Indoor Air Quality Capstone

Team 1

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Contents

List of Figures

List of Tables

Executive Summary

Air quality is very important for safe working conditions. In every indoor space there should be a monitoring system for environmental risks and air pollutants such as CO_2 and fine particulate matter (PM2.5), as well as ventilation rates. Our team's goal was to build a device to monitor elevated or dangerous quantities of these pollutants using as many commercial off-shelf components and open-source software as possible. Our aim was to create 3 to 10 wireless, battery powered initial prototypes that each have at least one year life span.

This project is sponsored by the Wireless Environmental Sensor Technologies (WEST) Lab in the Electrical and Computer Engineering Department at Portland State, run by Dr. David C. Burnett. The project's faculty advisor is Dr. John M. Acken.

This project will be improving on the project from spring of 2022[1] to report readings of carbon dioxide, particulate matter, and airflow in an indoor environemnt instead of N_2O, temperature, and humidity in an outdoor environment.

The team was successful in the project. We completed the project with 4 working nodes that communicate with each other using SmartMesh IP. The units can achieve a battery life of a year with reasonable capture times. Each unit is also equipped with the SGP30 CO_2 sensor, SPS30 PM2.5 sensor, and ClimateGuard Hotwire Anemometer to collect data. The system is housed in a cut acrylic box that can be mounted on walls or ceilings.

This report details the background of this project, project requirements, and our approach to tackling this project. We also included appendices that contain the operation manual, issues we faced and solutions, and the components and software we used throughout the project.

Background

Our team wanted to make it easy to continuously monitor an indoor environment, and report data back to a host. Our aim was to make monitoring easy by making cheap, reliable devices that do not require frequent recharging. Three features of indoor air quality are expected to be monitored: 2.5 µm particle count or PM2.5, carbon dioxide (CO_2) concentration, and local air flow rate.

Regarding CO_2, statistically significant decrements occurred in cognitive performance (decision making, problem resolution) starting at 1000 ppm. CO_2 concentration is also a good proxy for ventilation; high CO_2 levels mean the room is poorly ventilated, which increases the risk of passing airborne diseases such as COVID19.

Regarding PM2.5, the WHO recommends an upper limit of 5 µg/m3 (microgram per cubic meter) average annually and 15 µg/m3 average over a 24 hour period .

An air speed sensor, or anemometer, can help us calculate how much air is flowing into or out of a room and help understand why CO_2 and/or PM2.5 is high.

The system is based on components past capstone teams have successfully incorporated such as the TI MSP430 (selected for its particularly low-power sleep modes). In this iteration, a goal was to replace the closed-source proprietary SmartMesh IP wireless system with the OpenWSN open-source wireless networking system.

1 Requirements

The sensor system must:

- Sense PM2.5 and CO_2 often enough and accurately enough to ascertain indoor air quality relevant to occupants
- Include at least one node capable of sensing airspeed
- Maximize its battery life for sustained operation
- Locally store its measurement data
- Use as many commercial off-the-shelf components as possible
- Have an enclosure
- Wirelessly share its measurement data with a central monitoring system with communication range of at least 10 meters
- Utilize SmartMesh IP
- Have 3 iterations that cost no more than $1,000 total

The sensor system should:

- Include capability for any node to sense airspeed
- Have a battery life of at least 1 year
- Be open-source to the extent possible when using commercial off-the-shelf components
- Upgrade SmartMesh IP to utilize a low-power Wireless Sensor Network (WSN) system like OpenWSN
- Utilize Texas Instruments MSP430/432 class microcontroller unit
- Have 10 iterations that cost no more than $3,000 total

- Utilize 18650 lithium-ion battery cell(s)

The sensor system may:

- Source all power from a single 18650 battery
- Monitor other environmental conditions such as temperature and humidity
- Include self-configuration capability to detect which sensors are connected and adjust sampling rates accordingly
- Be usable outdoors
- Include a visualization dashboard to monitor the data graphically
- Be able to incorporate many more (greater than 10) sensor modules
- Match the lifetime of a fire detector (approximately 10 years)

2 Stakeholders and Preexisting Design

2.1 Stakeholders

Industry Sponsor : Portland State University Electrical and Computer Engineering Dept, WEST Lab (Dr. David C. Burnett)
Faculty Advisor: Dr. John M. Acken
Engineers:

- Adam A. Dezay
- Manuel A. Garcia
- Brandon P. Hippe
- Mercedes C. Newton

Customer: Any business or person in need of monitoring changing air quality conditions.

2.2 Pre-existing Design

This project used some of the research done in last year's capstone project. The final report from last year's project can be found under the documentation folder in the team's Github repository. The file is titled `Team 13 -- Final Report -- SensorSuite.pdf`. Link to the Github can be found in the project resources section.

Figure 1: Previous Teams Project
[1]

Even though last year's project measured temperature, humidity, and N_2O outdoors, both projects share the same controller, the MSP430. They both also use SmartMesh IP as a way to connect multiple nodes.

We faced many challenges with the microcontroller as well as SmartMesh that last year's team did not experience. Check Appendix A to see the solutions to unexpected problems we encountered that the previous team did not.

3 Objective and Deliverables

The following represent deliverables our team identified as significant to doccument the project:

- Complete documentation:
  - Project proposal
  - Weekly Progress Reports
  - Final report
  - ECE Capstone Poster Session poster
- Summary project report in the style of an IEEE conference paper
- Bill of materials
- System schematic and functional diagram
- Design files for any custom mechanical components or PCBs
- Source code
- Operation guide
- Demonstration of hardware
- Three to ten sensor system prototypes

4 Design

When selecting sensors for this project, the team had to select PM2.5 and CO_2 sensors that were energy efficient, relatively accurate for our setting, and fit within a budget of $3,000 for all 10 possible nodes.

When selecting the CO_2 sensor, the team considered selecting a true CO_2 sensor like the SCD30 which would produce very accurate readings yet was more expensive than an ECO2 (estimated CO_2) sensor which would prove to be less accurate due to its nature of estimating CO_2 based on ethanol and H_2 levels in the air. Our team ultimately chose to go with the SGP30 (equivalent CO_2) sensor as we are merely sensing elevated levels of carbon dioxide and therefore do not need to get incredibly precise readings. Anything over 1,000 PPM would simply be very high and might constitute an evacuation of room or need for more airflow.

Sensor	SGP 30	SCD 30
Type	eCO_2	CO_2
Additional sensors	VOC	temperature and humidity
Range	400-60,000 PPM	400-10,000 PPM
Accuracy	±15%	±30 PPM +3%
Price	$17.50	$58.95

Table 1: CO_2 Sensor Finalists

4.1 PM2.5 Sensor

For the PM2.5 sensor, the team decided to go with the SPS30 as it was the least power hungry among our options at the time. It was also the most readily available, and was sourced from Sensirion like the SGP30 which would cut costs if this product were to be mass produced. The PM2.5 Sensor Finalists table below shows the specific trade offs our team considered when selecting this sensor.

Sensor	PMS5003	PAS-IN-01	SPS30
Range (concentration)	0-500 ug/mˆ3	0-1500 ug/mˆ3	0-1000 ug/mˆ3
Accuracy	±10% or ±10 ug/m3, whichever is greater	±10% or ±10 ug/m3, whichever is greater	±10% or ±10 ug/m3, whichever is greater
Power Consumption (on)	∼500mW	∼350mW	∼275mW
Price	$39.95	$19	$49.53
Accurate data	30 seconds	15 seconds	10 seconds

Table 2: PM2.5 Sensor Finalists

4.2 Anemometer

When selecting an anemometer, we originally preferred the concept of designing and building an ultrasonic anemometer as it was significantly more energy efficient than hot wire anemometer options. Due to issues with building a custom sensor as well as difficulties with procuring parts in a speedy manner, we decided to pivot to a hot wire anemometer. This selection produced a drastic detriment to our anticipated battery life. We originally calculated that we could complete the project with just 1 battery, however we needed to add 3 more batteries to achieve the same battery life of a year with the substitution of a hot wire anemometer. To accommodate for the increased temperature, we also had to give the part extra space and keep it as far away from our other sensors as possible. We suggest future builds expand upon our ultrasonic anemometer research, implementation and documentation in an attempt to prevent the use of hot wire anemometers in this setting.

Sensor	Custom Ultrasonic Anemometer	PAS-OUT-01Wind Sensor Rev. C
Range	Unknown and size dependent	0-60 MPH
Power consumption (on)	∼14.52mW	∼150mW
Accuracy	Unknown and size dependent	Can detect "small puff of air at a distance of 18-24 inches"
Price	$7.90	$21.95
Relative size	∼25-36 cm apart	.68" x 1.59" x .25"

Table 3: Anemometer Sensor Finalists

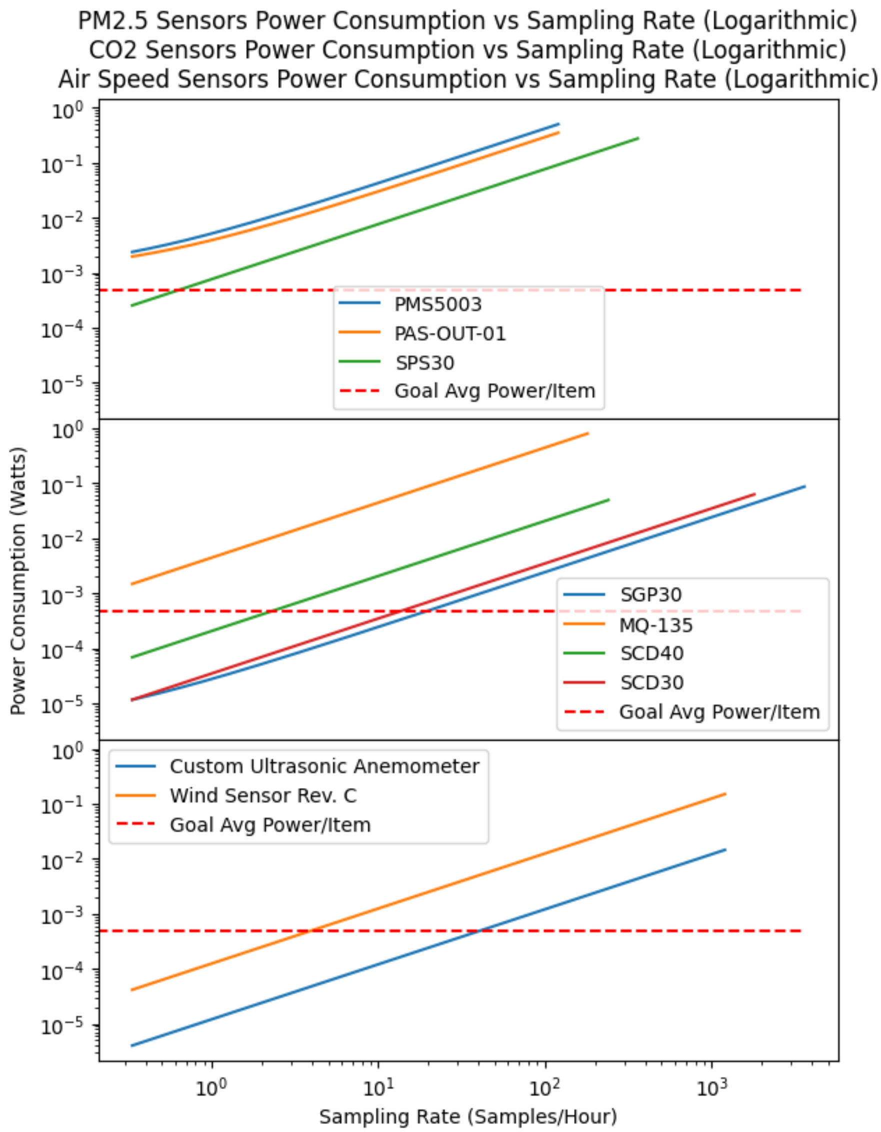


Figure 2: Power consumption measurements with sensor options

In Figure 2, the team created a python script to calculate the power consumption based on listed values from the specification sheets of the sensors. The python script can be found under the power testing folder in the documentation folder. The python script is titled `powerEstimation.py`. The link for the team Github page can be found in the project resources section. The red line shows the sampling rate needed to hit 1 year of battery life based on the estimates.

4.3 Enclosure

When deciding on our enclosure. We wanted to minimize our SWaP-C, which stands size, weight, power, and cost. For our first iteration, we built a system utilizing Portland State University's 3D printing. The 3D printer at the time only offered SLA. The helpers at the Electronics Prototyping Lab (EPL) recommended we switch to laser cutting acrylic as it is much cheaper, faster, and is clear. To cut the enclosure, we used MakerCase (https://www.makercase.com/#/) as recommended by the EPL. The laser cutter utilized at the time of project was the QD-1390.

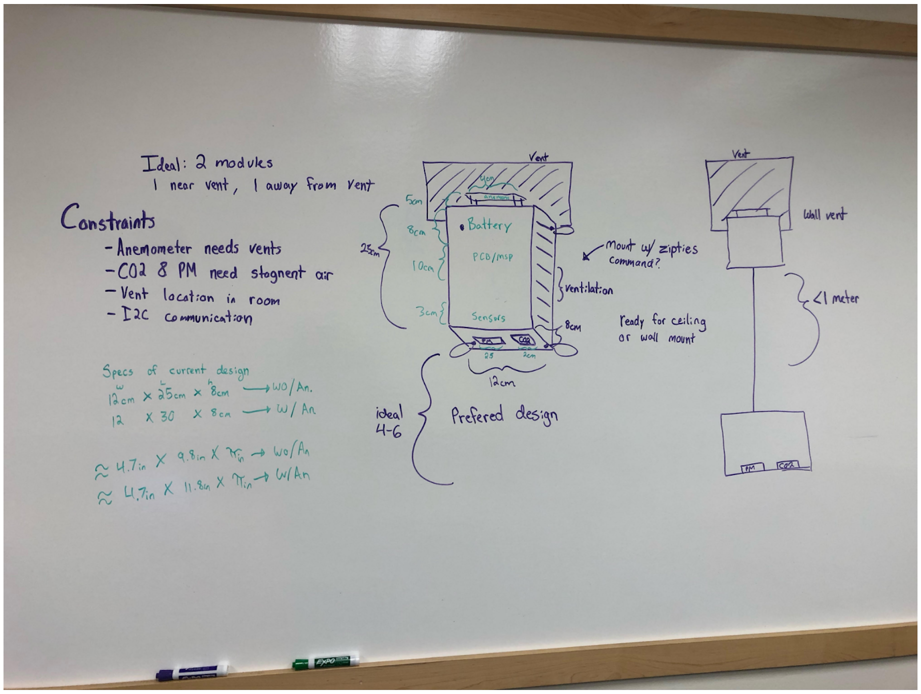


Figure 3: Original concepts for enclosure

When designing the enclosure, we originally came up with the two ideas shown above. The rightmost diagram represented 2 enclosures separated by an I2C cable. This would allow us to get accurate readings for CO_2 and PM2.5 in the bottom enclosure, and accurate anemometer readings in the above enclosure. Having two nodes seperated by an I2C cable would allow for the anemometer to be placed near a vent while the CO_2 and PM2.5 sensors could be placed in the desired range for accurate readings. This design proved to be infeasible because we were limited by the maximum 1 meter length for an I2C cable. We switched to the design on the left focusing on increased ventilation and allowing for proper separation of parts to ensure no damage is caused by the batteries. We also aligned the sensors to face downwards while the anemometer could face sideways towards the vent. Final dimensions came out to be 12 x 25 x 8 cm without an anemometer and 12 x 30 x 8 cm with an anemometer. This design requires several modules to be placed in one room, with an anemometer node being placed in front of an air vent while a second node without an anemometer could be placed in a stagnant area of the room. This accounts for both air entering the room as well as an accurate measurement of the air quality in the room. The non anemometer node should ideally be placed four to six feet above the ground as according the Environmental Protection Agency (EPA) for the most accurate CO_2 and PM2.5 readings

4.4 System Design

At the highest level view our system design started very simple. We have our microcontroller that communicates and receives data from all of our sensors, we have that microcontroller communicate with smartmesh to send out our measured data, and lastly we have a battery powering it all. We ended up having to make this system more complicated in order to extend our battery life and make the system generally more robustly. We added pmos transistors in order to cut off power and put our sensors in a deeper sleep then their internal circuits would allow. We added nmos transistors in order to perform logic level conversion for our 5V sensors. We added 3.3V and 5V power conversion in order to better supply off of our 3.7V batteries. Lastly, we added further functionality to our circuit with hardware system low battery warnings. Combined we now have a a fair amount of added resistors, voltage dividers, mosfets, and breakouts that allow for a more user friendly experience.

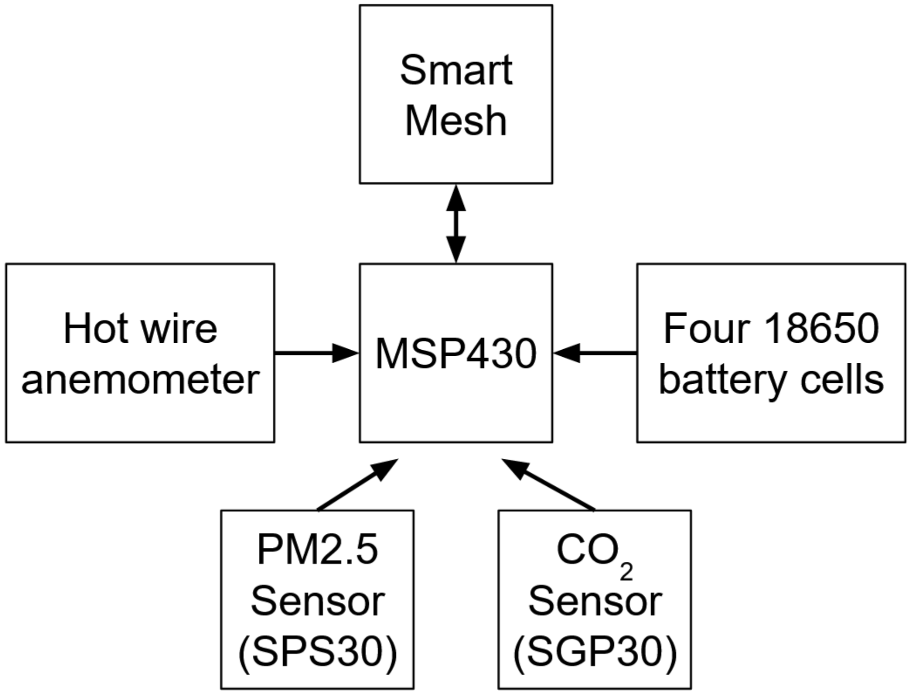


Figure 4: Block Diagram of individual Node

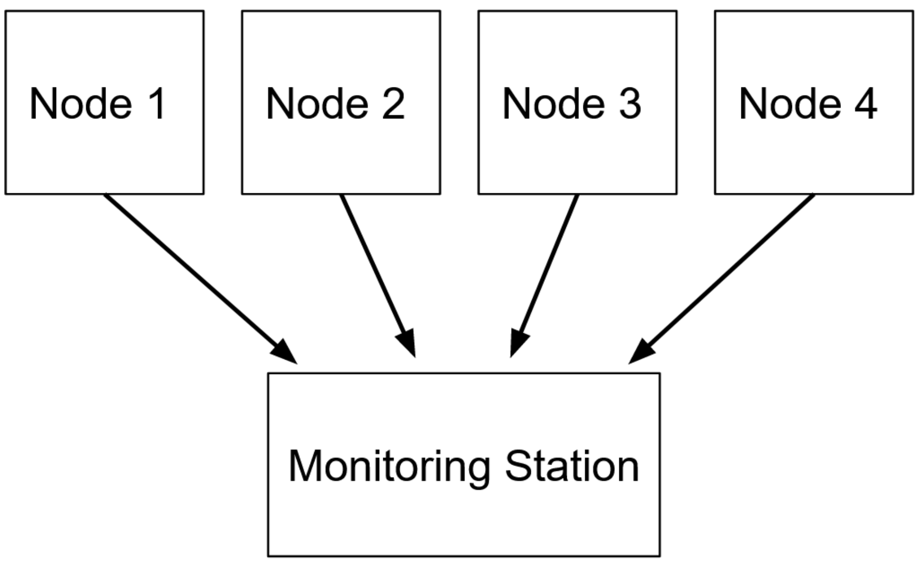


Figure 5: Block Diagram of Meshed System

4.5 PCB Design

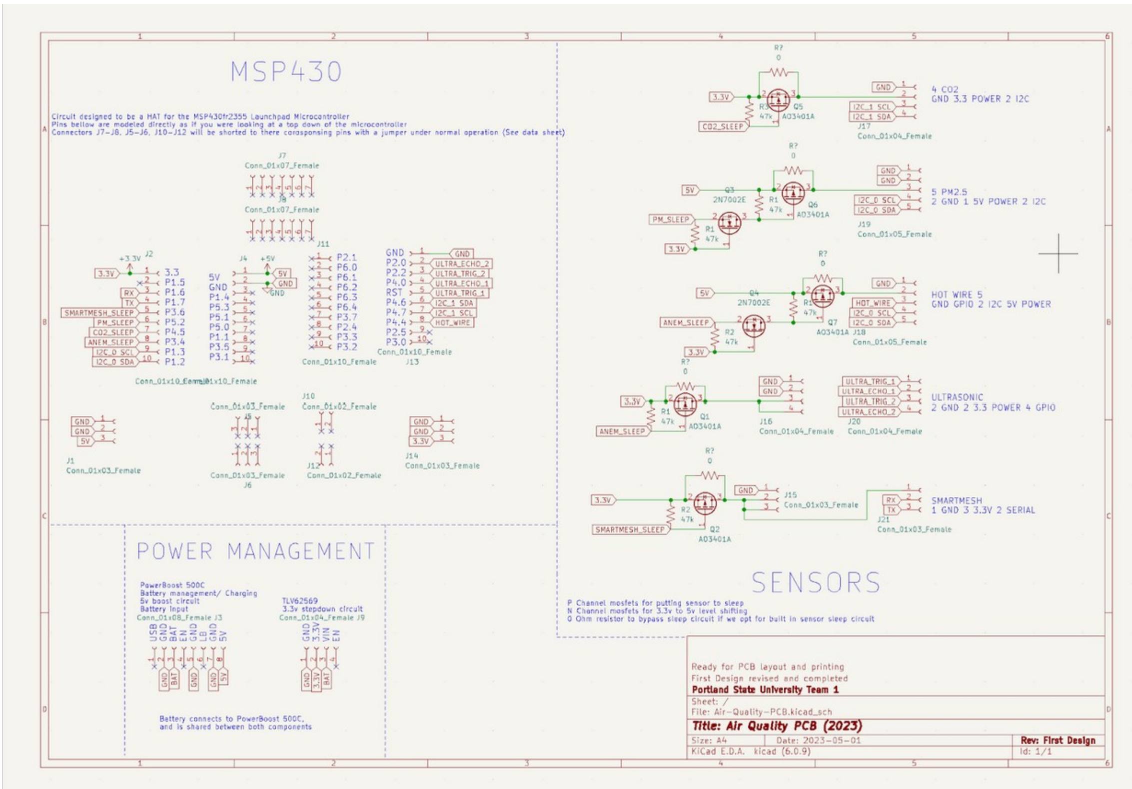


Figure 6: PCB Design

For our PCB, we decided that we wanted our system to be as compact and easy to use as possible. In order to make this a reality we made a hat For the MSP430, or in simpler terms a PCB that is placed directly on top of the MSP430 pins. This was a challenge because we were not able to find standard measurements for the MSP430FR2355 microcontroller, and had to take 15 or so measurements using digital calipers.

