ECE 452
Capstone Design

Project 2

Argos Scientific

ELECTRICAL ENGINEERING COURSE AND PROJECT OVERVIEW

The table below provides an overview of the design course, which includes the course objectives, project scope and description, project % in the course grading, and project evaluation methods. The following are the specifications and constraints defined by the project sponsor.

Overview of Design Course

ECE 452 Capstone Design II	
Instructor	John Lynch
Course Objectives	Assign students a project that will enable them to integrate a majority of the skills they have acquired over the last four years in engineering, science, design, and communication.
Course project scope and description	Work in teams of two to four on an industry-sponsored project and will design and realize electrical and electronic system design, including digital, analog electronics, computers, signals and systems, communications, microelectronics, or processes to meet desired needs and realistic constraints.
Project Attributes (requested of the sponsor)	The capstone design experience requires students to integrate the majority of the skills and knowledge they have acquired in their undergraduate program of study, specifically in engineering science, design, and communications. To this end, in a typical senior design project, the students are engaged in: • Analyzing needs to produce a problem definition for the project • Carrying out the design process (such as concept generation, modeling, evaluation, iteration) to satisfy project requirements • Working within realistic constraints (such as economic, environmental, social, political, manufacturability, health and safety, ethical, and sustainability) in realizing systems • Building prototypes that meet design specifications • Producing a variety of documents, such as project proposal, progress, and final reports, in a professional manner and delivering well-organized oral presentations at the end
Project % on the total grading	100 %

Project Two	**Argos Air Quality Monitoring Device**
Project Description	Scope, design, and build a solar-powered PM 2.5 air quality sensor with remote data access.
Design Work	Design a custom PCB to collect sensor data, then send it via LTE. In addition, the system will need local signal outputs to devices that can present the data locally. This can be in the form of a digital output and/or a multi-colored LED. Additionally, the system will include the ability to be powered via a small-scale solar panel.
Constraints	None
Prototype Building	PCB build, fabrication, and test; component purchases
Project Deliverables	Develop a prototype with complete design documentation, including a schematic and a bill of materials. Test the prototype against a Federal Reference Method PM 2.5 sampler at an Oregon DEQ ambient air monitoring station.

Introduction and Background

The project involves creating a passive air monitoring system for the sponsor, Argos Scientific. The motivation stems from the need to monitor air quality, particularly in areas like the Parkrose School District, which is affected by pollution sources such as the Kmart fire, truck emissions, and a Prologis Warehouse. Environmental burdens often disproportionately affect minority and low-income communities, and Parkrose has a high minority enrollment and many economically disadvantaged students.

Scope and Objective

The goal for this project is to create a passive air monitoring device (the "B.O.N.G.O."), which was previously developed with off-the-shelf components and breadboards. Our job was to consolidate the functionality of this board onto a single PCB, which we would design and order. The B.O.N.G.O. (Figure 1) stands for Baseline Observer with Networked Glowing Outputs. The B.O.N.G.O. (Baseline Observer with Networked Glowing Outputs) aims to provide accessible air quality data. A key feature is the "glowing outputs," which consists of a strip of multi-color LEDs. These LEDs serve as an immediate visual indicator of current air quality conditions, with different colors or patterns corresponding to the overall air quality index (AQI) ranges, such as green for good, yellow for moderate, red for unhealthy. This allows for at-a-glance understanding by community members without needing to access the website data directly. It contains several types of sensors, including those that monitor temperature, humidity, and particulate matter. It was required to be low-cost and durable. Once deployed, data collected will be displayed on Argos website, which will allow for widespread, real-time tracking of pollution and potential identification of new polluters.

Constraints

The main areas of setback and complexity within the project were the low power requirements, the compatibility with several different sensors being used, the LTE Hat for data transfer, ensuring ease of development for the CS team, and the time for turnaround on printing. A primary goal was low power consumption, targeting operation below 5W to enable long-term deployment, potentially using solar power. The final prototype achieved consumption under 0.5W for core monitoring functions, although integrating the LTE hat presented a challenge due to its higher 15W peak requirement. The device needed to operate reliably in environmental conditions typical of the Parkrose area, including typical outdoor temperature ranges (0°F to 110 °F) as well as resistance to rain and humidity, as highlighted when one prototype was damaged by rain. While specific size dimensions were not initially mandated, a key objective was to consolidate the previous breadboard setup onto a single, compact PCB for improved durability and easier enclosure, resulting in a final board significantly smaller than the original. However, we had little to no documentation of the previous attempts to design this board, which led to mixed messaging as to our goals in the project. This lack of documentation made interpreting the original design intent difficult, particularly regarding areas like power management or sensor interface. All of these made developing the PCB more challenging and required additional time and design consideration.

Methods

We used several different tools to complete our project. These include When2Meet, Trello and SharePoint to organize the project. To design and develop the PCB, we used EasyEDA, which printed using JCLPCB's parts and methods. The code was written using MicroPython (ideal for Embedded Systems) and done so in Visual Studio Code. Much of the design process was done based on the requirements presented by the sponsor. When following that, the process was rather reliant on existing documentation and pre-existing implementations and designs to aid our iterations. We made our first iteration (Figure 2(a)), which had several issues, most of which required a reprint to fix. This was done in version 2 (Figure 2(b)). During this project, each of us learned the basics of PCB design, embedded systems programming, and measuring air quality through PPM, temperature, and humidity sensors.

