Miniature Multi-Sensor Array for air quality measurement using drones or balloons.

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Introduction & Background

There are numerous college research groups doing high altitude ballooning and working with drones. Many of these are making air quality measurements. Those measurements are effectively random. We are designing an inexpensive and easy to build assembly that others can build for under $500 with the goal of having a uniform data set that can be compared. This will provide more useful data for atmospheric studies. Our first version had too many noise issues and the gas sensor signals were unstable. In December 2020 Winsen Sensors (China) came out with a "multi-in-one sensor module," the ZPHS01B. At a price point of approximately $150 we decided to completely revise our design.

Introducing the miniature Multi-Sensor Array ("miniMSA") version 2.0!

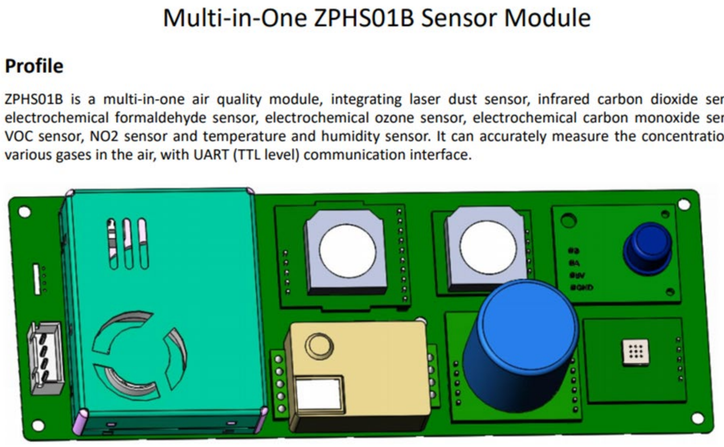

Figure 1. From the Winsen ZPHS01B datasheet.

This module measures: PM1.0, PM2.5, PM10, CO, CO_2, -OH ("formaldehyde"), VOC, O_3, and NO_2. The particle sensor is the common Plantower PMS7003M. The datasheet says that the three ranges measure 0.3-1.0 µm, 1.0-2.5 µm, and 2.5-10 µm.

Design Overview

Version 2.0: Raspberry Pi

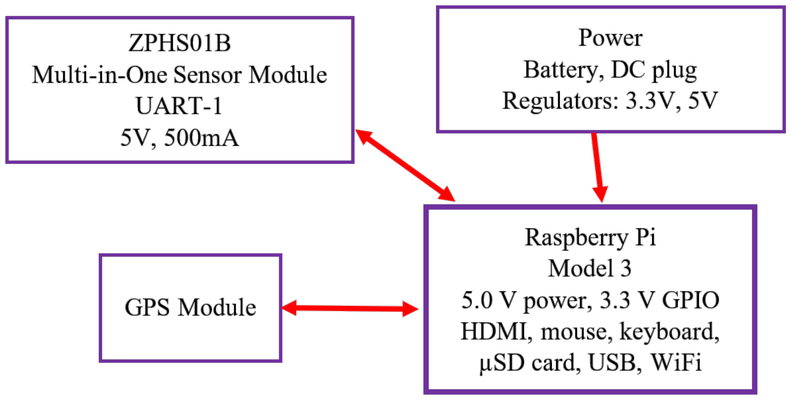

Figure 2. Block diagram of the sensor system.

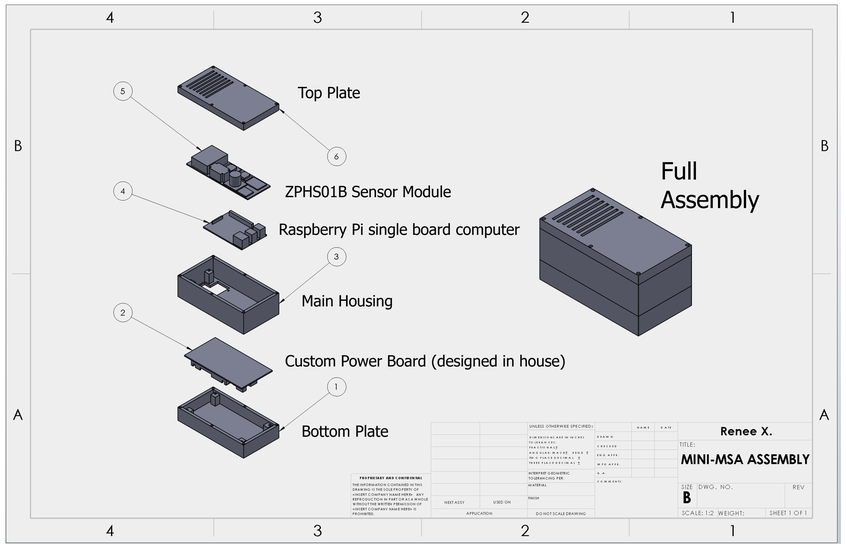

Figure 3. Prototype housing design. The final design will have more air flow and attachment points for hanging under a balloon or drone. The GPS module will be added inside the assembly as well.