Designing a hat as our board design created unique opportunities that allowed us to streamline and simplify connections, and ended up leading to a cleaner looking final design. We were able to position our power management as close to the microcontoller power ports as possible, and place our signal wires extremely close to where the signals originated from, limiting potential losses that we might have had with longer or messier signal routing.

4.6 Scheduling

The team Created a followed the following Gantt charts to reflect the schedule for the project beginning in December of 2022 and concluding in June of 2023.

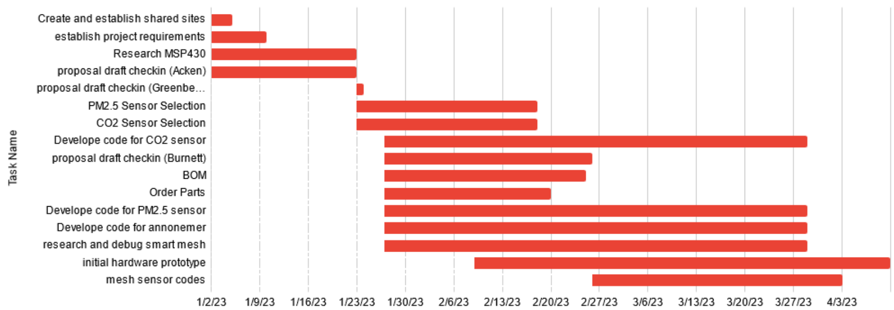


Figure 7: Gantt chart for winter term

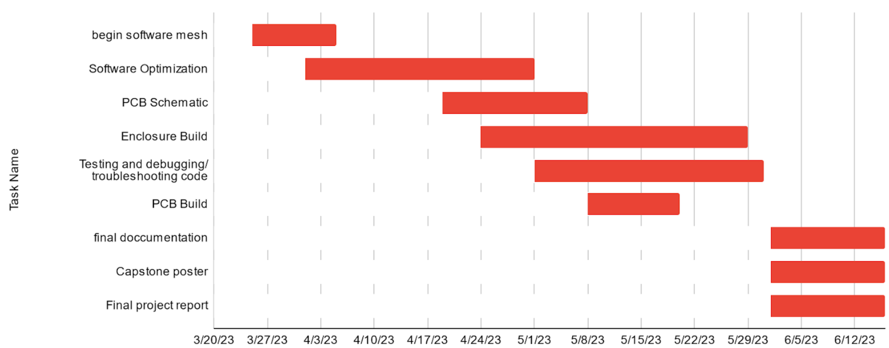


Figure 8: Gantt Chart for spring term

5 Test Plan

5.1 Power Consumption

As we were building the modules, we tested the power consumption of the parts to determine what sensor measurement periods would allow us to achieve 3 months, 6 months, and 1 year battery life. The following is how we tested our power consumption.

Equipment needed: Joulescope JS110, Breadboard Prototype w/battery management circuitry
Values needed:

1. Combined MSP430 and SmartMesh power consumption during sleep (no sensors active & SmartMesh inactive)
2. Combined CO_2, MSP430, and SmartMesh charge consumption for a CO_2 measurement
3. CO_2 power consumption while sleeping between measurements
4. Combined PM2.5, MSP430, and SmartMesh charge consumption for a PM2.5 measurement
5. PM2.5 power consumption while sleeping between measurements
6. Combined Anemometer, MSP430, and SmartMesh charge consumption for an airspeed measurement for both Ultrasonic and Hot wire anemometers
7. Anemometer power consumption while sleeping between measurements

Instructions for Combined MSP430 and SmartMesh power consumption during sleep:

1. Unplug all sensors from system, and unplug 5V, 3.3V, and RXD jumpers from EnergyTrace System on MSP430

2. Set up power supply and Joulescope to supply 3.7V to battery management circuitry, with the Joulescope set up to monitor current consumption to the battery management circuitry
3. Set up host SmartMesh node
4. Change line 6 from `#define powerTest false` to `#define powerTest true`, if necessary
5. Run `indoor_air_quality_v2.ino`
6. Turn on power supply
7. Ensure node connects to host node, and transmits two packets consisting of (48879, 48879)
8. Turn off power supply
9. Start collecting data on Joulescope
10. Turn on power supply
11. Let ˜5-10 packets of (48879, 48879) transmit to host node
12. Stop data collection on Joulescope
13. Analyze JouleScope data, and obtain average power consumption from the low, flat portions of the graph (when the MCU is in sleep). Store this number in the Power Consumption Test Results google sheet under `Typical Power Consumption (off)` for `Micro Com`. Make sure to include correct units with prefix (e.g. mW for milliWatts, uW for microWatts)

Instructions for Combined Sensor, MSP430, and SmartMesh charge consumption, along with Sensor sleep power consumption

1. Unplug all sensors, except sensor under test, from breadboard, and unplug 5V, 3.3V, and RXD jumpers from EnergyTrace System on MSP430

2. Set up power supply and Joulescope to supply 3.7V to battery management circuitry, with the Joulescope set up to monitor current consumption to the battery management circuitry
3. Set up host SmartMesh node
4. Turn on power supply
5. Run `indoor_air_quality_v2.ino`
6. Change line 6 from `#define powerTest false` to `#define powerTest true`, if necessary
7. Ensure node connects to host node, and transmits one packet consisting of (48879, 48879), followed by sensor initialization and one packet of sensor data
8. Turn off power supply
9. Start collecting data on Joulescope
10. Turn on power supply
11. Let ˜5-10 packets of sensor data transmit to host node
12. Stop data collection on Joulescope
13. Analyze JouleScope data, and obtain average charge consumption from the higher portions of the graph, which should be approximately the same amount of time as the time needed for that sensor to collect its data (˜15 seconds CO2, ˜30 seconds PM2.5, ˜10 seconds Hot Wire Anemometer, ˜6 seconds Ultrasonic Anemometer). Store this number in the Power Consumption Test Results google sheet under `Charge Consumed (On)` for that sensor. Make sure to include correct units (e.g. mC for milliCoulombs, uC for microCoulombs)
14. Using the same JouleScope data, obtain average power consumption from the lower, flat portions of the graph (when the sensor is asleep). Take this number and subtract the power consumption obtained for the MSP430 and SmartMesh

sleep power consumption. Store this number in the Power Consumption Test Results google sheet under `Typical Power Consumption (off)` for that sensor. Make sure to include correct units with prefix (e.g. mW for milliWatts, uW for microWatts)

Instructions for calculating sensor measurement periods

1. Export the Power Consumption Test Results google sheet. Save it as `Power Consumption Test Results - Power Consumption.csv` in the directory `/Documentation/Power Testing`
2. Run the python script `powerData.py`. Follow the prompts it gives you. It will calculate the measurement periods for each sensor, and display other useful information about the components power consumption.
3. If you would like, there are a few easy to edit values in the `powerData.py` script. These are available in the first ˜20 lines of the program, and are as follows:
   - `BAT_MAH`: capacity of your battery(s), in mAh (milliAmphours)
   - `BAT_VOLT`: nominal voltage of your battery(s), in volts
   - `BAT_NUM`: number of battery(s), if wired in parallel
   - `MAX_T`: maximum allowable sensor measurement period, in hours
   - `GOAL_DAYS`: Goal battery life, in days

5.2 Long–term testing

After finishing the sensor nodes, we set them up in the rooms used by the WEST Lab. The host node was set up on the presentation system, with the graphing script visible on the presentation TV. The four sensor nodes were set up in each of the rooms (60–23, 60–24, 60–26) and the hallway outside of the lab.

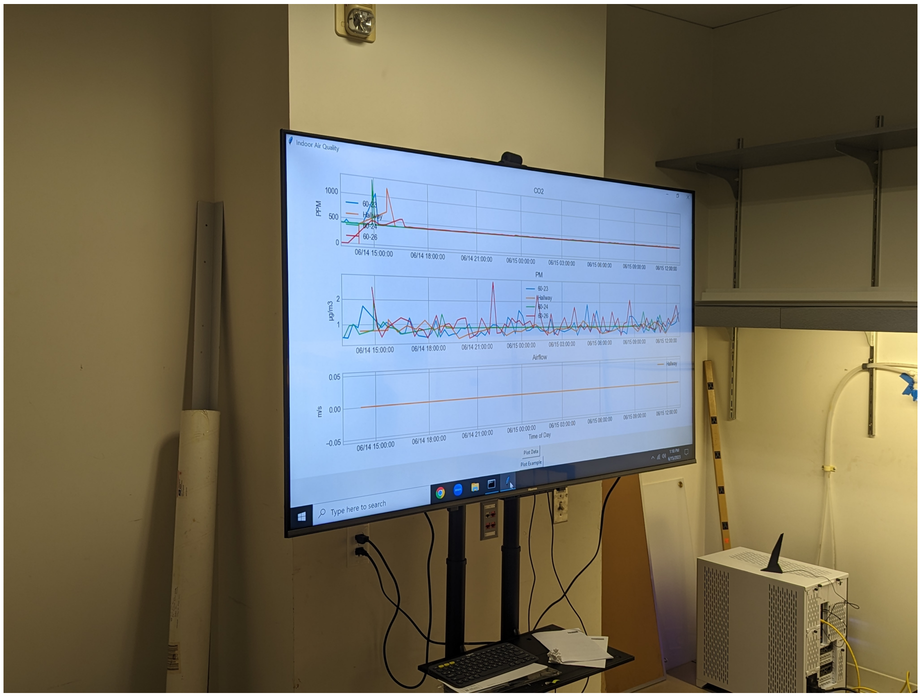


Figure 9: Graphing script running on Lab TV

Figure 10: Unit in FAB Basement Hallway

Figure 11: Unit in FAB 60–23

Figure 12: Unit in FAB 60–24

Figure 13: Unit in FAB 60–26

6 Results

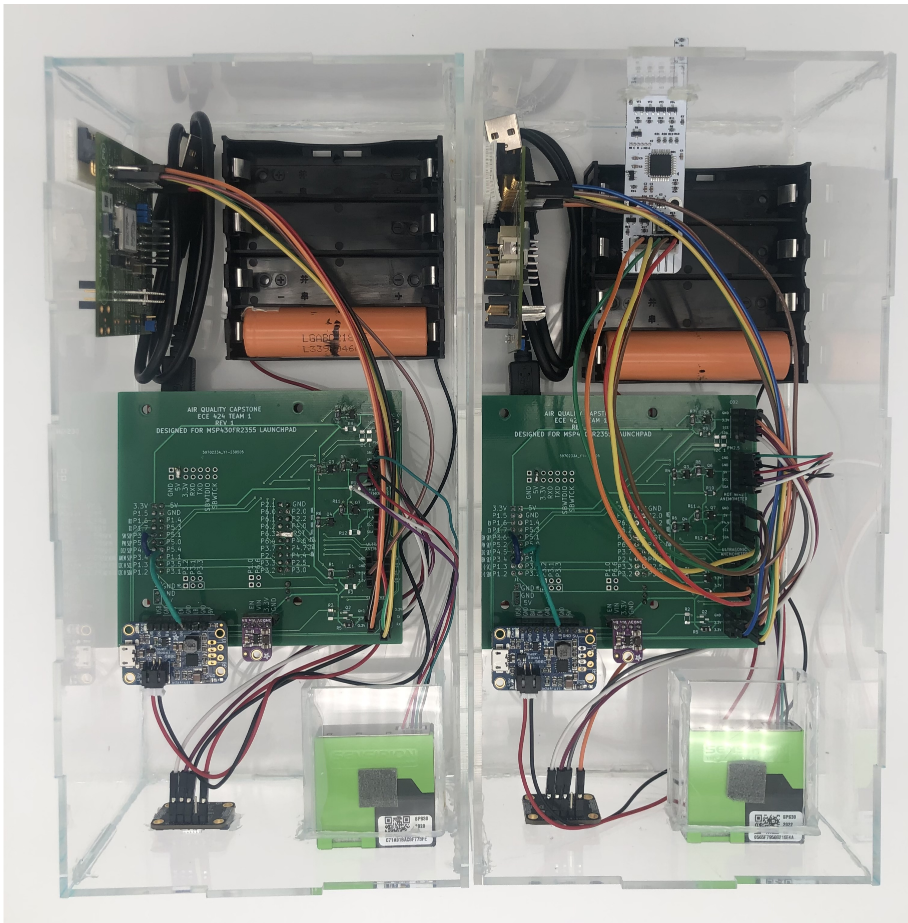


Figure 14: Top view of the nodes

Our project was successful in satisfying all requirements. Our team was able to build 4 working nodes that all communicate using SmartMesh. The CO_2 and PM2.5 sensors are working properly within the acrylic enclosure built. The tables below show estimations of how often we can collect and publish data based on how long we want our batteries to last. The captured intervals can be modified using only 1 line in the code for the system. As shown in the power consumption figure, the hot wire anemometer is the most power hungry part of this project. We recommend that teams look into using an alternative option like the ultrasonic anemometer.

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO_2	8 min 30 sec (510 sec)	18 min (1,080 sec)	37 (2,220 sec)
PM2.5	16 min (960 sec)	34 min (2,040 sec)	72 min (4,320 sec)

Table 4: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units without anemometer

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO_2	27 min (1,620 sec)	61 min (3,660 sec)	170 min (10,200 sec)
PM2.5	32 min (1,920 sec)	72 min (4,320 sec)	195 min (11,700 sec)
Hotwire Anemometer	14 min 38 sec (878 sec)	33 min (1,980 sec)	90 min 50 sec (5,450 sec)

Table 5: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units with a hot wire anemometer

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO_2	12 min (720 sec)	25 min (1,500 sec)	51 (3,060 sec)
PM2.5	22 min (1,320 sec)	48 min (2,880 sec)	105 min (6,330) sec
Ultrasonic Anemometer	10 sec	20 sec	40 sec

Table 6: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units with an ultrasonic anemometer

Configuration	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
Without Annemometer	∼820 KB	∼810 KB	∼700 KB
Ultrasonic Anemometer	∼16.15 MB	∼16.14 MB	∼16.27 MB
Hotwire Anemometer	∼370 KB	∼334 KB	∼258 KB

Table 7: Log file sizes after draining batteries for each configuration set to 3 month, 6 month, and 1 year battery life

Post Mortem

In retrospect, we feel our project was very successful. Our team was able to collaborate in order to execute this project. Our team played to each of our specific talents which made for an excellent work environment.

Our team faced a variety of challenges in regards to using MSP430s, SmartMesh, enclosure building and PCB design. Connecting each team member to their respective MSP430 proved to be more challenging than many of us had anticipated. Documentation surrounding MSP430 was scarce and oftentimes unhelpful. Most of our team members needed to delete Energia files and redownload before each use to connect with the MSP430. SmartMesh also had many problems that previous teams have not encountered. Our original ultrasonic anemometer proved to be much harder to work with which is why we switched to the hotwire option despite the huge discrepancy in power use.

The combination of all these problems and our approach to doing each part separately proved unfruitful as we had not built a prototype by the midpoint of the timeline. This is when we switched to dedicating a set time to work on the project weekly, in person, as a team. This proved to accelerate our progress as it allowed us to help each other at roadblocks. We also learned that some of our MSP430s were much more prone to having issues than others. This allowed us to rapidly prototype a working node on the fastest system and MSP430. This also allowed different members to shift rapidly to complete auxiliary projects like reports and presentations.

Many thanks to our industry sponsor and faculty advisor who requested that we present our progress a several times throughout our project as well as requesting an updated Gantt chart weekly. This allowed us to compile our progress and have a clear path at a glance. Weekly meetings with at least 1 of the advisor or sponsor also proved necessary to work through a multitude of problems and is credited to keeping us working on the requirements.

Documentation was something that we excelled at throughout the project. Notes of weekly meetings were documented on the team's Trello board. Weekly reports and any documentation was copied to the team's Google Drive, Github repository, Trello board, and emailed to the advisor and sponsor. We also built a website to host some of this information.

Project Resources

Software links List of used software and links:

- Energia (https://energia.nu/download/)
- Python (https://www.python.org/downloads/)
- FTDI Drivers (https://ftdichip.com/drivers/)
- KiCad(https://www.kicad.org/download/)
- Github Repository (https://github.com/brandonhippe/Indoor-Air-Quality-Monitor)
- FreeCAD (https://www.freecad.org/downloads.php)
- JLCPCB (https://cart.jlcpcb.com/quote)
- MakerCase (https://www.makercase.com)

Versions used at time of build:

- Energia 1.8.10E23
- Python 3.11
- KiCad 7.0.2
- FreeCAD 0.20.2

Website: https://web.cecs.pdx.edu/ dburnett/capstone2023/

Software Manual

6.1 Setting up the Host Node

1. Download Python. Links to download as well as versions used at the time can be found in the project resources section of this report. Install matplotlib and PySerial using the command `pip install <module name>` in a Python terminal.

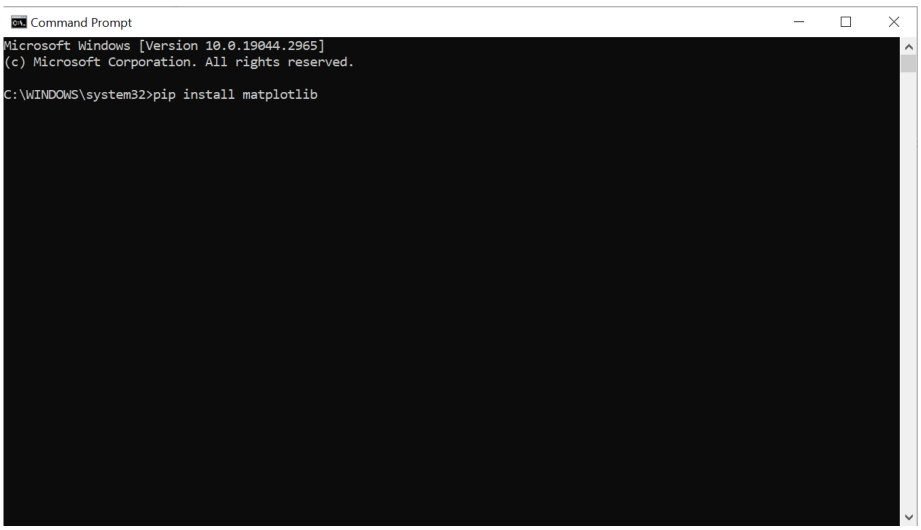


Figure 15: Installing matplotlib

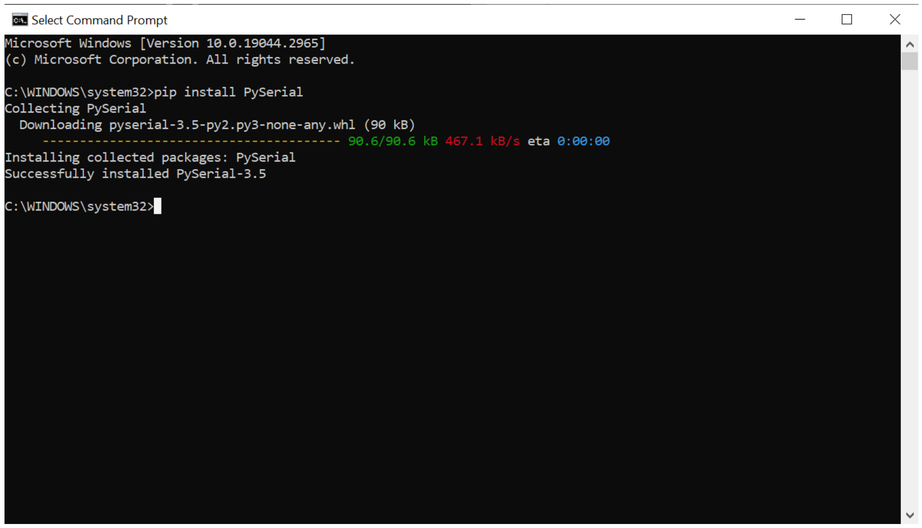


Figure 16: Installing PySerial

2. Clone or download the GitHub repository as a .zip file. If downloaded as a .zip file, extract all of its contents.

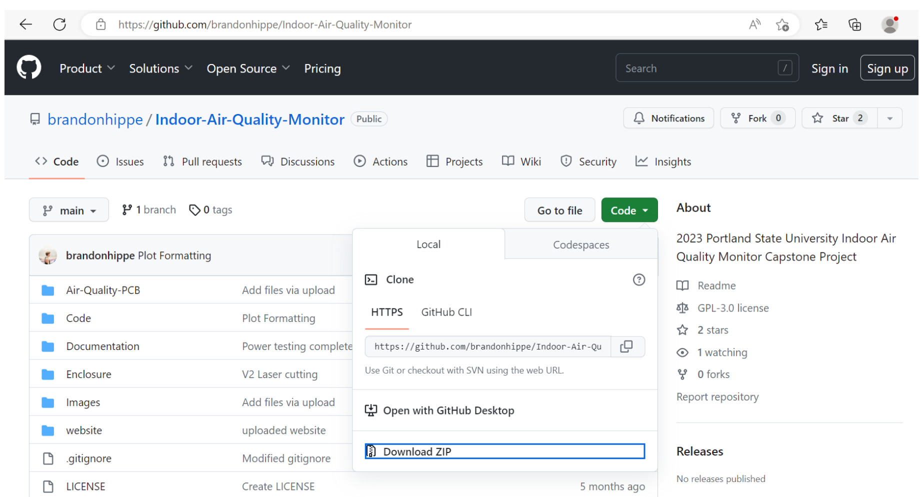


Figure 17: Github Download Page

3. Open Device Manager and expand the Ports drop-down. Plug the DC2274A-A manager into the computer. Four new COM ports will appear. Take note of the largest of these new ports.

