.

    Regardless of the reason, this missed detection is another example of the limited reliability of the low-cost sensors.

V. Conclusion

The laboratory-based and outdoor-based experiments demonstrated the differences between a high-end analyzer and a low-cost sensor. The results show that the LI-800 detects concentration changes faster, and its data is smoother and has less noise. On the other hand, the simple CU-1106 sensor faces the drawback of sometimes either outputting extreme concentration values or not detecting concentration changes. Despite these performance differences, the CU-1106 sensors can still capture the general trend of the gas concentrations.

Additional resources are contained in the Wireless Sensor Network repository[5] and the CSR Arduino Collection repository[6].

References and Useful Links

[1] Assessment of the SCD30 sensor
https://github.com/jkub6/WirelessSensorNetwork/blob/master/Section1-Prototyping/Assessment-SCD30/Document-AssessmentSCD30.pdf

[2] GasLab CU-1106 Product Information:
https://gaslab.com/products/single-beam-ndir-co2-sensor-cubic?variant=31908344758387

[3] GasHound LI-800 Datasheet
https://www.licor.com/documents/3a029cfc7eyih2ryt8x1

[4] CU-1106H-NS DataLogger Guide and Code:
https://github.com/RiceAllDay22/CSR_Arduino_Collection/tree/main/Data_Loggers/CU-1106H-NS_Logger

[5] Wireless Sensor Network Repository
https://github.com/jkub6/WirelessSensorNetwork

[6] CSR Arduino Collection Repository
https://github.com/RiceAllDay22/CSR_Arduino_Collection

Contact

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