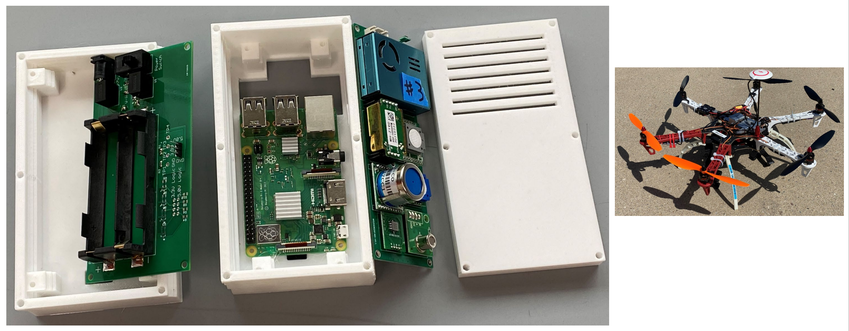

Figure 4. Preliminary assembly will have attachment points added. This will be suspended under a drone (inset) or balloon.

Version 3.0: Custom Microcontroller (still being built)

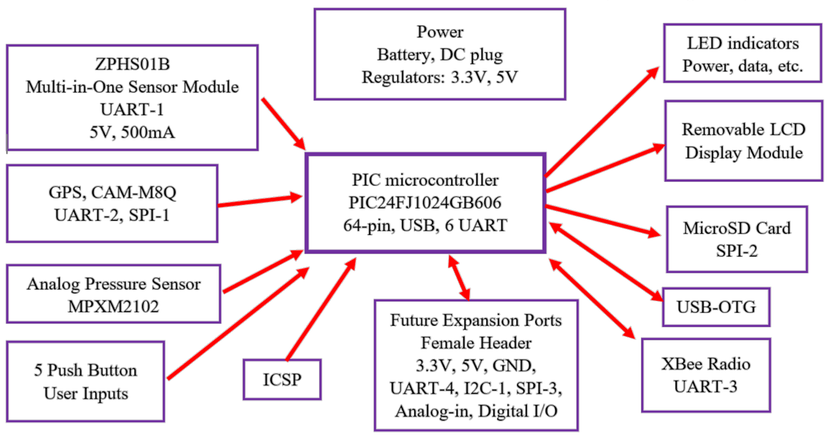

Figure 5. Basic layout of the system. Everything will be on a single circuit board except the ZPHS01B. This system will provide on-board data logging, long range data telemetry, and have expansion ports for adding additional sensors.

Calibration

Initial calibration runs have been disappointing at best. Winsen's accuracy claims in their datasheet are simply wrong. Simple initial tests found:

- Temperature sensor was reading about 7 °C low.
- %RH was reading about 20%-points too high.
- The VOC sensor never responded to any alcohols, but the "formaldehyde" sensor responded to any alcohol and human breath.
- Both the CO2 and NO2 sensors responded to breathing.
- The O3 sensor had reasonable responses to an electric discharge.

All of these flaws appear to be easy to fix in the code.

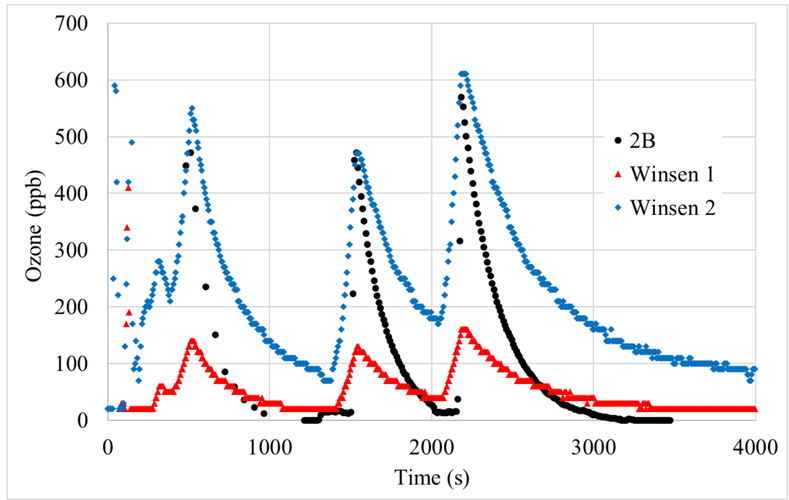

Figure 6. Board to board variance seems large. Both Winsen sensors failed to reach zero. Their response time is slow as well. Output will need calibration but appears to be tracking together.

Initial Applications

We have partnered with Northrop Grumman in a high school outreach project to measure vehicle exhaust while idling at the school drop off. Those measurements will begin in early April. NG has purchased 4 miniMSAs for this project.

We will also partner with NG to make preliminary measurements of rocket exhaust plumes during the next rocket motor test firing.

We will fly several payloads in the next few months carrying an AtmoSniffer and/or an ozonesonde. These will also carry a miniMSA for comparison.

In late April 2021 we will fly a miniMSA through woodsmoke at a controlled burn at a local landfill.

Conclusions

Some of the gas sensors have strong cross-species sensitivity which will reduce the usefulness of the miniMSA, but most of the problems can be calibrated out. There appears to be a large variance between sensor sets. Initial tests support this being a useful, yet inexpensive, way to make rapid air quality measurements under small drones, balloons, or just sitting on a table.

Full calibration and testing will be completed by August 2021.

Contact us if you would like to be an alpha tester.

Acknowledgements

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