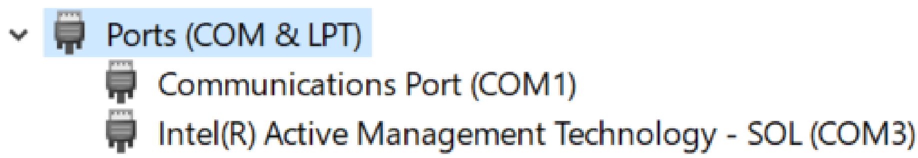


Figure 18: Before plugging in manager

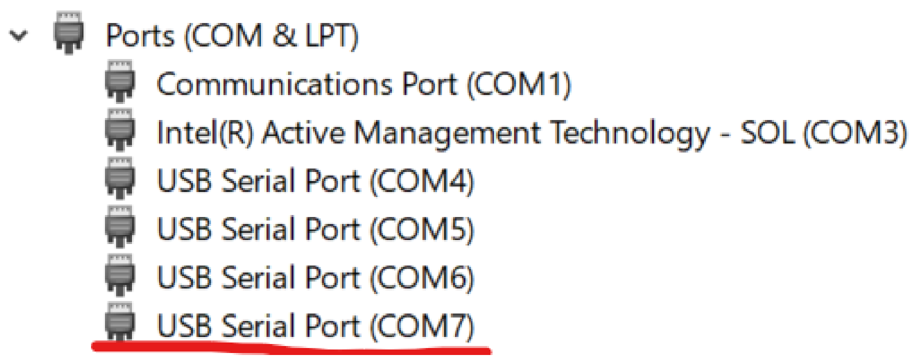


Figure 19: After plugging in manager. Note: 4th COM port is underlined

4. Navigate to the `Code/Host Node/app/SensorDataReceiver` folder. Run the `SensorDataReceiver.py` script. In the popup window, under the port name, type in the COM port from step 3, including "COM." Click connect, and the box should turn green to indicate a successful connection.

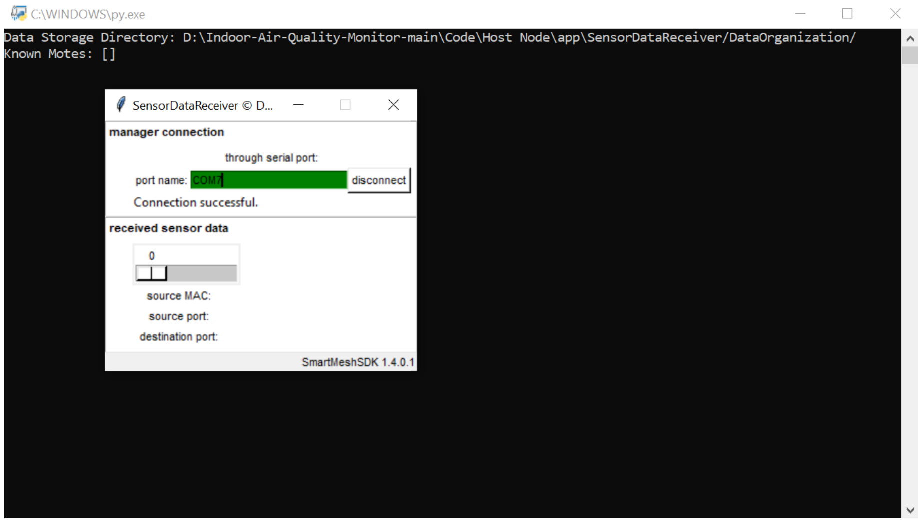


Figure 20: Manager Connected

5. From the same folder, run the `iaqGraphing.py` script. A window with three plots should appear on the screen. At the bottom, click the "Plot Example" button. Example data should be plotted in each of the plots.

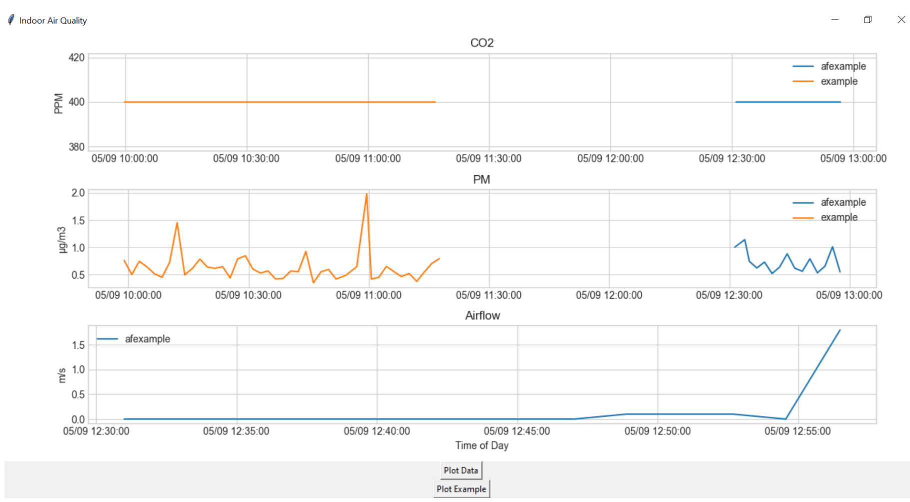


Figure 21: Example data plotted

6. Now click on the "Plot Data" button. The graph will now plot new data received from the sensors approximately every 10 seconds and display all the

data over the last 24 hours.

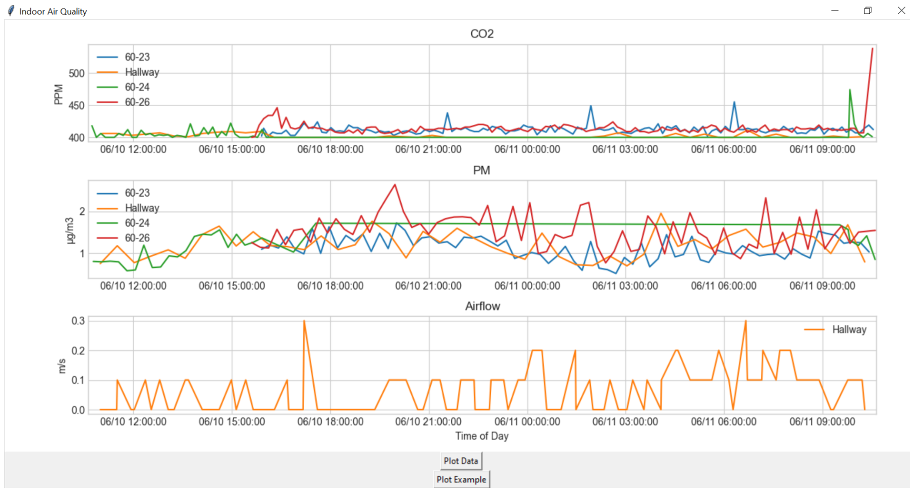


Figure 22: Sensor Data Plotted

6.2 Setting up Sensor Nodes

1. Download Energia. Links to download as well as versions used at the time can be found in the project resources section of this report.

2. Open the `Code/Sensor Mote/libraries` folder in the downloaded repository. Copy the contents of this folder into the library folder of your Energia installation (for easiest use, move the Energia folder to the C drive, so the path is something like `C:\energia-1.8.10E23`).

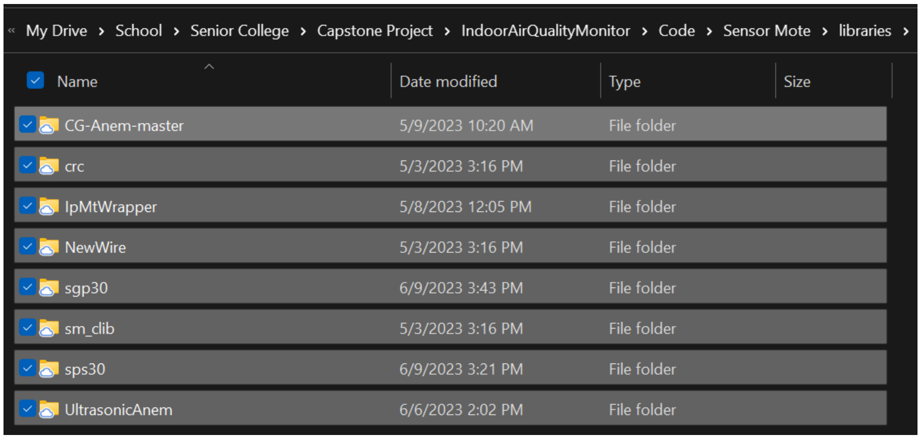


Figure 23: Energia libraries needed

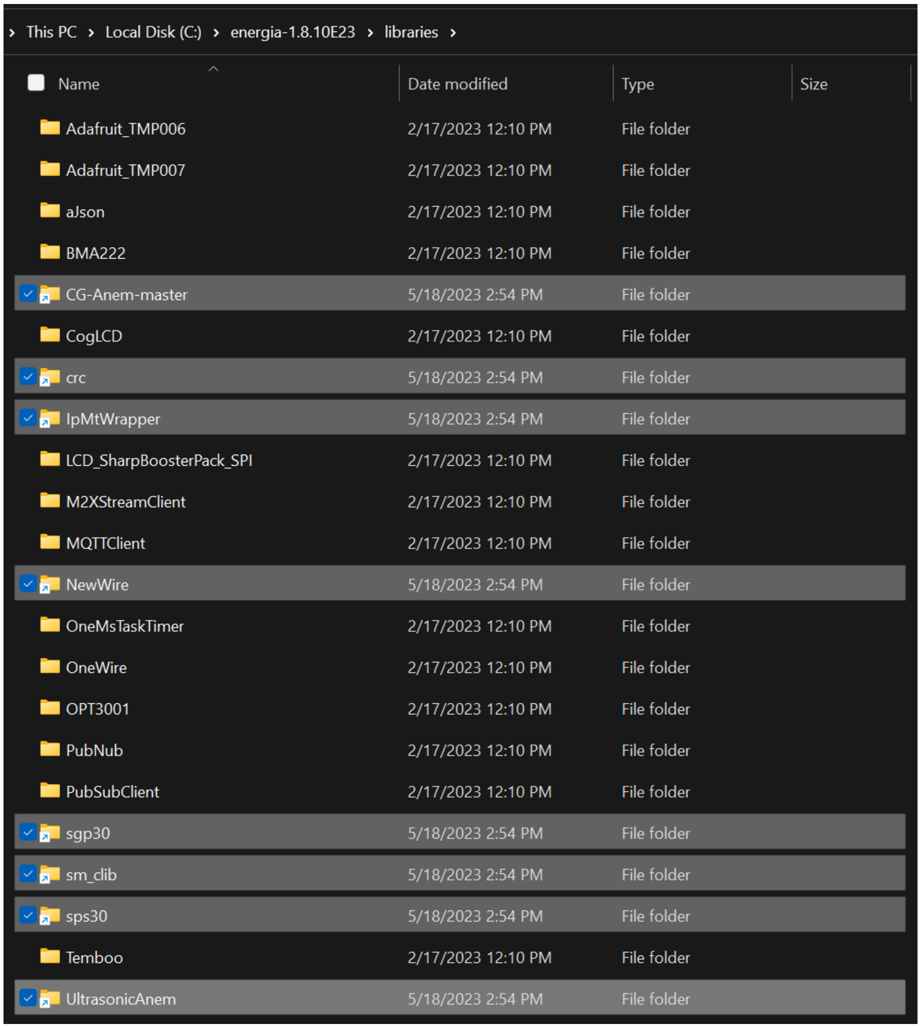


Figure 24: Libraries copied to `C:\energia-1.8.10E23\libraries` folder

3. Launch Energia and make sure to select the "MSP-EXP430FR2355LP" in the board section under the Tools tab.

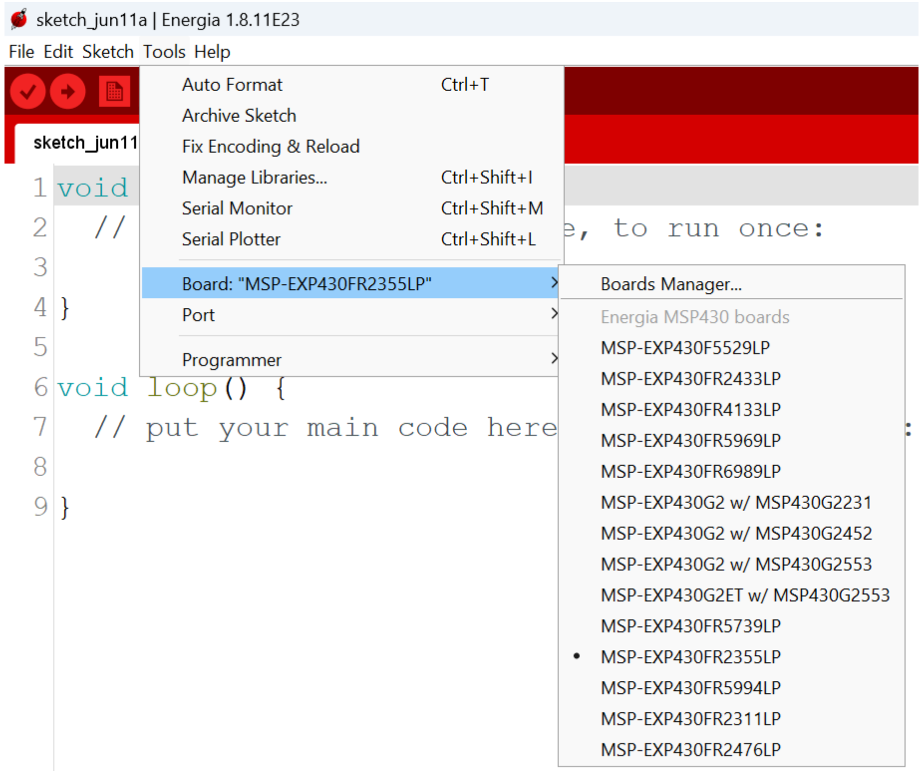


Figure 25: MSP430FR2355 Selected

4. Under File, press open, then navigate to the downloaded repository. Navigate to `Code/Sensor Mote/indoor_air_quality_v2` and open `indoor_air_quality_v2.ino`.

5. Click on the red checkmark to verify the code and make sure it compiles without errors.

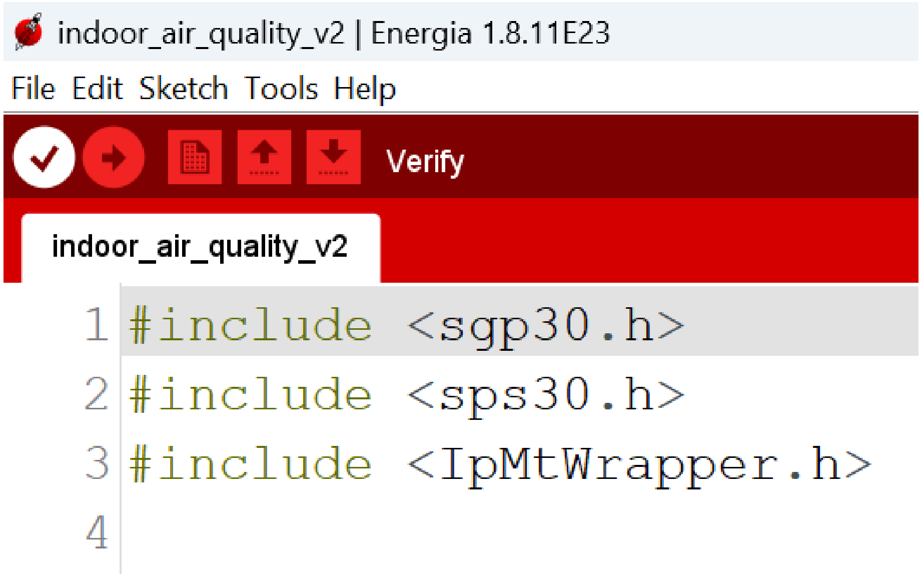


Figure 26: Verify button

Figure 27: Code compiled without errors

6. Remove the lid of the sensor node.

7. Plug the other end of the USB cable plugged into the MSP430 into the computer.

8. Open Device Manager and check under the Ports drop-down for a device named "MSP Application UART 1" and take note of the COM port number associated with it.

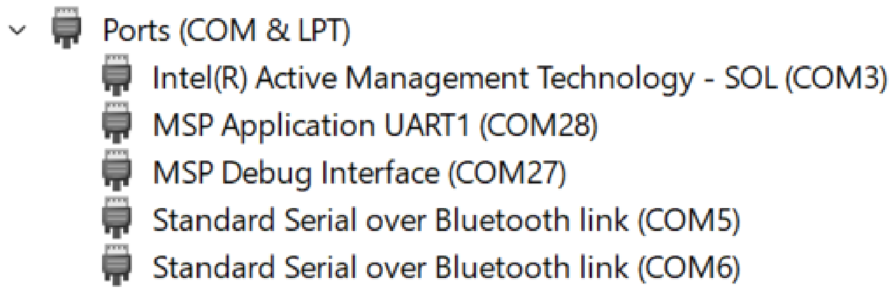


Figure 28: MSP430 in device manager

9. In Energia, select the COM port from step 10 in the Port section under the Tools tab.

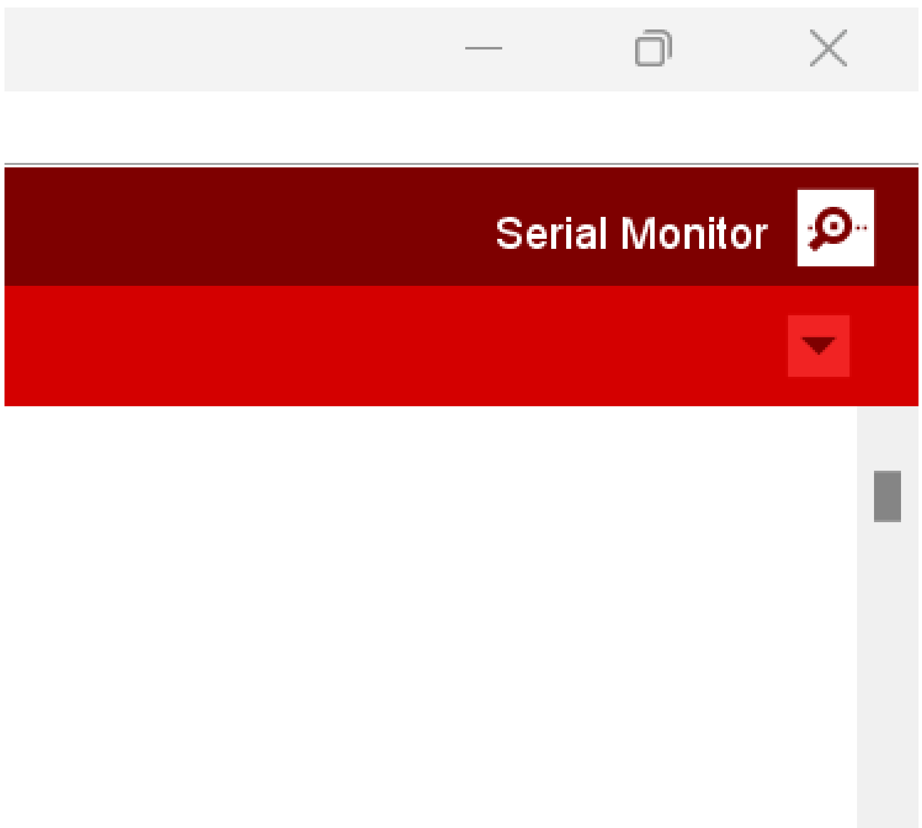


Figure 29: Serial monitor button

10. Open the Serial Monitor by clicking on the magnifying glass in the top-right corner. Have this visible to see debug output after programming the MSP430.

11. Click the red right arrow next to the checkmark to upload the code to the MSP430.

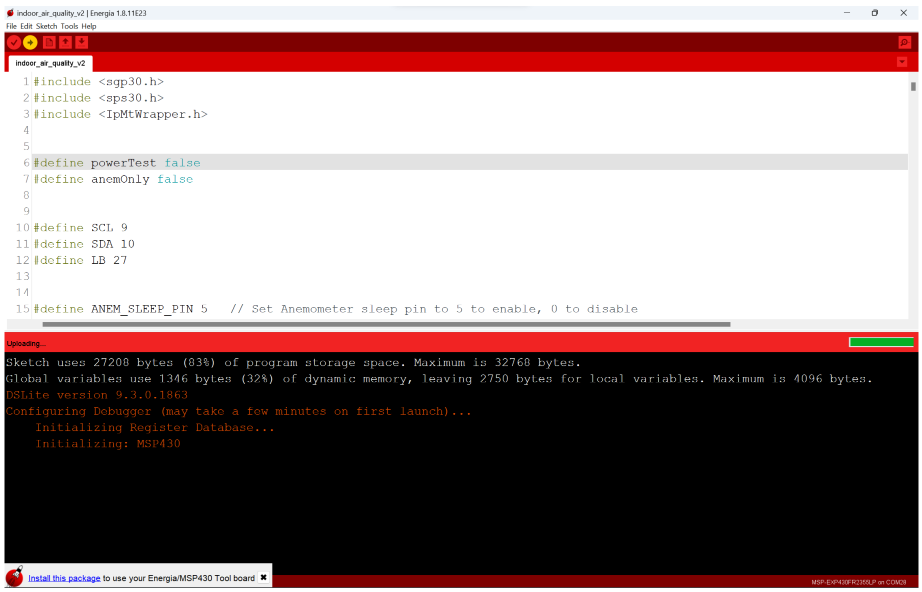


Figure 30: Code uploading to MSP430

12. Watch the Serial Monitor. You should see messages related to the SmartMesh system connecting to the host node. Once it connects, you'll see each of the installed sensors take their first measurements and send them to the host node.

13. On the SensorDataReceiver.py terminal, verify that the first measurements from the sensors are received. It is now safe to unplug the USB cable from the computer, place it back in the sensor node, close the sensor node, and mount the node wherever you'd like to collect indoor air quality data.

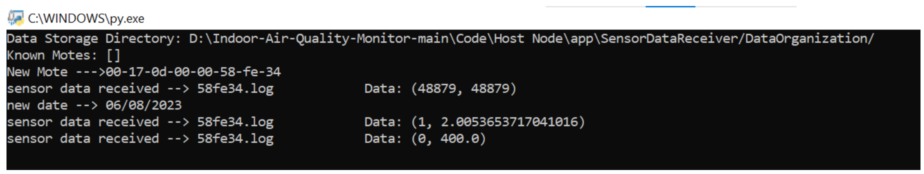


Figure 31: Data received by host node

14. Repeat steps 7-14 for any additional sensor nodes.

Hardware Manual

6.3 Part 1: Building PCB

1. Go to GitHub Repository and save all the .gbr files under the Air-Quality-PCB folder.

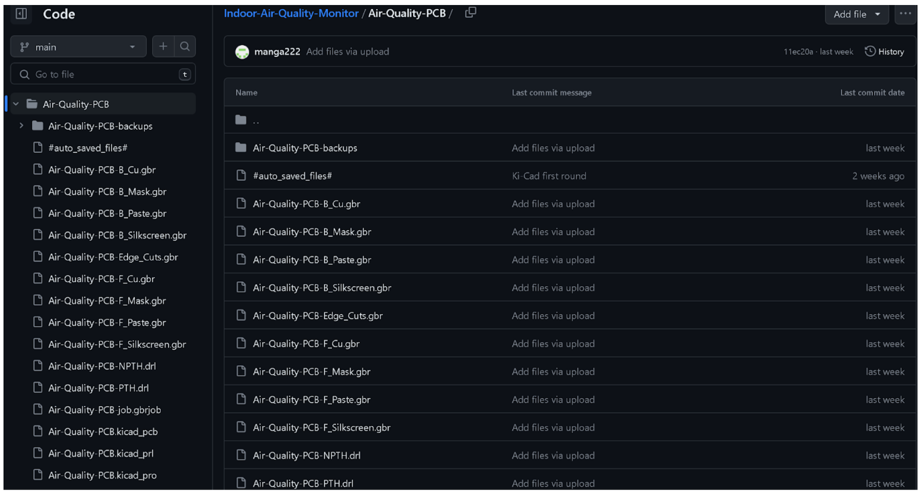


Figure 32: GitHub Repository

2. Open the website of your PCB manufacturer and go to their ordering page
3. We used JLCPCB for the project as they were the cheapest and fastest at the time. Link can be found in the project resources section
4. Drag and drop all the .gbr files
5. Select your options
6. We selected the default options at time but chose to go with faster delivery
7. Solder on connection points so the MSP430 can be seated onto the PCB
8. Solder pins onto powerboost charger as well as the 3.3V converter
9. We ended up removing LED (power and Low indicators) since they consumed too much power and were always on

6.4 Part 2: Building Enclosure

1. Using a laser cutter, cut out the file `box_v2.dxf`. It is designed to be cut out of $\frac{1}{8}$ inch thick acrylic, but any other $\frac{1}{8}$ inch thick material should work. For different thickness materials, the enclosure would have to be redesigned. For reference, a 16 inch x 24 inch sheet is enough to cut out parts for one enclosure. Alternatively, a pre-built plastic enclosure of a similar size could be used, with holes cut for sensors at the same size as our enclosure holes.

2. The batteries and anemometer must be placed as far away from the PM2.5 and CO_2 sensor as possible.

3. The PM2.5 and CO_2 must be mounted at the bottom of the enclosure to ensure that they are not susceptible to particle build up. Mount the PM2.5 sensor so that the green side is facing out and away from the wall when mounted.

4. Hot glue the sides of the enclosure while placing the components in the box as it is being assembled. Do not hot glue the lid on. Use clear tape to secure the lid.

6.5 Part 3: Mounting the Enclosure

1. Once the enclosure build is complete, attach 4 Command Picture Hanging Velco Strips, 1 to each corner of the back wall of the enclosure.

2. Select a wall to mount enclosure to. For the Anemometer enclosure, mount the unit near air source or vent. For enclosures without an anemometer, mount away from doors, windows or vents. Mount enclosures without anemometers approximately 4-6 feet above ground.

3. When batteries need to be changed, detach system. Reattach system when batteries are replaced by again securing system to wall via velcro.

Appendix 1: BOM

Quantity	Model # and description	Manufacturer	Price per unit	Total Price
1	CG-Anem (Wind Sensor With I2C Interface)	Climate Guard	$23	$23
1	SGP30: (eCO_2 Sensor)	Adafruit	$17.50	$17.50
1	US-100 Ultrasonic Distance Sensor Module	Adafruit	$6.95	$6.95
1	SPS30 (PM2.5 Sensor)	Sensirion	$50.25	$50.25
4	P Channel Mosfet	Alpha-Omega	$0.35	$1.40
2	N Channel Mosfet	Alpha-Omega	$0.33	$0.66
6	47k Resistor	Yageo	$0.04	$0.24
3	0 ohm Resistor	Yageo	$0.05	$0.15
9	Pin Header	Sullins	$0.57	$5.13
2	Pin Header Male	Molex	$0.67	$1.34
1	MSP-EXP430FR2355	Texas Instruments	$15.33	$15.33
4	LI18650JL PROTECTED	Jauch Quartz	$13.05	$52.20
1	BK-18650-PC8 (4 cell 18650 battery holder)	MPD	$8.06	$8.06
1	DC9003A-C (SmartMesh)	Analog Devices	$642	$642

Model # and description	Link
CG-Anem (Wind Sensor With I2C Interface)	`https://www.tindie.com/products/climateguard/wind-sensor-with-i2c-anemometr-arduino/`
SGP30: (eCO_2 Sensor)	`https://www.digikey.com/en/products/detail/adafruit-industries-llc/3709/8258468`
US-100 Ultrasonic Distance Sensor Module	`https://www.digikey.com/en/products/detail/adafruit-industries-llc/4019/9808308?s=N4IgTCBcDaIK4GcCOBGADGkBdAvkA`
SPS30 (PM2.5 Sensor)	`https://www.digikey.com/en/products/detail/sensirion-ag/SPS30/9598990`
P Channel Mosfet	`https://www.digikey.com/en/products/detail/alpha-omega-semiconductor-inc/AO3401A/1855773`
N Channel Mosfet	`https://www.digikey.com/en/products/detail/alpha-omega-semiconductor-inc/AO3422/1855787`
47k Resistor	`https://www.digikey.com/en/products/detail/yageo/RC1206FR-0747KL/728931`
0 ohm Resistor	`https://www.digikey.com/en/products/detail/yageo/RC1206JR-070RL/729184`
Pin Header	`https://www.digikey.com/en/products/detail/sullins-connector-solutions/PPPC101LFBN-RC/810182`
Pin Header Male	`https://www.digikey.com/en/products/detail/molex/0022284104/313970`
MSP-EXP430FR2355	`https://www.digikey.com/en/products/detail/texas-instruments/MSP-EXP430FR2355/9491427`
LI18650JL PROTECTED	`https://www.digikey.com/en/products/detail/jauch-quartz/LI18650JL-PROTECTED/12396970`
BK-18650-PC8 (4 cell 18650 battery holder)	`https://www.digikey.com/en/products/detail/mpd-memory-protection-devices/BK-18650-PC8/2330515`
DC9003A-C (Smart Mesh)	`https://www.mouser.com/ProductDetail/Analog-Devices/DC9003A-C?qs=ytflclh7QUUd5QPivzMO2w%3D%3D`

Total Price: $166.88 excluding given parts $182.21 including MSP430

Appendix 2: Troubleshooting

2.1 Energia Issues

Make sure "Energia MSP430 boards" is updated to version 1.0.7 or later by going to Tools, then Board, then Board Manager.

2.2 Java Runtime Environment error

To solve this issue, You must save Energia to your C: Folder and open it from there each time. The Desktop Shortcut will keep giving you this error.

2.3 Sensor Issues

Sensors drawing too much power:
We removed the power and low power LEDs on all of the sensors used as they were drawing too much.
CO2 sensor showing 400 PPM or 55K PPM:
Stop calibrating, run it for 30 seconds.

Appendix 3: Weekly Progress Reports

The following represents the 11 weekly reports we, Team 1, have submitted to our Industry Sponsor and Academic Advisor. The reports below are presented in the original form with the respective week and date bolded for easy viewing.

Team 1 Open Source Air Quality Monitoring

Week 1: January 2nd 2022 - January 9th 2022

Sponsor: Dr David Burnett

Advisor: Dr John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team established meeting times.
    - Team will meet with John Acken every Monday at 4:30.
    - Team will meet independently every Tuesday at 6:35.
- Team scheduled a meeting for Monday January 16th with Dr. Burnett to discuss questions and project proposals.
- Team established a shared drive, github and trello for record keeping and collaboration.
- Team curated questions and discussed our project proposal in preparation for our first meeting with Dr. Burnett. Questions listed below:
    - What percent accuracy do we require for our CO2 sensor?
    - Should we use Eco2 to estimate CO2 or a Real CO2 sensor?
    - Can we use the other microcontroller or should we use MSP430?
- Team conducted initial research and began brainstorming potential solutions.

Individual Review

Adam Dezay: Agreed to create wiki for team Github.

Brandon Hippe: Began python script for component power consumption estimations.

Manuel Garcia: Conducted initial research and began weighting benefits of specific components.

Mercedes Newton: Curated team Report.

Team 1 Open Source Air Quality Monitoring

Week 2: January 10th 2022 - January 17th 2022

Sponsor: Dr David Burnett

Advisor: Dr John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team further curated questions and discussed our project proposal in preparation for our first meeting with Dr. Burnett. Questions listed below:
  - Size constraints? (Will affect battery life)
  - Sensor accuracy requirements, Eco2 vs Real CO2?
    - Our current constraints are that the Ec02 sensors we have looked into require extensive autocalibration and would have too long of start ups for a low power application.
  - Anemometer implementation?
    - Indoor applications will have low air speed so traditional anemometers might not make sense unless we placed it in an air duct.
  - Micro controller requirements?
    - We are currently looking at the esp32 because it has built in wifi and a deep sleep.
  - Web server preferences?
    - Current thoughts are to use a raspberry pi, running a web server, that we are able to access remotely.
  - Should we use open WSN and if so what microcontroller should be implemented?
    - Our team would prefer not to.
  - What is our budget? What will be provided by our sponsor?
    - We will require a maximum of $300 to create 1 unit, factoring varying prices and component requirements.
- Team conducted research and began brainstorming potential solutions.
- Team discussed power consumption in components
- Team developed rough draft of project proposal
- Team delegated tasks for the current week with emphasis on the project proposal and research, specific tasks are listed below.

Individual Review

Adam Dezay: Developing project Gantt chart, documented project in the project proposal

Manuel Garcia: Conducted initial research and began weighting benefits of specific components, assisted in documenting projects in the project proposal.

Brandon Hippe: Further developed python script for component power consumption estimations, sensor research, assisted in documenting project in the project proposal

Mercedes Newton: Curated team Report, further documented project in the project proposal

Team 1 Open Source Air Quality Monitoring

Week 3: January 16th 2022 - January 23th 2022

Sponsor: Dr David Burnett

Advisor: Dr John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

This week, we met with Dr. Burnett for the first time

- After our first class meeting and meeting with our industry advisor, our team has come to the following decisions
  - We must produce 3 prototypes, with a chance of producing the initially requested 10 due to funding.
  - We shall further research and discuss how frequently our sensors take in data as informed by power requirements.
  - Spreadsheet and protocol was established for obtaining equipment from both Dr. Burnett's lab and the EPL.
  - Team established another meeting time and workshop time.
  - Team assigned Brandon as point person and Mercedes as leader.
  - Team created a discord for communication.
- Gantt chart was revised to be more informative.
- Using a CO2 vs ECO2 sensor is still being debated.
- Team assigned each member with a sensor to specialize in.
- Team finished rough draft of project proposal
- Team delegated tasks for the current week with emphasis on the research and planning.

Individual Review

Adam Dezay: Created and revised gantt chart during team meeting, began CO2 sensor research

Manuel Garcia: Continued Smart mesh and kicad research

Brandon Hippe: Finished python component power analysis script. Graphs and text outputs are available on github. Started basic tests on viability of custom ultrasonic anemometer, will continue and develop final anemometer pending results.

Mercedes Newton: Reached out to faculty about HVAC system used at PSU, began PM sensor research. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 4: January 23rd 2022 - January 30th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team submitted project proposal draft to Dr. Acken.
- Team reviewed rough draft of the project proposal and made adjustments according to the feedback from Dr. Acken.
- Team submitted rough draft of project proposal to Andrew Greenberg before our final review.
- Team received feedback from Dr. Elliott Gall in regards to HVAC systems in PSU.
- Team delegated tasks for the current week with emphasis on the research.
- Continued HVAC research and discussed the possibility of scheduling a tour with engineering building facilities, this will be a topic during our 4:30 meeting with Dr. Acken.
- Checked with EPL for parts availability, found sensors not available. How should we go about purchasing sensors? We're currently building spreadsheet(s) with our necessary components, would we be able to send that information to Dr. Burnett for him to order?

Individual Review

Adam Dezay: Continued CO2 sensor research.

Manuel Garcia: Continued Smart mesh and kicad research.

Brandon Hippe: Started basic tests on viability of custom ultrasonic anemometer. Continues to develop final anemometer pending results.

Mercedes Newton: Reached out to faculty about HVAC system used at PSU, continued PM sensor research. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 5: January 31st 2022 - February 6th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team submitted project proposal to Dr. Burnett.
- Team prepared project proposal presentation for Dr. Acken.
- Team continued prototype sensor/smartmesh development.
- Checked part availability in the EPL.

Individual Review

Adam Dezay: Continued CO_2 sensor research. Worked on presentation.

Manuel Garcia: Continued Smart mesh and kicad research. Worked on presentation.

Brandon Hippe: Continued ultrasonic anemometer research and design. Worked on presentation.

Mercedes Newton: Continued PM sensor research. Organized team trello/documentation. Worked on presentation.

Team 1 Open Source Air Quality Monitoring

Week 6: February 6th 2022 - February 13th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Conducted first team check in with professor Greenberg.
- Further solidified sensor choices, aim to order sensors during Monday meeting.
- Looked into alternate microcontrollers that would fit our application better.
- Worked on getting example code working on our MSP 430s
- Working towards getting list of components ready to purchase
- Making final tweaks to project proposal before submission by Friday noon

Questions for moving forward

- Can we get the template for submitting order requests so we can order components soon?
- Is there any chance of using the STM32 L series chip?
- When is our next meeting with Dr. Burnett?

Individual Review

Adam Dezay: Continued CO_2 sensor research. Updated wiki

Manuel Garcia: Continued Smart mesh and kicad research, worked on initial MSP430/ Energia / Code Composer Studio setup, Researched other microcontrollers that may fit our application better

Brandon Hippe: Continued to develop final anemometer pending results.

Mercedes Newton: Continued PM sensor research. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 7: February 13th 2022 - February 20th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Conducted first in person team check in with Dr. Burnett.
- Solidified sensor choices.
- Worked on getting example code working on our MSP 430.
- Achieved working MSP 430/energia on ¾ team member computers.
- Created a list of components ready to purchase.
- Making final tweaks to the project proposal before submission by Monday the 20th.

Individual Review

Adam Dezay: Continued CO_2 sensor research, decided on SGP30, worked on final project proposal, updated Wiki, Started on CO_2 code, Updated final proposal.

Manuel Garcia: Continued Smart mesh and kicad research, worked on initial MSP430/ Energia / Code Composer Studio setup, assisted teammates with MSP 430.

Brandon Hippe: Continued to develop final anemometer pending results, organized ordering spreadsheet, updated proposal, assisted teammates with MSP 430.

Mercedes Newton: Continued PM sensor research, decided on SPS30. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 8: February 20th 2022 - February 27th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Worked on getting example code working on our MSP 430.
- Achieved working MSP 430/energia on ¾ team member computers.
- Enhanced gantt chart
- Submitted final project proposal
- Began parts ordering process
- Discussed potential of moving team meetings to better accommodate schedules.
- Canceled in person friday meeting due to ice and snow
- Waiting on order to arrive

Individual Review

Adam Dezay: Continued CO2 sensor research, decided on SGP30, worked on final project proposal, updated Wiki, Started on CO2 code, Updated final proposal.

Manuel Garcia: Continued Smart mesh and kicad research, worked on initial MSP430/ Energia / Code Composer Studio setup, assisted teammates with MSP 430.

Brandon Hippe: Continued to develop final anemometer pending results, organized ordering spreadsheet, updated proposal, assisted teammates with MSP 430.

Mercedes Newton: Continued PM sensor research, decided on SPS30. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 9: February 28th 2022 - March 6th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- All 4 members have access to Energia
- Ordered and received all sensors
- Began working individually on sensors/components
  - Adam - CO_2
  - Manuel - SmartMesh
  - Brandon - Anemometer
  - Mercedes - PM

Upcoming week:

- Have all components and sensors work independently with generic code and breadboard
- KiCAD rough draft complete

Individual Review

Adam Dezay: began first draft of code & circuit for CO_2 sensors, updated Wik and some documentation

Manuel Garcia: Completed Energia setup for team mate, continued SmartMesh Code, KiCAD draft

Brandon Hippe: Continued Anemometer code & circuit.

Mercedes Newton: Continued PM sensor code & circuit. Organized team trello/documentation.

Team 1 Open Source Air Quality Monitoring

Week 10: March 6th 2022 - March 12th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- After extensive feedback from both our advisor and industry sponsor, our team has dedicated additional focus on clear documentation.
- All team members are connecting to and coding in Energia.
- Team members are each working on specified sensor/component tasks.
- Enhanced gantt chart as shown in figures 1-4.
- Moved team meetings to better accommodate schedules.
    - New times, effective immediately are Monday @ 4:30pm, Tuesday @ 7:30pm, Thursday @ 7:30pm .
- Team discussed changing meeting time with Dr. Acken for the upcoming term
    - Potential advisor meeting times that work for the team: Thursday @2-4pm or Friday at 8am, set to be discussed during Monday meeting on 3/13/2023.
    - Starting april 6, 3pm meetings.

Individual Review

Due to recent sponsor and advisor feedback, we have produced a more detailed description of individual progress and current roadblocks.

Adam Dezay: CO_2 sensor updates - working on connecting CO_2 sensors to Energia. Having issue getting I2C to work, following previous years example, yet to have success connecting using msp430 and energia. Spent around 8 hours this week troubleshooting code, finding and importing libraries, will update when progress has been made.

Manuel Garcia: Attempted to get both Smartmesh and I2C working on the MSP430. Worked more on getting specific sensors into our KiCad schematic.

SMARTMESH - able to power on a node and connect it to the host PC via coin cell power and software from analog devices. Unable to communicate with the board or power it on via power pins, Also unable to get the previous years python gui to run, suspected issues with libraries and python being different versions, need to either spend time updating code to current libraries, re-write the application to better fit our needs, or try and locate all outdated zip files of old project in order to get running. I have found that the documentation for the smartmesh system has been far less comprehensive than I was hoping for, I am not sure if I am just looking in the wrong places, however after several day long attempts I have not had success getting it to work or finding documentation on how exactly it should be set up for our purposes.

ENERGIA & MSP430 - Having issues with working with Energia and the MSP430, getting to the point where I might switch to code composer studio and re-write the whole project in C. Right now an error I get almost every time I turn on the energia IDE requires that I delete the whole “Energia15” folder from my %appdata% and reinstall it, I have not found a workaround for this. Deleting this folder has been a nuisance, however has been doable since it does not delete the code I have written. This however changes now that we are using I2C to communicate with our sensors and the smartmesh boards. I looked into how the previous year was able to use I2C and they showed how they needed to edit several files and values in the “Energia15” folder in order to get their code to run. We have not successfully re-done what they have shown because their documentation is for a different msp430 than we are using with a different pinout and chip, and the edits they made are chip specific. On Top of needing to do the work of editing these files in order to get I2C to work for our chipset, when I get this daily error requiring me to delete this subfolder I will also need to go back and make the same 20 or so code edits in order to program the IDE to work with our MSP430fr2355 chip. I also have not found good documentation on doing this online and would have to reverse engineer what last year's capstone team did and hope that with enough edits and iterations that it would work for our chip. This has led me to further consider using code composer studio because all of the official documentation from TI, as well as any other reputable source, uses code composer studio and the C language. This would require a severe overhaul of our code and take a significant amount of time to do, however I believe it would lead to more reliable and reproducible code for ourselves and any future team that was interested in continuing on with this project.

Brandon Hippe:

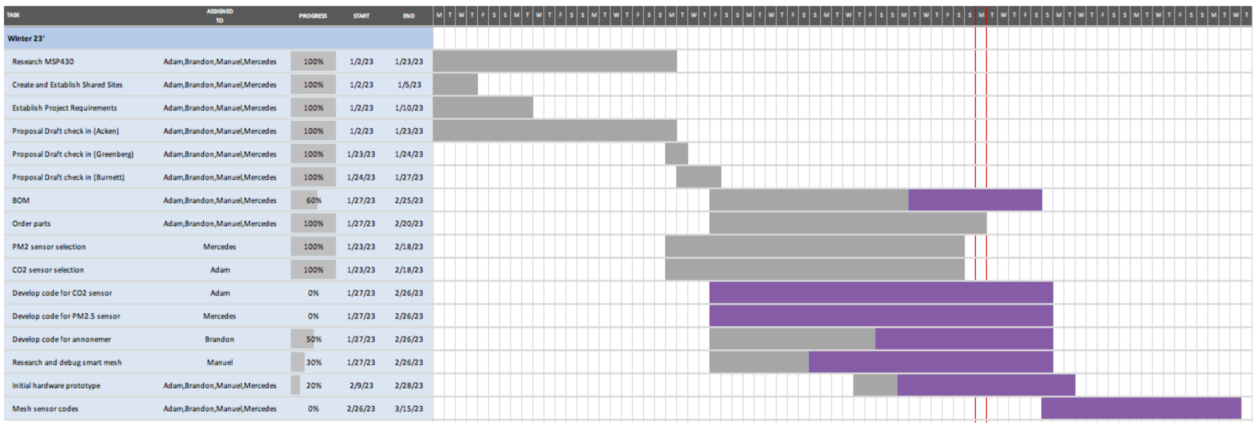
Anemometer updates - UART communication with both sensors is inconsistent. Each one works individually, but both don’t work simultaneously. I’ve been trying to use the same transmit pin for both so that they trigger at the same time, but I’ll have to try to get them both working separately but at the same time before trying again. Otherwise, could use the pulse duration mode, but it seemed to be very inconsistently responding to airflow.

Mercedes Newton:

PM2.5 sensor updates - Working on connecting PM2.5 sensor to Energia and producing working code. Experiencing difficulty updating sensor libraries from arduino to Energia. Currently reviewing last year’s capstone documentation and attempting to model the switch after last year’s team. Exerting new focus on documentation in order to update advisor and sponsor on team progress.

Gantt Chart and Timeline Updates:

Below is both the general timeline of the project as a whole as well as a breakdown of the specific tasks that are left moving forward. Due to delay in selecting and receiving sensors, as well as team difficulty in implementing them, we have postponed several of our due dates to better reflect our progress. Additionally, we have switched our gantt chart format from Excel to Google Sheets to make editing more efficient and legible. All gantt charts are representative of the timeline for this term only. In the week eleven report we intend to have an updated timeline for spring term.



TASK	ASSIGNED TO	PROGRESS	START	END
Winter 23'				
Research MSP430	Adam,Brandon,Manuel,Mercedes	100%	1/2/23	1/23/23
Create and Establish Shared Sites	Adam,Brandon,Manuel,Mercedes	100%	1/2/23	1/5/23
Establish Project Requirements	Adam,Brandon,Manuel,Mercedes	100%	1/2/23	1/10/23
Proposal Draft check in (Acken)	Adam,Brandon,Manuel,Mercedes	100%	1/2/23	1/23/23
Proposal Draft check in (Greenberg)	Adam,Brandon,Manuel,Mercedes	100%	1/23/23	1/24/23
Proposal Draft check in (Burnett)	Adam,Brandon,Manuel,Mercedes	100%	1/24/23	1/27/23
BOM	Adam,Brandon,Manuel,Mercedes	60%	1/27/23	2/25/23
Order parts	Adam,Brandon,Manuel,Mercedes	100%	1/27/23	2/20/23
PM2 sensor selection	Mercedes	100%	1/23/23	2/18/23
CO2 sensor selection	Adam	100%	1/23/23	2/18/23
Develop code for CO2 sensor	Adam	0%	1/27/23	2/26/23
Develop code for PM2.5 sensor	Mercedes	0%	1/27/23	2/26/23
Develop code for annonemer	Brandon	50%	1/27/23	2/26/23
Research and debug smart mesh	Manuel	30%	1/27/23	2/26/23
Initial hardware prototype	Adam,Brandon,Manuel,Mercedes	20%	2/9/23	2/28/23
Mesh sensor codes	Adam,Brandon,Manuel,Mercedes	0%	2/26/23	3/15/23

Figure 1: Original Gantt chart as seen on project proposal

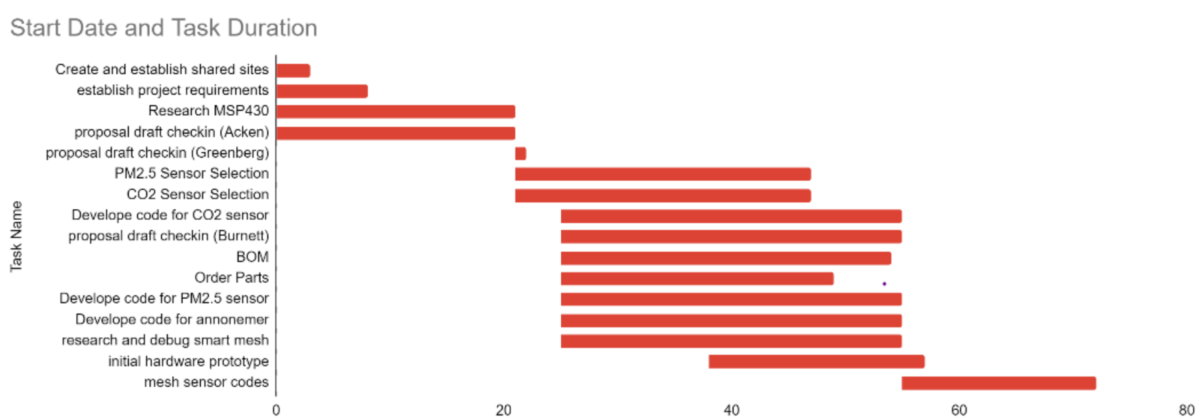


Figure two: Original gantt chart remade in Google Sheets

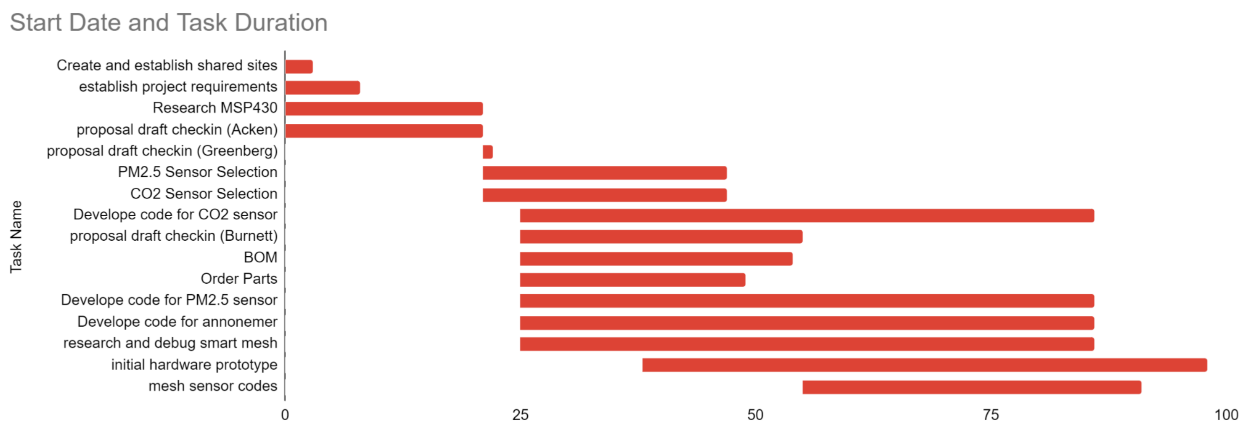


Figure three: New gantt chart with updated deadlines

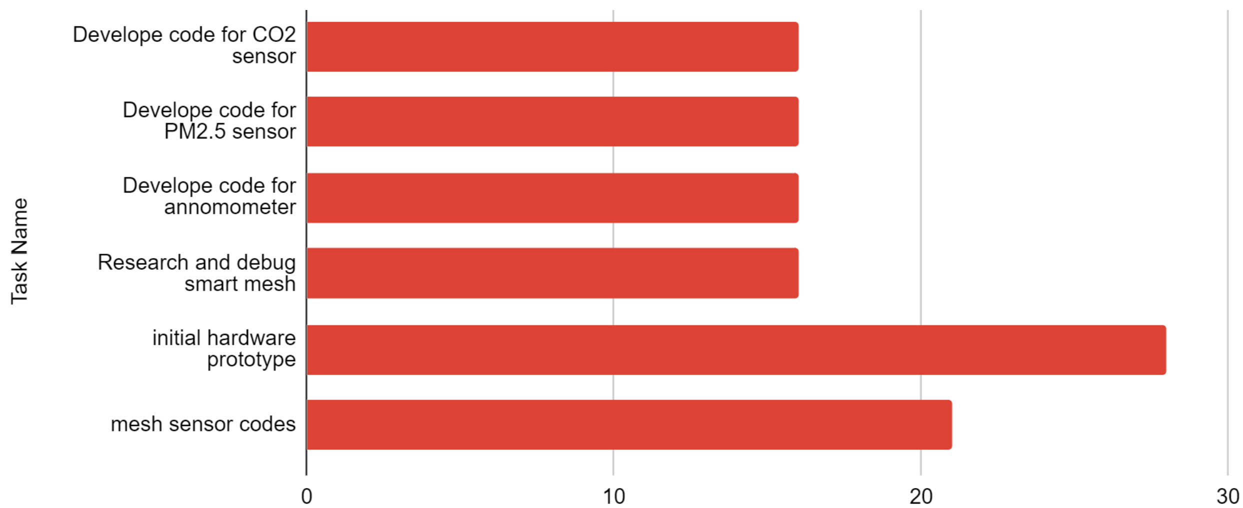


Figure four: Pending tasks with updated finishing dates in relation to current date 3/13/2023

Task Name	Expected Completion Date
Develop code for CO2 sensor	3/29/23
Develop code for PM2.5 sensor	3/29/23
Develop code for anemometer	3/29/23
Research and debug smart mesh	3/29/23
initial hardware prototype	4/10/23
mesh sensor codes	4/3/23

Table 1: current tasks with updated expected completion dates

KiCad:

Current Top-Level Kicad schematic, filling in internal subsheets with components and wires as we figure out what we need. Will post sub level schematics as we make progress in future reports.

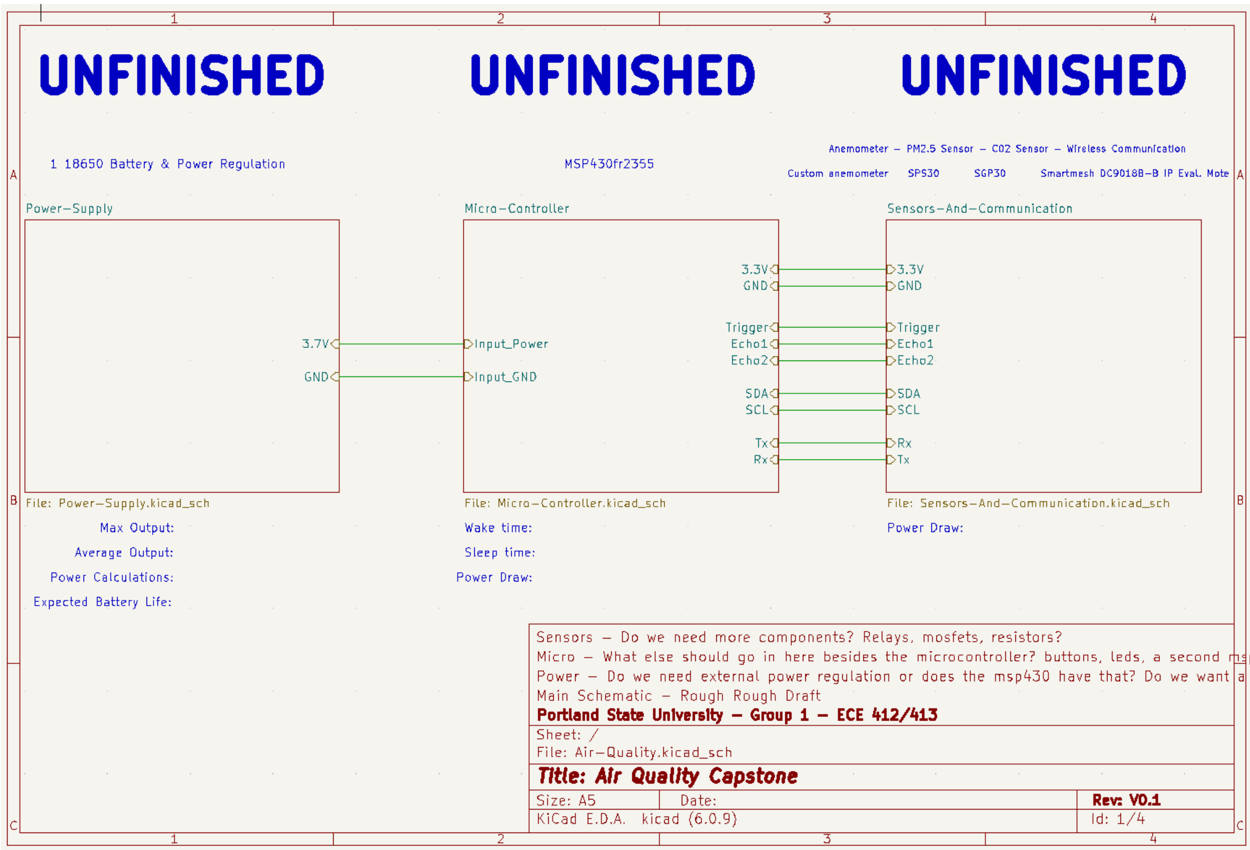


Figure Five: Top level KiCad Schematic

Team 1 Open Source Air Quality Monitoring

Week 11: March 13th 2022 - March 19th 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- All team members are connecting to and coding in Energia.
- Team members are each working on specified sensor/component tasks.
- Enhanced gantt chart as shown in figures 1 and 2.
- Gantt chart and schedule for upcoming term (shown in figure 3).
- Moved team meetings to better accommodate schedules.
  - New times, effective immediately are Monday @ 4:30pm, Tuesday @ 7:30pm, Thursday @ 7:30pm .
- Team changed meeting time with Dr. Acken for the upcoming term.
  - Starting April 6 we will be conducting Thursday 3pm meetings.

Individual Review

Adam Dezay:

Worked with Brandon on getting I2C with energia working. Yet to have full success connecting with our hardware, however prospects look positive on making progress this upcoming week.

Manuel Garcia:

Did not have a chance to do a ton of work on the project this week preparing for finals. Plans in place to dedicate time to the project before the next report.

Brandon Hippe:

Anemometer updates - Still no consistent changes in ultrasonic output values with respect to wind. Planning on removing transducers from sensors and reattaching with wires to space them out and follow this guide. Also helped Adam figure out I2C communication with MSP430 in Energia, and going to start working on helping with making Energia I2C code for SPS30 and SGP30 sensors.

Mercedes Newton:

PM2.5 sensor updates - Working on connecting PM2.5 sensor to Energia and producing working code. Experiencing difficulty updating sensor libraries from arduino to Energia. Preparing for finals. Assisted team in planning for the upcoming term and created gantt chart

Gantt Chart and Timeline Updates:

Below is both the general timeline of the project as a whole as well as a breakdown of the specific tasks that are left moving forward. Gantt charts in figures 1 and 2 as well as table 1 are representative of the timeline for this term only. Figure 3 represents an outline of the schedule for spring term. Our team has factored in additional time for potential delays, however the current dates are subject to change. We intend to have our 3 modes built by the end of may, as displayed in our figure 3 gantt chart.

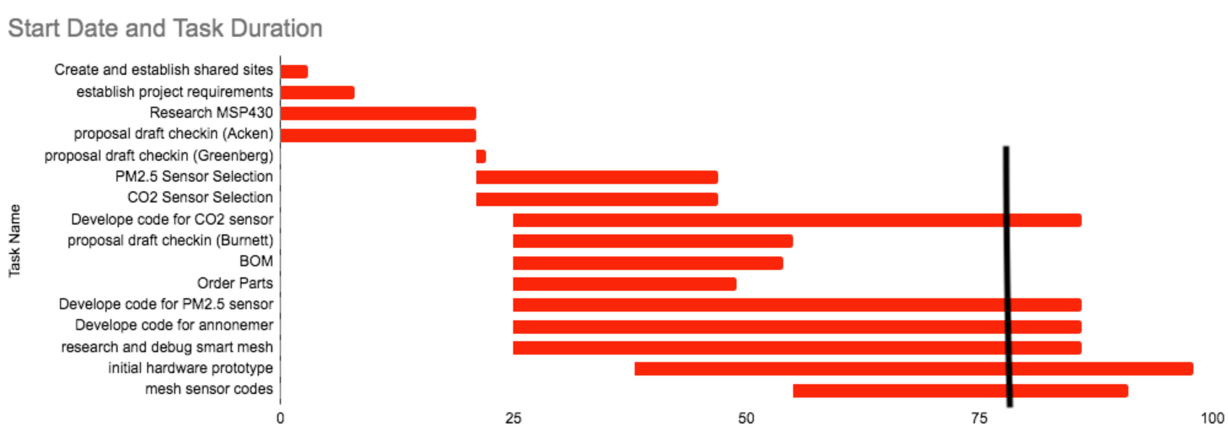


Figure One: Gantt chart with updated deadlines, black line signifies today’s date, monday 3/20/23

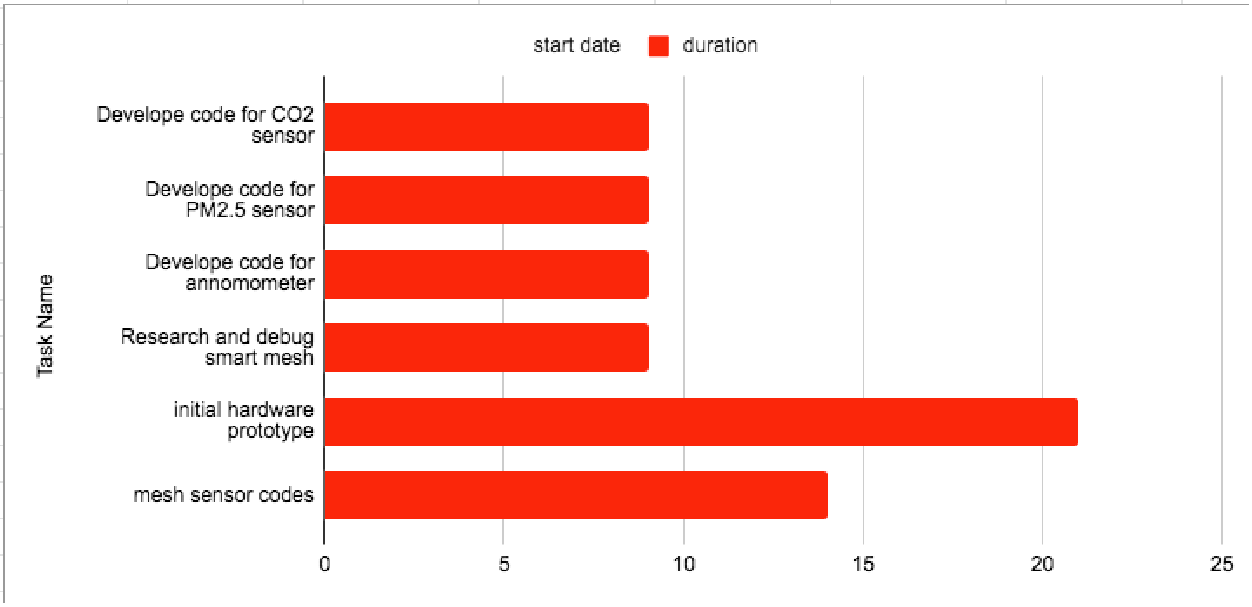


Figure Two: Pending tasks with updated finishing dates in relation to current date 3/20/2023

Task Name	Expected Completion Date
Develop code for CO2 sensor	3/29/23
Develop code for PM2.5 sensor	3/29/23
Develop code for anemometer	3/29/23
Research and debug smart mesh	3/29/23
initial hardware prototype	4/10/23
mesh sensor codes	4/3/23

Table 1: current tasks with updated expected completion dates

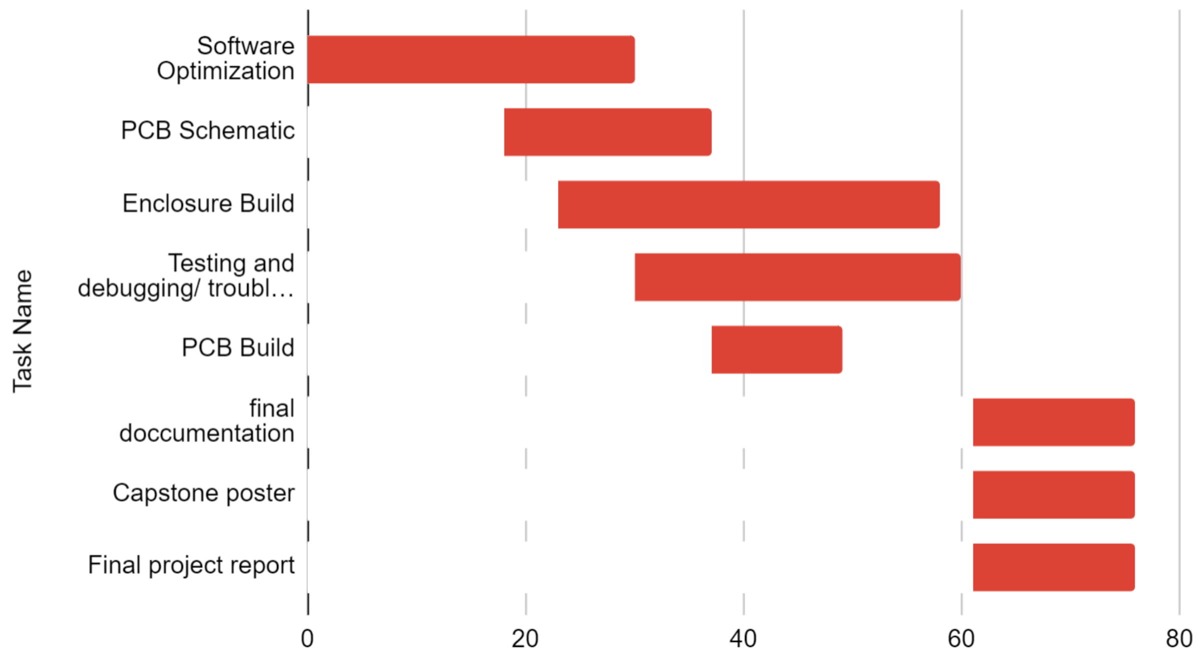


Figure three: Gantt chart for Spring term starting April 1st 2023

Task Name	Start date	End date
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023
Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table two: Tasks for spring term with expected completion dates *completion dates subject to change*

Team 1 Open Source Air Quality Monitoring
Week 12: March 20th 2022 - March 27th 2022
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- All team members are connecting to and coding in Energia.
- Team members are each working on specified sensor/component tasks.
- Enhanced gantt chart as shown in figures 1 and 2.
- Moved team meetings to better accommodate schedules.
  - New times, effective immediately are Monday @ 4:30pm, Tuesday @ 7:30pm, Thursday @ 7:30pm .
- Team changed meeting time with Dr. Acken for the upcoming term.
  - Starting April 6 we will be conducting Thursday 3pm advisor meetings.
  - Affective April 3rd Monday @ 7pm, Thursday @ 3 and Friday at 7pm
- Team intends to finish individuals codes and begin code meshing this week

Individual Review

Adam Dezay:
Worked with Brandon on getting I2C with energia working. Yet to have full success connecting with our hardware, however prospects look positive on making progress this upcoming week.

Manuel Garcia:
Did not have a chance to do a ton of work on the project this week preparing for finals. Plans in place to dedicate time to the project before the next report.

Brandon Hippe:
Shifted to working on making libraries for CO_2 and PM2.5 sensors due to traveling for break. Finished coding them, but don't have hardware to test with. Code is uploaded to github.

Mercedes Newton:
PM2.5 sensor updates - No updates, planning on finishing up sensor code and connection this week.

Gantt Chart and Timeline Updates:

Below is both the general timeline of the project as a whole as well as a breakdown of the specific tasks that are left moving forward. Gantt charts in figures 1 and 2 as well as table 1 are representative of the timeline for this term only. Figure 3 represents an outline of the schedule for spring term. Our team has factored in additional time for potential delays, however the current dates are subject to change. We intend to have our 3 modes built by the end of may, as displayed in our figure 3 gantt chart.

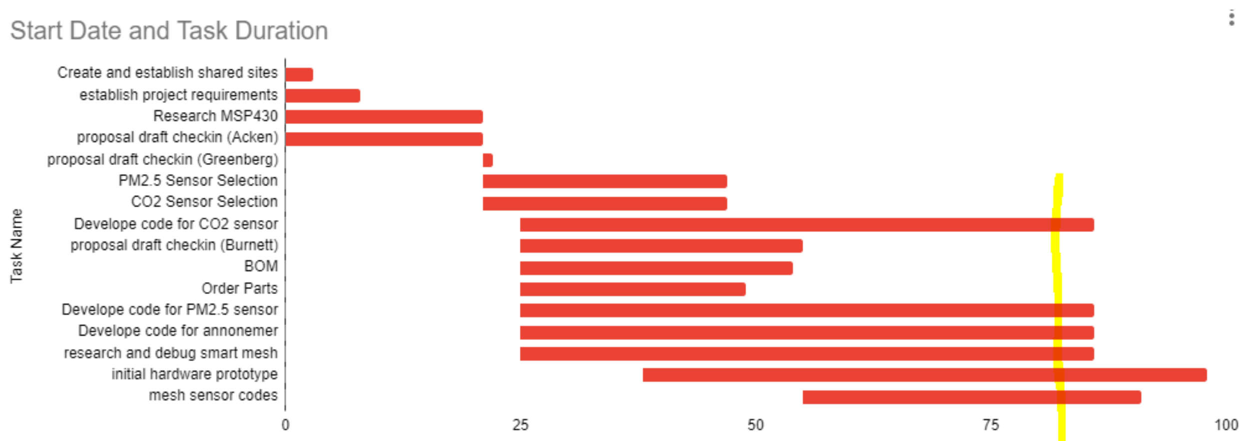


Figure One: Gantt chart with updated deadlines, highlighted line signifies today's date, monday 3/27/23

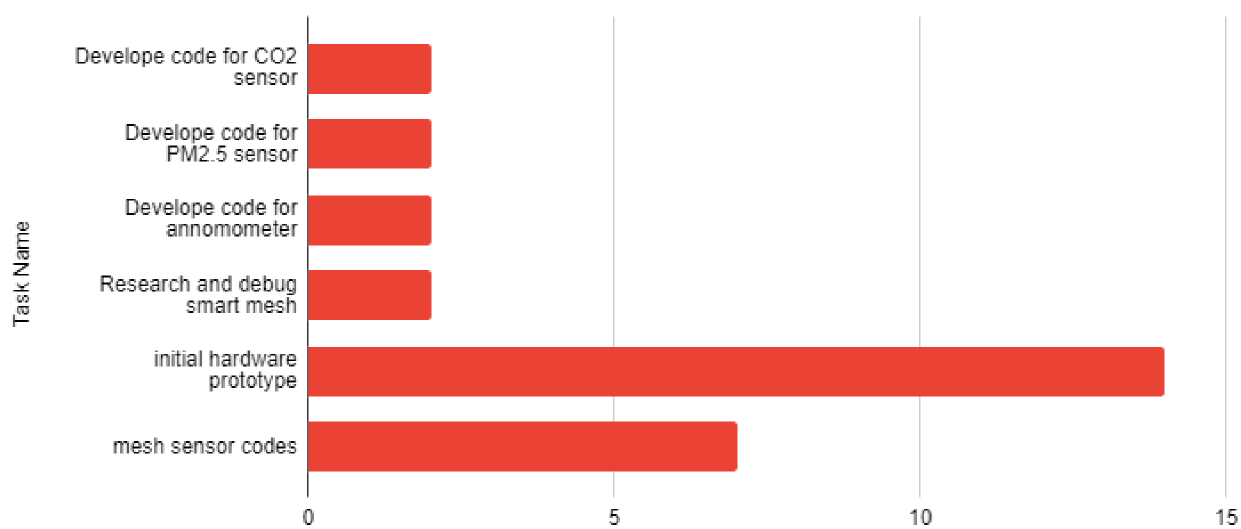


Figure Two: Pending tasks with updated finishing dates in relation to current date 3/27/2023

Task Name	Expected Completion Date
Develop code for CO2 sensor	3/29/23
Develop code for PM2.5 sensor	3/29/23
Develop code for anemometer	3/29/23

Research and debug smart mesh	3/29/23
initial hardware prototype	4/10/23
mesh sensor codes	4/3/23

Table 1: current tasks with updated expected completion dates

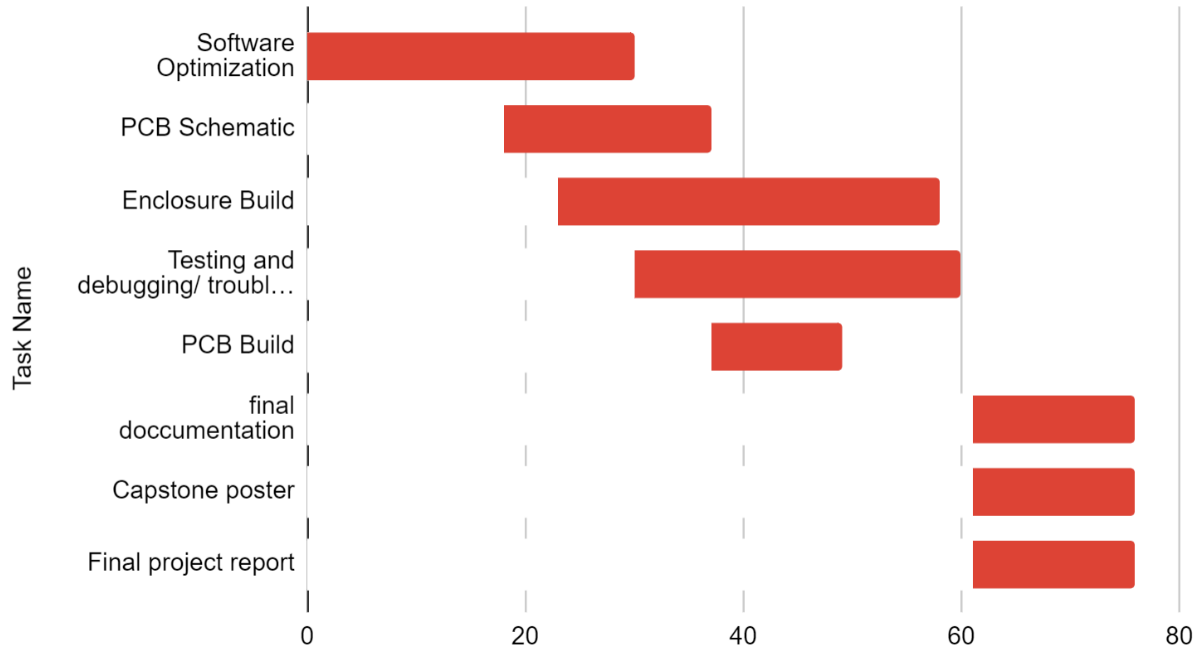


Figure three: Gantt chart for Spring term starting April 1st 2023

Task Name	Start date	End date
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023
Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table two: Tasks for spring term with expected completion dates *completion dates subject to change*

Team 1 Open Source Air Quality Monitoring
Week 13: April 3rd 2022 - April 10th 2022
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team members are each working on specified sensor/component tasks.
- Enhanced gantt chart as shown in figures 1 and 2.
- Gantt chart and schedule for upcoming term (shown in figure 3).
- Moved team meetings to better accommodate schedules.
    - New times, effective today, are today Monday @ 7pm, Thursday advisor meeting @ 3pm and friday at 7pm
- Team changed meeting time with Dr. Acken for the upcoming term.
    - Starting April 6 we will be conducting Thursday 3pm meetings.
- Team prepared Thursday progress presentation for Dr Burnett
- Shifting emphasis to meshing codes

Individual Review

Adam Dezay:
Worked with Brandon on getting I2C with energia working. Yet to have full success connecting with our hardware, however prospects look positive on making progress this upcoming week.
Code finally compiles thanks to brandon. Connections to beadboard are too short so soldering might be needed.

Manuel Garcia:
Worked on planning logistics for the upcoming term and project goals. Spent a brief amount of time trying to integrate microcontroller with wireless network.

Brandon Hippe:
Got EnergyTrace working, and found the sleep() function in Energia, which puts the MSP430 into LPM3 mode. Created libraries for the SPS30 and SGP30, although they haven't been tested yet. Started work on the main code for the node.

Mercedes Newton:

PM2.5 sensor updates - Working on connecting PM2.5 sensor to Energia and producing working code. Experiencing difficulty updating sensor libraries from arduino to Energia. Coordinated team planning for upcoming term and updated gantt charts.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

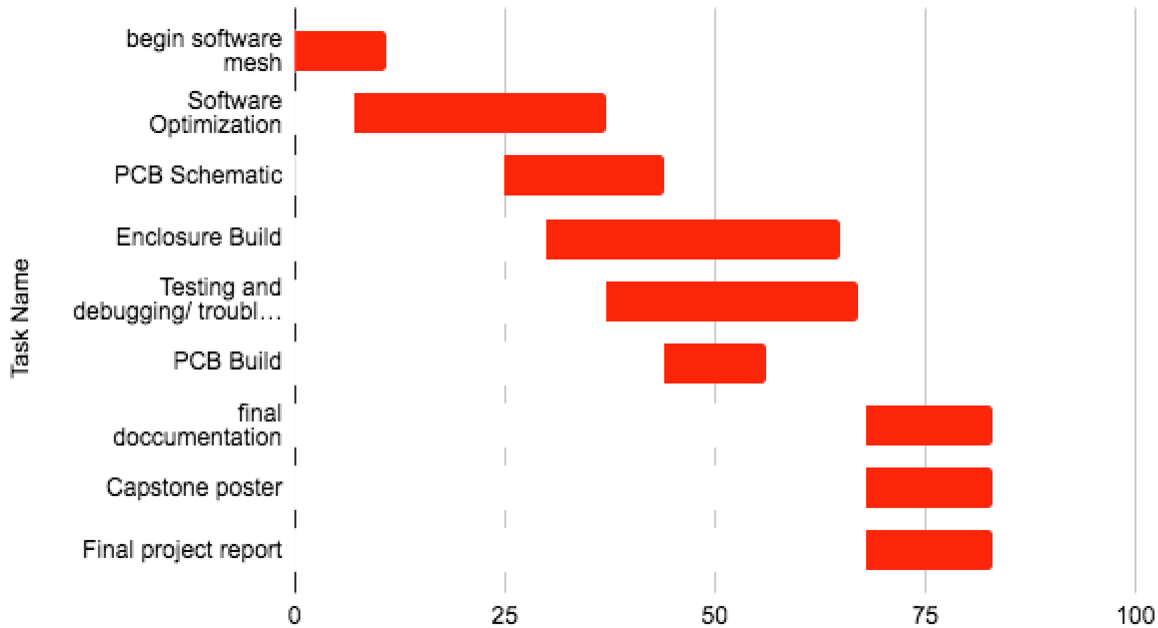


Figure One: Gantt chart for Spring term starting March 25th 2023

Task Name	Start date	End date
Begin software mesh	3/25/2023	4/5/2023
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023

Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

Team 1 Open Source Air Quality Monitoring
Week 14: April 10th 2022 - April 17th 2022
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Team members are each working on specified sensor/component tasks.
- Team submitted new equipment request
    - Alternative anemometer
    - Jumper cables for PM sensor
- Gantt chart and schedule for current term (shown in figure 1).
- Team decided to meet in person each week on campus at 2pm on Thursdays before advisor meetings
- Team will meet with Dr. Burnett for the next two weeks while Dr. Acken is at conferences.
- Shifting emphasis to meshing codes

Individual Review

Adam Dezay:
Worked Soldering connections to see if I am able to get a proper signal from the sensor. Debugging code once uploaded to the sensor
Helped prepare update 1 presentation.

Manuel Garcia:
Worked on learning more about UART & setting up a ESP8266 web server connected to the MSP430 to show proof of concept. Unable to currently get the smartmesh system working, but think the problem was with my individual module. I will be testing a few more modules this week and attempting to finalize the smartmesh portion of this project preparing for integration.

Brandon Hippe:
Worked to debug issues compiling sensor code. Discovered that we need cables for PM sensors. Worked to find a new anemometer alternative. Still working on ultrasonic anemometer.

Mercedes Newton:

PM2.5 sensor updates - Working on connecting PM2.5 sensor to Energia and producing working code. Libraries are created and code runs on ½ computers. Waiting on jumper cables to connect sensor to energia.

Coordinated team planning for upcoming term and updated gantt charts.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

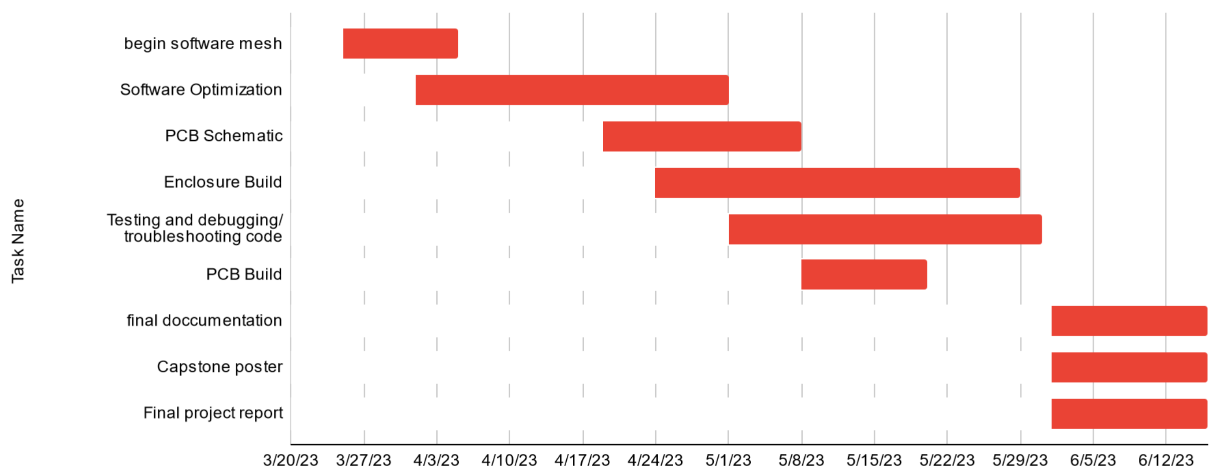


Figure One: Gantt chart for spring term (first task starts 3/25/2013)

Task Name	Start date	End date
Begin software mesh	3/25/2023	4/5/2023
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023
Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

Team 1 Open Source Air Quality Monitoring
Week 15: April 17th 2022 - April 24th 2022
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Team members are each working on specified sensor/component tasks.
- Team submitted new equipment request
    - New MSP430 boards
- Team received new equipment
    - PM sensor cables
    - Still waiting on anemometer
- Established communication with PM and eCO2 sensors! Data is coming in!
    - PM and eCO2 sensor code is complete and (hopefully entirely) debugged
- Breadboard prototype (minus anemometer and SmartMesh) is ready (shown in figure 2)
- Gantt chart and schedule for current term (shown in figure 1).
- Team decided to meet in person each week on campus at 2pm on Thursdays before advisor meetings
- Team will meet with Dr. Burnett for this week while Dr. Acken is at conferences.

Individual Review

Adam Dezay:
I finally got a signal to the sensors thanks to help from Brandon and Mercedes. We are getting CRC code error but were unable to quickly debug it. Needs more work.
Wiki caught up to week 14 of work. Gave my MSP430 to Brandon since his got fried

Manuel Garcia:
Got UART working on the MSP430. Successfully pulling outside data on the msp430, transmitting that data over UART to an esp32, hosting that data on a local server via the esp32 that is accessible via the web browser. Have not had successful transmissions with the smartmesh yet, but now that we can tell that we are successfully transmitting data we just need to figure out proper smartmesh pin settings and baud rate.

Brandon Hippe:

Fried an MSP430 (lesson learned: don't short 5V and ground together if you don't want a glowing inductor/resistor and magic smoke). Wired up breadboard prototype (shown in figure two) and worked on debugging PM and eCO2 sensor code. Both are working fully as intended. Wrote a library for anemometer so debugging can begin as soon as it arrives.

Mercedes Newton:
PM2.5 sensor updates - Continued debugging efforts for PM sensor and worked to connect to UART with brandon.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

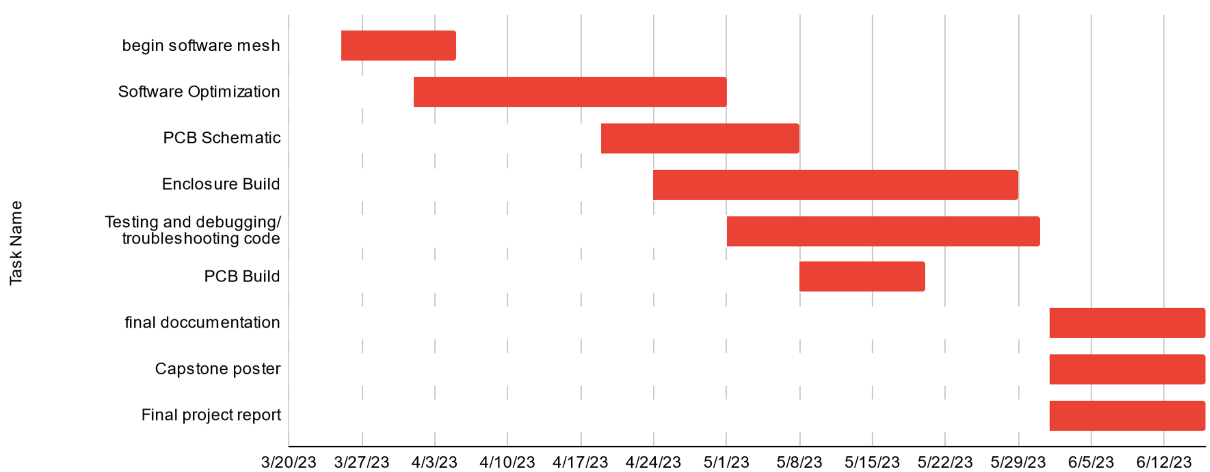


Figure One: Gantt chart for spring term (first task starts 3/25/2013)

Task Name	Start date	End date
Begin software mesh	3/25/2023	4/5/2023
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023

final documentation	6/1/2023	6/16/2023
Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

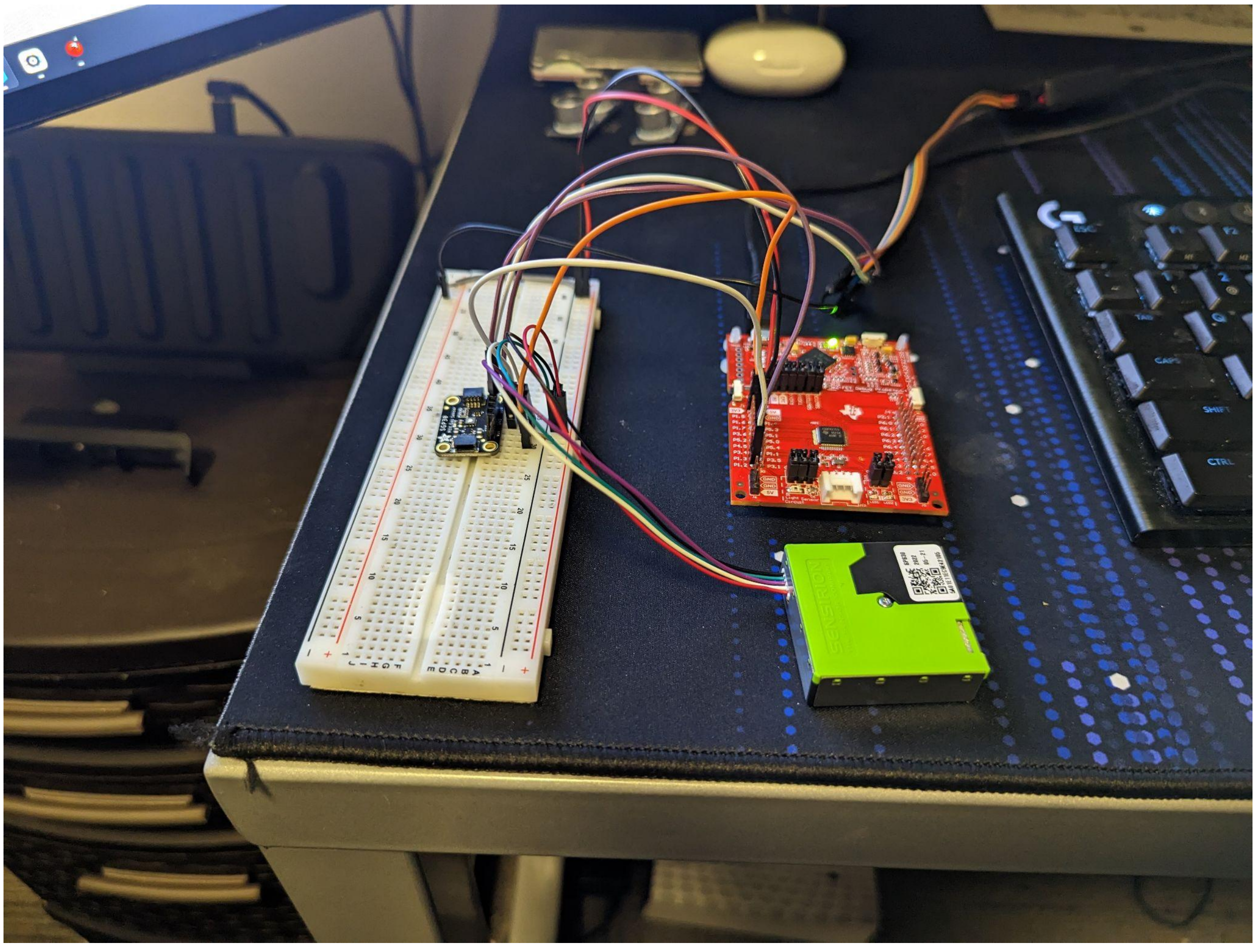


Figure Two: Image of Breadboard prototype

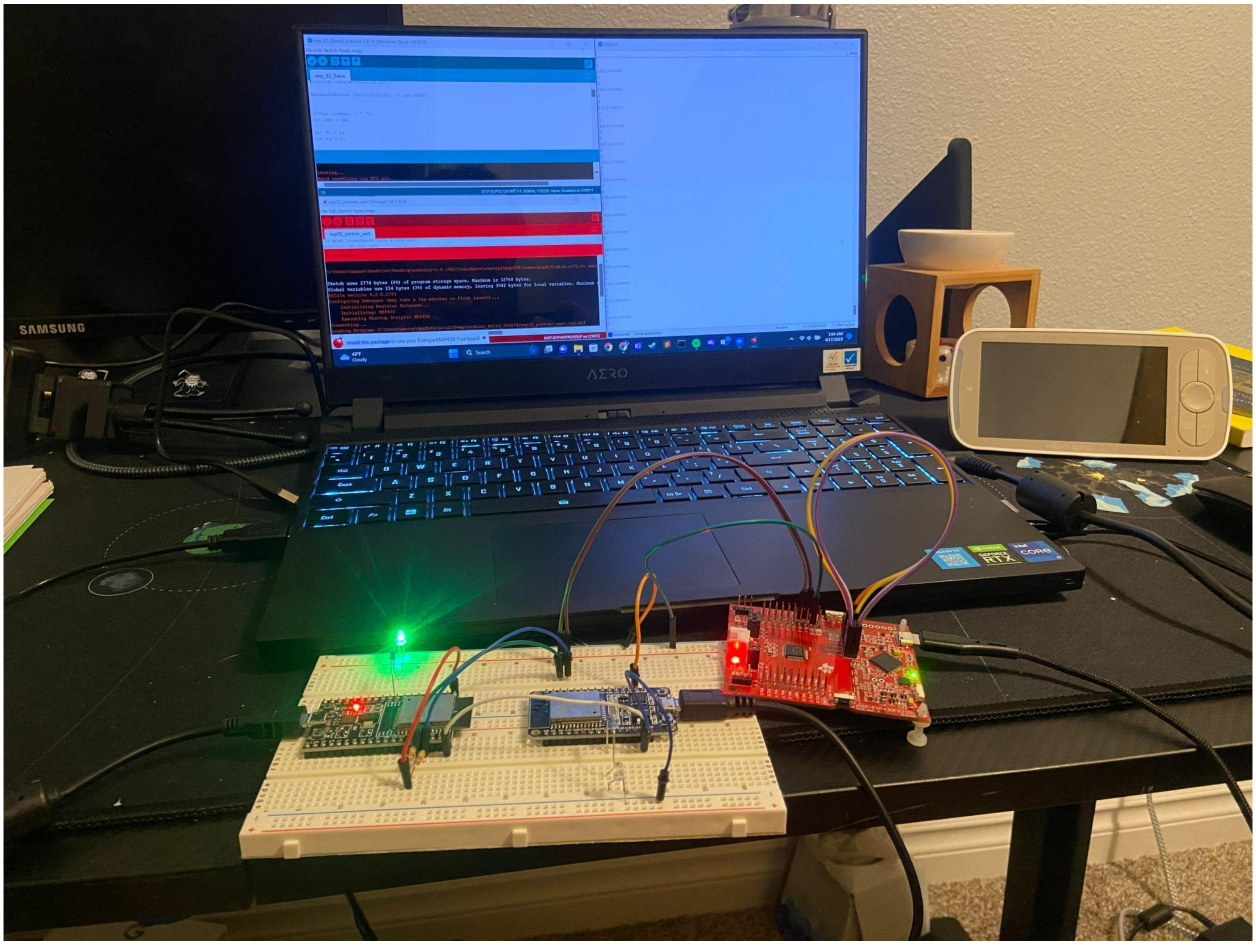


Figure Three: MSP430 transmitting to esp32 webserver

Team 1 Open Source Air Quality Monitoring

Week 16: April 25th 2022 - May 1st 2022

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Met with Dr. Burnett to discuss progress as well as giving a demo of the first working prototype of PM and CO2 sensor.
- Discussed switching gears on the Anemometer
- Splitting teams into 2 when we meet for our weekly workshop time
  - Manuel and Brandon will work on code optimization and getting Smartmesh to work
  - Adam and Mercedes will work on PCB design and enclosure
- Moving away from EnergyTrace due to the voltage/current requirements

Individual Review

Adam Dezay:

Learning how to design PCB and how to use KiCAD. Updated Wiki. Teaming up with Mercedes to make the enclosure. Writing meeting notes for the week as we make decisions on how we are going into the last stretch of the project.

Manuel Garcia:

Troubleshot briefly Smartmesh with Professor Burnett. Attempted to connect last years capstone project with the host node, however still unable to connect smartmesh node. We are digging into the code for the smartmesh to see what we are missing. Worked on the battery regulating circuit, almost fully complete, however need to find 3.7 to 5v power conversion.

Brandon Hippe:

Started work on power measurements, using Joulescope instead of EnergyTrace due to 5V requirement and current specs. Wrote a python program to calculate measurement periods based on power consumption. Fixed CO2 sensor not sleeping

Mercedes Newton:

PM2.5 sensor updates - Worked on debugging some of the pm2.5 sensor code. Started the process of designing our PCB and physical CAD model. Making key decisions that will affect where things go and mount and should start serious drafting in the coming weeks.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

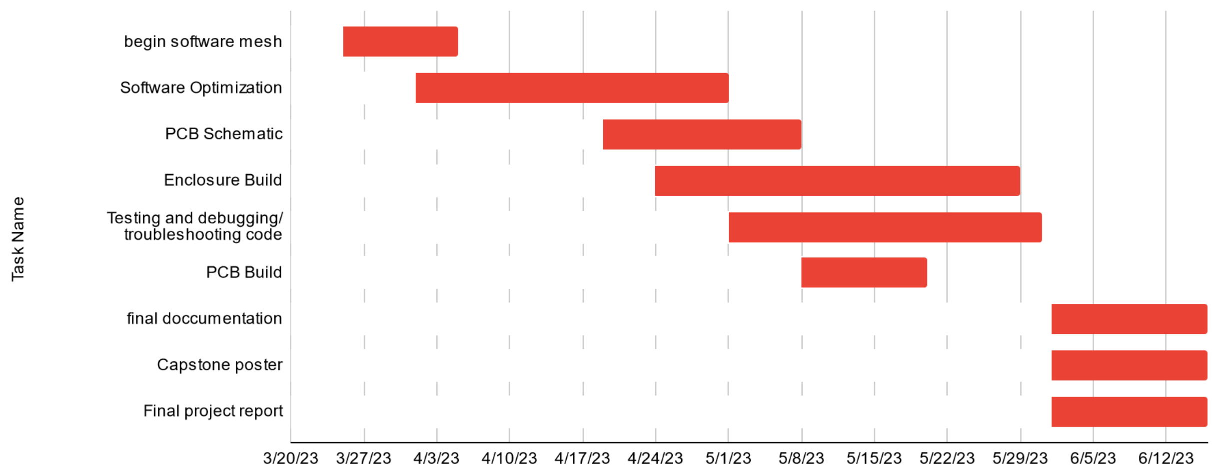


Figure One: Gantt chart for spring term (first task starts 3/25/2013)

Task Name	Start date	End date
Begin software mesh	3/25/2023	4/5/2023
Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023
PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023
Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

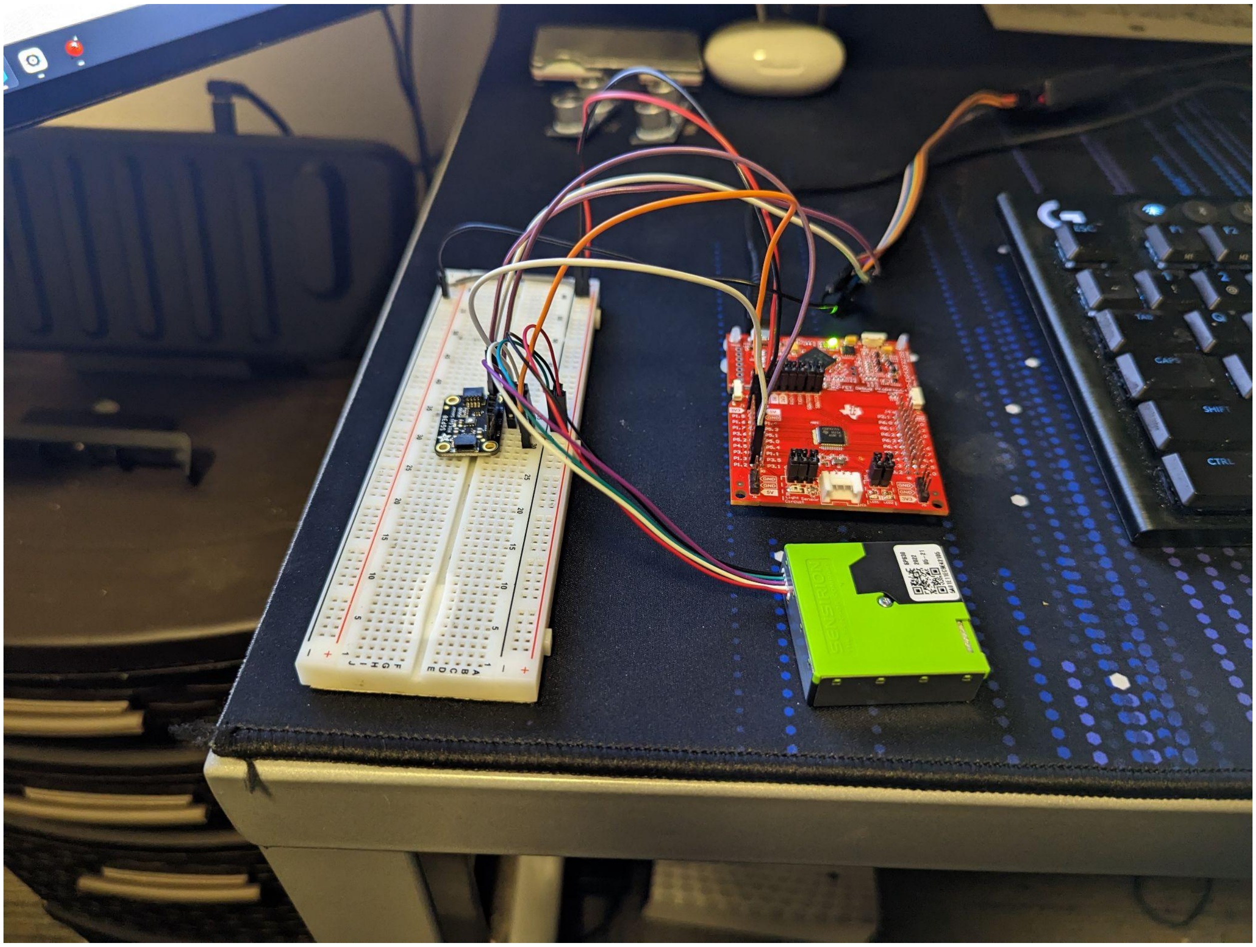


Figure Two: Image of Breadboard prototype

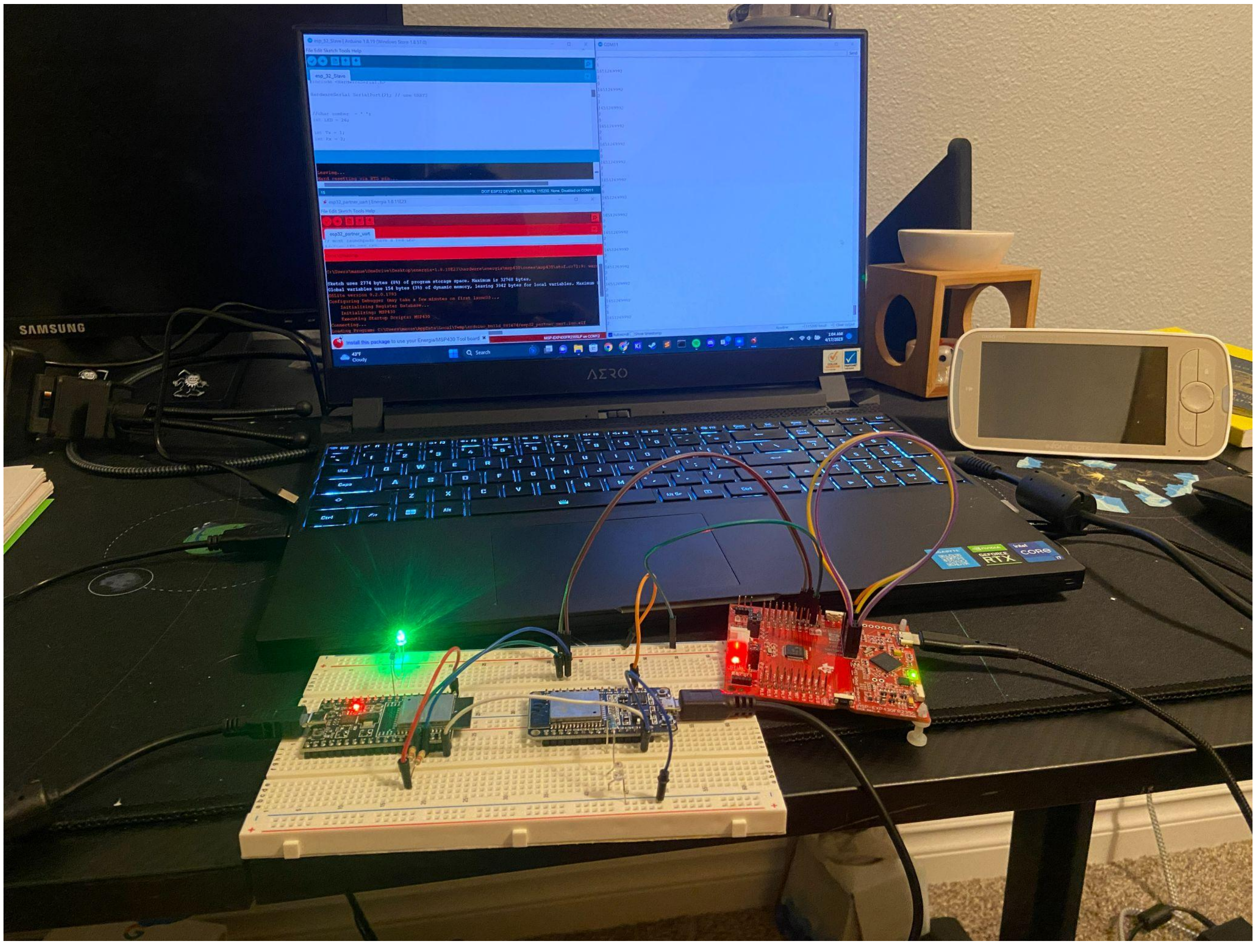


Figure Three: MSP430 transmitting to esp32 webserver

Figure Four: Team working during one of our three weekly meetings

Team 1 Open Source Air Quality Monitoring
Week 17: May 1st 2022 - May 8th
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Met with Dr. Acken in person to update team progress and outline a plan for the upcoming month.
- Finished PCB schematic, now focusing on PCB routing
- Pushed enclosure build date forward to give time for anemometer calibration
- Began enclosure design to be completed this week

Individual Review

Adam Dezay:
Updated wiki and began on making the manual for the machine including instructions for build. Focusing on learning how to design and build PCBs and learning how to use 3D printers in the EPL so I can be better help for Manuel and Mercedes

Manuel Garcia:
Turned over smartmesh progress to Brandon, and switched focus to PCB design and layout. After troubleshooting for a few months we are almost certain that we have the correct hardware configuration for the smartmesh, but still do not have code functioning for communicating the smartmesh with the host node. Going to continue making smartmesh progress while our PCB is printing.

Designed the first round PCB schematic, as a team we decided to make a hat for the msp430. Made key decisions on some components to use such as the battery management circuits, as well as what mosfets to use in order for proper voltage level shifting and putting sensors to sleep. Working on making the correct layout for the msp430 hat, so that it will fit right on top of the pins of our microcontroller. Should be able to send a board out for production within the next couple of days. Planning on using OSH park for the first round prints.

Brandon Hippe:
Switched to working on smartmesh integration with breadboard prototype. Running into a problem where smartmesh boards indicator LEDs don’t light up when power is supplied, except when physically pressing on the header pins with my fingers. Manny hasn’t had this issue, so I'm waiting to get my hands on one of the boards he’s been working with. Indicator LEDs not lighting up likely isn’t an issue for the project as

long as the smartmesh boards are actually working, but troubleshooting the connection with the host node isn't easy without them.

Mercedes Newton:
Focused on designing physical CAD models in FreeCAD. Began a 3d printing draft to be completed and put in the printing queue for the EPL by May 6th (designing to be printed by "Hyde" machine in EPL).

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

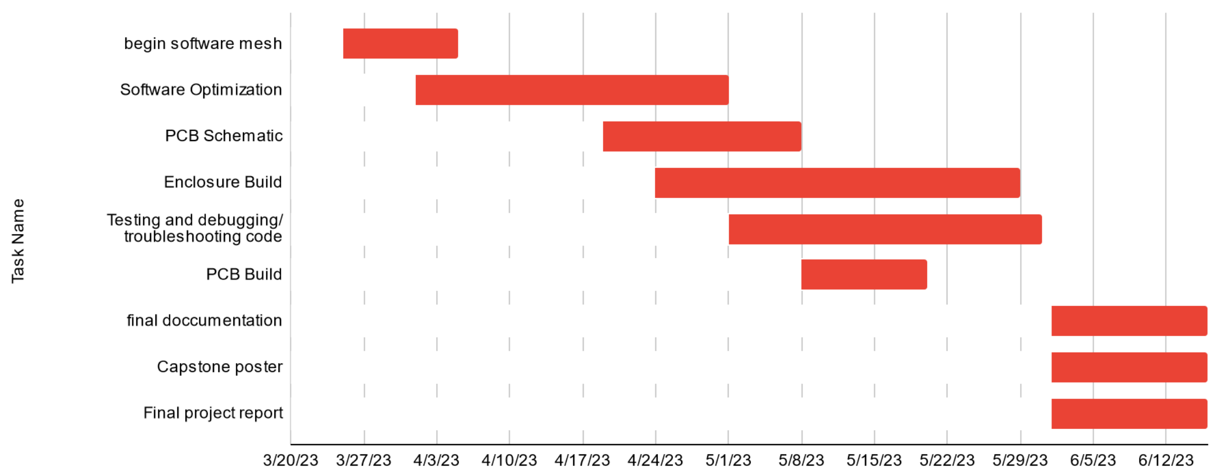


Figure One: Gantt chart for spring term (first task starts 3/25/2013)

Task Name	Start date	End date
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Software Optimization	4/1/2023	5/1/2023
PCB Schematic	4/19/2023	5/8/2023
Enclosure Build	4/24/2023	5/29/2023
Testing and debugging/ troubleshooting code	5/1/2023	5/31/2023

PCB Build	5/8/2023	5/20/2023
final documentation	6/1/2023	6/16/2023
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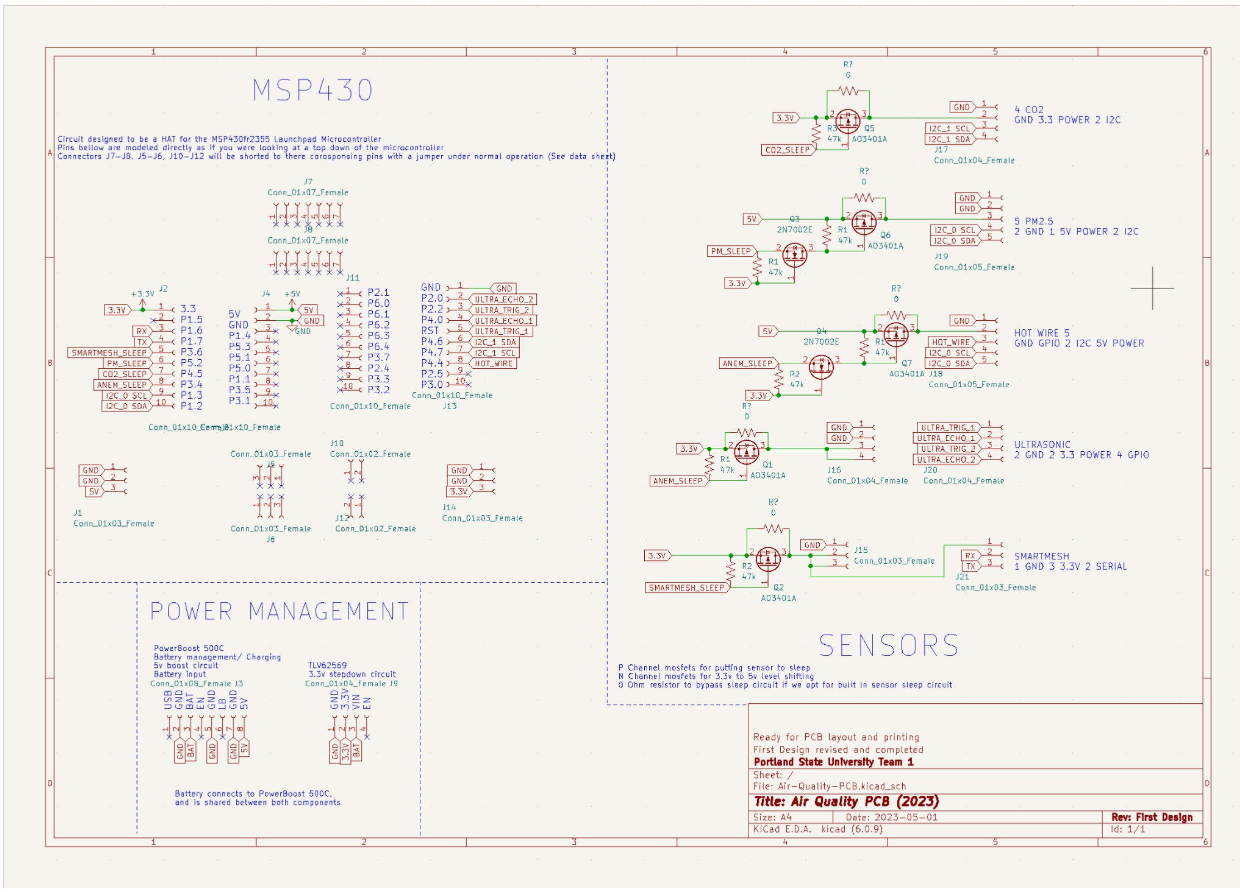

Completed PCB Schematic (Revision 1) ~ PCB layout in progress

Team 1 Open Source Air Quality Monitoring
Week 18: May 8th 2022 - May 15th
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Met with Dr. Acken and Dr Burnett in person to update team progress and outline PCB, enclosure, and mounting plans
- Finished PCB version 1, waiting on arrival
- Enclosure 3D Models being finalized, getting ready to print in EPL
- Figured out SmartMesh IP functionality, ran 3hr test during WEST Lab Group Meeting obtaining CO2 and PM data

Individual Review

Adam Dezay:
Updated wiki to include last week's report as well as the home page for the Wiki. Received the enclosure files from mercedes and am looking to get started on printing it and making adjustments as we see fit to match any of our components using FreeCAD. Also got more of the manual/instructions complete to include any trouble we encountered.

Manuel Garcia:
Made several small changes to the original PCB schematic. Sourced and ordered components for PCB. Found footprints and designed KiCad model. Ordered PCB with express shipping. PCB should be in within the next week (Hopefully before friday). Finalized battery/ power management design and ordered those parts as well.

Brandon Hippe:
Figured out SmartMesh issues, fixed up main code and ran first tests. Starting to work on modifying last year's python scripts to fit our use case.

Mercedes Newton:
Drafted several concept designs for final project enclosure. Got the go ahead on one model with several different configurations depending on included sensors. Designed in FreeCAD, the first edition of our

enclosure to be made on the “HYDE” 3d printer in the EPL. Turned over to Manuel & Adam to get 3D printed this week. Adjusting and editing 3d models as changes are suggested and discrepancies found.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

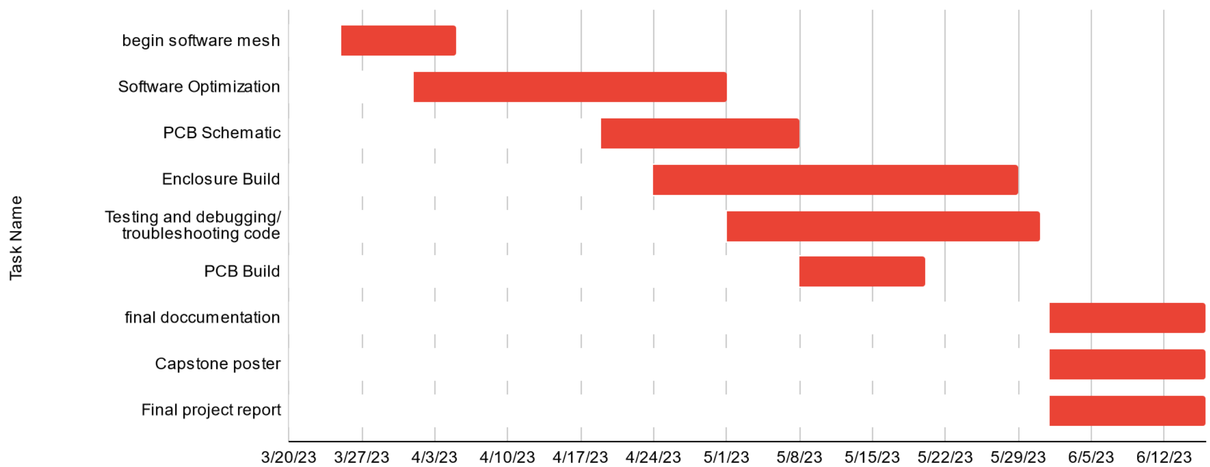

Figure One: Gantt chart for spring term (first task starts 3/25/2013)

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PCB Build	5/8/2023	5/20/2023
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Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

Team 1 Open Source Air Quality Monitoring
Week 19: May 15th - May 22
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Team 3d printed the enclosure in the epl and decided to utilize laser cutting as opposed to 3d printing in interest of selecting a more price efficient option
- Discussed starting on documentation soon as opposed to waiting until June 1st
- Discussed increasing number of batteries, based on initial power consumption testing, 1 will not be enough for 1 year battery life. Enclosure will have space for 4 18650 cells, so ultimately it's a matter of cost vs measurement rate. Measurement periods calculated using current power measurements are shown in table two.
- Discussed PCB revisions. New PCB order will be sent out this week, if necessary.

Individual Review

Adam Dezay:
Started on the final report rough draft as well as finishing up the BOM and manual. Updated Wiki

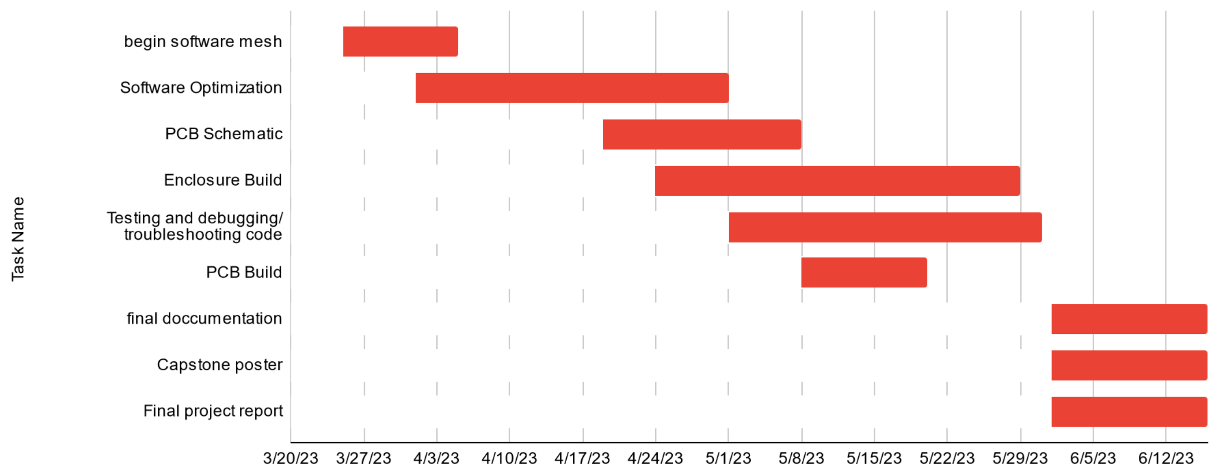
Manuel Garcia:
Built 2 different PCB configuration, one with high side mosfet and the other with low side mosfets. Having issues with power draw still in both configs, attempting to troubleshoot solution.

Brandon Hippe:
Started on power consumption testing. Figured out high idle current issue, for some reason setting one of the GPIOs to high on the MSP430 consumes ~10mA of current, even though the pin isn't connected to anything. Tried connecting a load (used 1.8 kΩ resistor) to see if that would bring the current back to expected levels, but that just added to the current used for setting the pin high. Upon further testing, it turns out setting pin 8 high draws ~10.2 mA of current and setting pin 32 high draws ~29.7 mA of current, but all other pins do not have any noticeable current draw, so those will be used instead. Also worked on laser cutting model, and did first test cuts.

Mercedes Newton:
Reviewed the first 3d printed model and discussed steps moving forward. Switching focus from enclosure to assembly and documentation.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.



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Final project report	6/1/2023	6/16/2023

Table One: Tasks for spring term with expected completion dates *completion dates subject to change*

	4 Cells, sensor	4 Cells, full	3 Cells, sensor	3 Cells, full	2 Cells, full

	sleep modes	sensor shutoff	sleep modes	sensor shutoff	sensor shutoff
PM2.5	90 min	87 min	160 min	140 min	325 min
CO2	33 min	26 min	74 min	40 min	95 min
Anemometer	No Data Yet	No Data Yet	No Data Yet	No Data Yet	No Data Yet
Battery life (W/O Anemometer)	366.37 days	365.68 days	367.61 days	365.33 days	365.19 days

Table Two: Sensor measurement periods and battery life estimates for 2-4 cells. Full sensor shutoff numbers are just estimates; haven't tested power consumption with shutoff transistors yet.

Team 1 Open Source Air Quality Monitoring
Week 20: May 22 - May 29
Sponsor: Dr. David Burnett
Advisor: Dr. John Acken
Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team began working on a rough draft of the final report as well as an academic report per Dr. Burnett's suggestion
- Team is writing a website to show our work then adding a QR code to our final poster that links to that. We hope to get it hosted by the university.
- Building the last 2 enclosures and soldering the last nodes
- Working on having 2 working final nodes to present on Thursday to Dr. Burnett

Individual Review

Adam Dezay:
Almost finished with the first draft of a website. Still need to figure out how to get it hosted on the university's website. Finishing up the draft of the final report. Updating Github.

Manuel Garcia:
Built 2 more PCBs, finished modifications of PCBs and made changes to existing ones. Order and built batter supply modules, and tested them with our ful built circuit. Prepared test setup for week 20 demo

Brandon Hippe:
Continued to work on ironing out hardware issues, graphing script, and power testing. Planning to work on demo builds this week and cleaning up GitHub.

Mercedes Newton:
Began documentation process and transferred team documentation to final report in LaTex. Soldered and modified PCB boards.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.

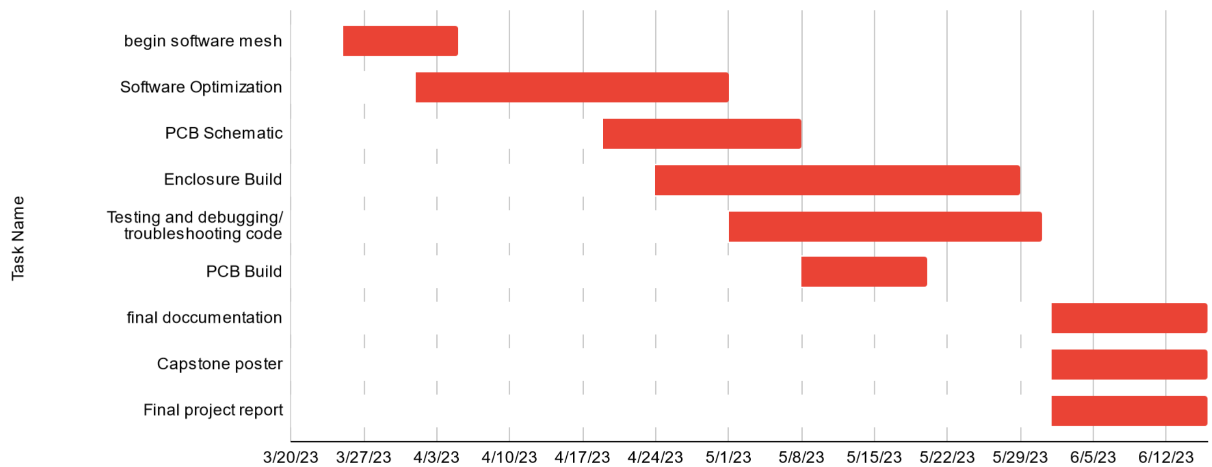

Figure One: Gantt chart for spring term (first task starts 3/25/2013)

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Capstone poster	6/1/2023	6/16/2023
Final project report	6/1/2023	6/16/2023

Team 1 Open Source Air Quality Monitoring

Week 21: May 29 - June 5

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay, Manuel Garcia, Brandon Hippe, Mercedes Newton

Team Review:

- Team continued working on a rough draft of the final report as well as an academic report per Dr. Burnett's suggestion
- Demonstrated 2 working nodes, received feedback on small additions to add
- Preparing to add low battery notice, update graphing script, and build 2 more nodes.
- Began working on the final poster

Individual Review

Adam Dezay:

Almost done with the final report draft (90%done), almost done with the website (75%), started on the final poster. Finishing up Wiki + github for clarity and to include latest information (95%), started on the academic report for Dr. Burnett(10%).

Manuel Garcia:

Troubleshot and repaired two PCBs, designed and started modifying the PCBs to have additional functionality (improve the charging circuitry and make the design more robust). Designed an integration for the low battery indicator to output to the msp430.

Brandon Hippe:

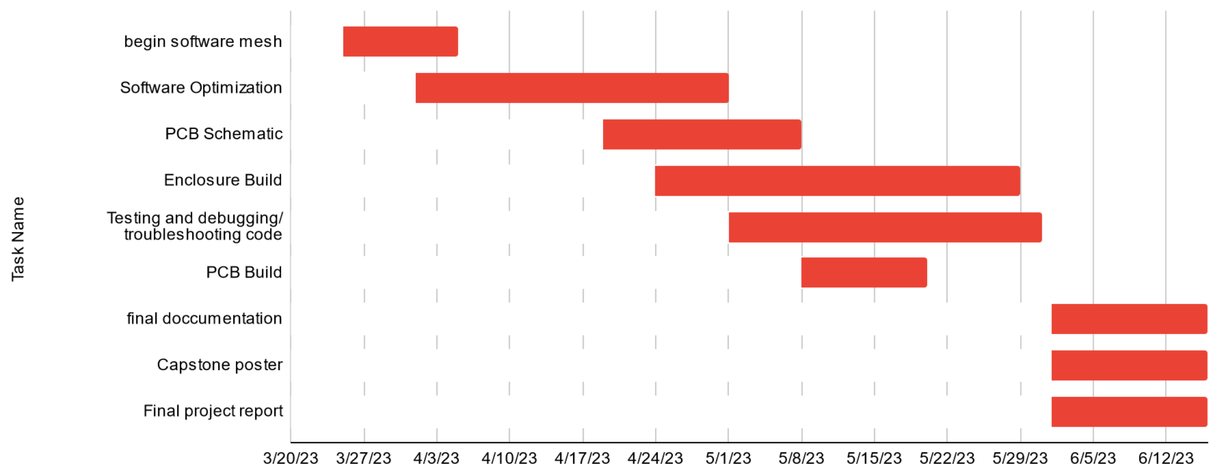
Worked to build 2 demo nodes, finalizing code and planning on working to build 2 more units to deploy. Finished power consumption testing and calculated sensor periods for all configurations for 3 month, 6 month, and 1 year battery life. Measurement periods were calculated so that each of the sensors in the configuration used approximately equal power on average. These results are available in tables 1, 2, and 3 below. Also calculated approximate log file size per node for each configuration and battery lifetime, shown in table 4.

Mercedes Newton:

Continued documentation efforts with Adam in regards to converting report to latex.

Gantt Chart and Timeline Updates:

Below is both the timeline of the projected project progress for spring term. Figure 1 represents the gantt chart for the term with expected completion dates beginning March 25th. All specific dates for the upcoming term are specified in the table below.



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Final project report	6/1/2023	6/16/2023

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO2	8 min (480 sec)	17 min (1020 sec)	37 min (2220 sec)
PM2.5	15 min (900 sec)	32 min (1920 sec)	72 min (4320 sec)

Table One: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units without anemometer

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO2	11 min (660 sec)	22 min (1320 sec)	51 min (3060 sec)
PM2.5	20 min (1200 sec)	43 min (2580 sec)	105 min (6300 sec)
Ultrasonic Anemometer	0.167 min (10 sec)	0.333 min (20 sec)	0.667 min (40 sec)

Table Two: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units with ultrasonic anemometer

Sensor	3 Months Battery Life	6 Months Battery Life	1 Year Battery Life
CO2	37 min (2220 sec)	83 min (4980 sec)	220 min (13200 sec)
PM2.5	43 min (2580 sec)	97 min (5820 sec)	260 min (15600 sec)
Hotwire Anemometer	15 min (900 sec)	33 min (1980 sec)	86 min (5160 sec)

Table Three: Component Measurement Periods for 3 month, 6 month, and 1 year battery life for units with hotwire anemometer

Configuration	3 Months Battery Life (Log file size after 3 months)	6 Months Battery Life (Log file size after 6 months)	1 Year Battery Life (Log file size after 1 year)
Without Anemometer	~820 KB	~810 KB	~700 KB
Ultrasonic Anemometer	~16.15 MB	~16.14 MB	~16.27 MB
Hotwire Anemometer	~370 KB	~334 KB	~258 KB

Table Four: Log file sizes after draining batteries for each configuration set to 3 month, 6 month, and 1 year battery life

Team 1 Open Source Air Quality Monitoring

Week 22: June 5 - June 12

Sponsor: Dr. David Burnett

Advisor: Dr. John Acken

Team Members: Adam Dezay , Manuel Garcia , Brandon Hippe , Mercedes Newton

Team Review:

- Team finished rough drafts of final report and poster
- Team built the 4th unit and conducted a successful test of all 4 units running over the weekend.
- Team finished graphing script, shown in figure two.
- Team ordered batteries to fill the sensor units with
- Questions:
  - How do we give over code and design files and documentation?
  - Where in the Lab should the sensors be put up?
  - What computer should Host Node and graphing script be run on?
  - How to host our website

Individual Review

Adam Dezay:

Completed report,website, poster, and github.Helped Mercedes with Latex report

Manuel Garcia:

Helped finish the assembly of the last nodes. Worked on cleaning up documentation for the end of our capstone project. Reviewed poster, and worked on writing the final report.

Brandon Hippe:

Worked to build the 4th sensor node, and ran test of all 4 nodes over the weekend. Two of the nodes stopped running, one due to a wire coming unplugged, and the other just needed to be reset. Worked to finish the graphing script. Got the ultrasonic airflow sensor detecting airflow from a fan, but found that it is unlikely it will be able to respond to the very low airflow from the vent(s) in the lab.

Mercedes Newton:

Completed LaTex conversion of final report. Reviewed poster. Submitted report to Andrew Greenberg .

Gantt Chart and Timeline Updates:

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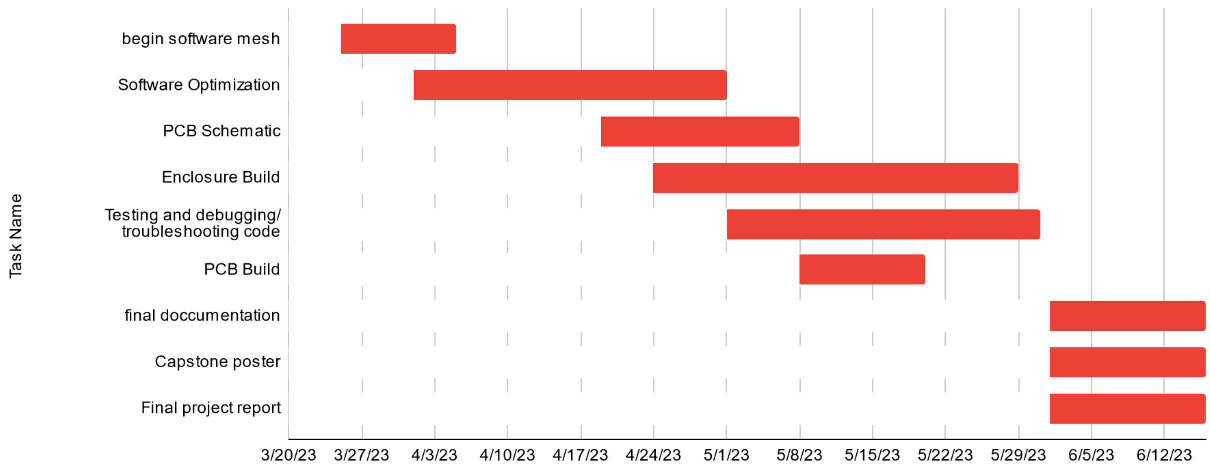

Figure One: Gantt chart for spring term (first task starts 3/25/2013)

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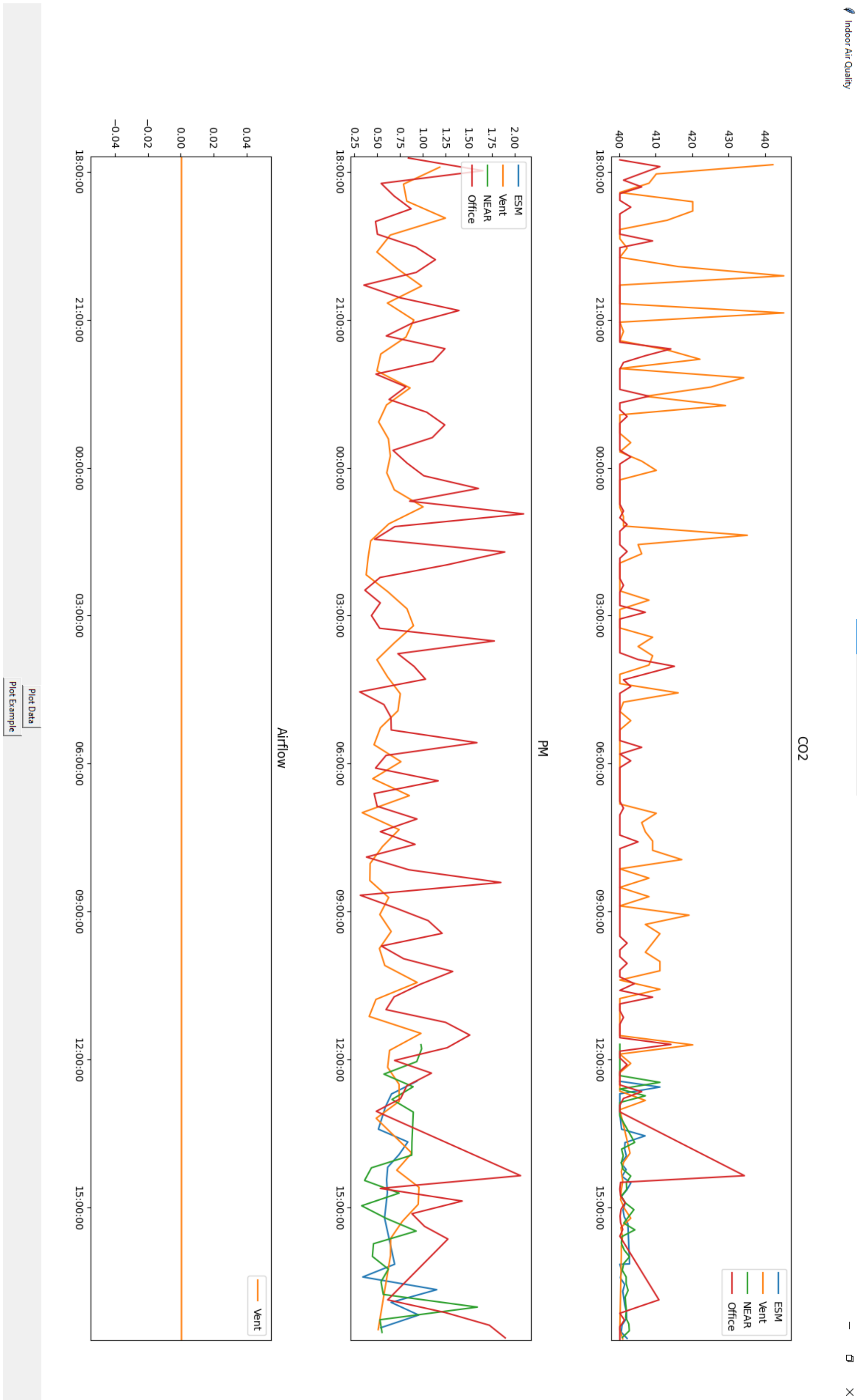

Figure Two: Graphing python script displaying data collected from 4 sensor nodes

References

[1] R. Leon, W. Bi, E. Eynis, T. Johnson, W. Yan, J. Acken, and D. C. Burnett. The networked nitrous node: A low-power field-deployable cots-based n2o gas sensor platform. *IEEE Sensors Letters*, 7(6):1–4, June 2023.

Authors

Adam A. Dezay is a recent BS Electrical Engineering graduate from Portland State University. Adam works for Analog Devices at the time of publishing

Manuel A. Garcia is a recent BS Electrical Engineering graduate from Portland State University. Manuel is pursuing his dream of becoming a stay at home father with great success so far.

Brandon P. Hippe is a recent BS Computer Engineering graduate from Portland State University. Brandon is seeking to complete his masters after graduation, and continue his research with the WEST Lab.

Mercedes C. Newton is a recent BS Electrical Engineering graduate with a Minor in mathematics from Portland State University. Mercedes has accepted a position as an Electrical Engineer at Jacobs engineering starting in July of 2023.

Acknowledgements

The authors would like to acknowledge their Industry Sponsor Dr. David C. Burnett and their Faculty Advisor Dr. John M. Acken for their commitment to both the project and our team's growth.

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