Results and Discussion

Two prototypes were developed. Prototype 1 had programming issues due to design flaws, but it had a stable power converter. Prototype 1, while power-stable, suffered programming difficulties primarily due to incorrect pin mapping for the microcontroller, or signal interference between traces placed too closely, and much of the original design was done without regard to the proper specifications. Prototype 2 rectified these issues by reducing board layers from 6 to 2, which simplified routing, and by refining component placement based on a single ground plane and power plane. After these components were removed, all peripherals used the same voltage high (3.3 V), making routing and organization much easier and straightforward. Critical circuits, such as the UART channels and Temp and Humidity sensor lines, were redesigned following datasheet recommendations for improved stability. Despite these improvements, integrating the required sensors proved difficult because the pin pitches did not match the available breakout boards', necessitating custom adapter cables. Further challenges arose when implementing the CS team's code; specifically, the pins that were defined for one of the PPM sensors were not used on our microcontroller, so the library that defines our pins when coding didn't view them as UART pins. The LTE hat also consumed significant power (15W peak) and required specific mounting hardware holes on the PCB, complicating integration.

Prototype 2 was programmable, power-stable, and ran code from the previous board, though sensor connectors were challenging. Issues remained with implementing the CS team's code, particularly with shared UART channels, and the LTE hat's high-power consumption (15W) and pin requirements. Custom adapter cables were needed. Sensor data was logged to CSV, and LED output was based on averaged readings. The final working version primarily featured the particulate matter sensor, consuming less than 0.5W, and was significantly smaller and cheaper than its predecessor. We were able to run a 21-hour test (Figure 4) that collected data that matched with local AQI reports taken at the time. Full LTE implementation was pending but not expected to significantly increase costs. This could be done in a future revision of the board.

To validate the functionality of Prototype 2, a 21-hour continuous monitoring test was conducted. The device was set up on one of the members porches overnight and configured to log particulate matter (PM2.5) readings approximately every 13 minutes to a CSV file. The resulting data (Figure 4) shows fluctuations consistent with typical diurnal air quality patterns. When compared with publicly available AQI data from the nearest official monitoring station for the same period, our sensor readings showed a similar trend in peak concentrations during morning hours, while the actual values we collected were slightly lower at all recorded times. This validated the sensor's basic accuracy and the system's ability to capture meaningful environmental data.

Workload
Max – Primary PCB designer and debugger. Debugged and discovered flaws with various iterations. Helped implement and rework CS team's code onto custom board.
Mike – Literature Study, Safety Research, Documentation, testing electrical properties of prototypes
Noah – Handled communication within team, recorded meeting notes, submitted weekly reports, and designed final presentation slides

Budget and Cost
Original Prototype: $75.03
1st Iteration: $27.13 (63.8% cost savings)
2nd Iteration: $21.49 (71.4% cost savings)

Impact of Project and Solution
The project aims to assist the Parkrose community in identifying and reducing air pollutants like asbestos and VOCs. Making data publicly available promotes community involvement and awareness. Data security is prioritized to prevent interference. Scaled deployment could provide valuable air quality information to many communities, especially those affected by pollutants or wildfires.

Recommendations
Further improvements could be made by adding LTE for cellular data transmission, incorporating a display (LCD or 7-segment) for time, temperature, and humidity, and adding element shielding to protect the device from weather, as one prototype was damaged by rain. We will ensure proper documentation of our designs and process will be made and shared with the next group of students who take on this project.

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Appendix

Figure 1: B.O.N.G.O.

This image shows the overall device that is used to measure and collect data. The image shows the target device the team worked on to replicate and improve upon. The PCB, sensors, and LEDs are placed inside for protection and ease of display of information.

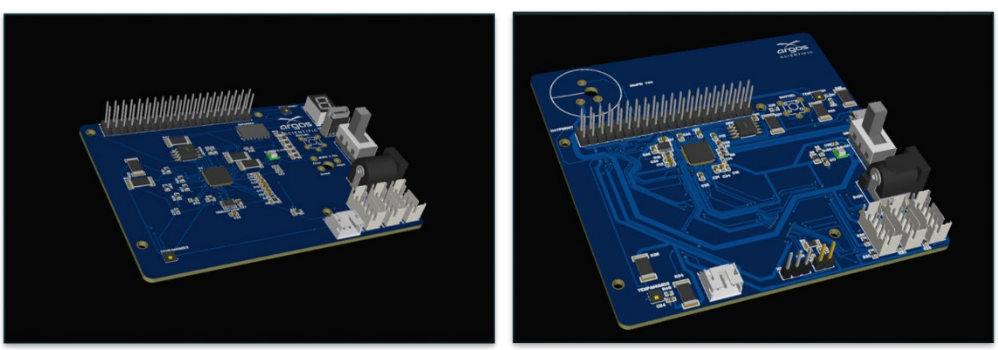

Figure 2(a) and 2(b): 3D Models of V1 (left) and V2 (right)

These 3D models generated in EasyEDA show the progression from V1 (left) to V2 (right). Note the reduced complexity, improved trace routing visible in V2, and different component layout aimed at resolving issues identified in V1.

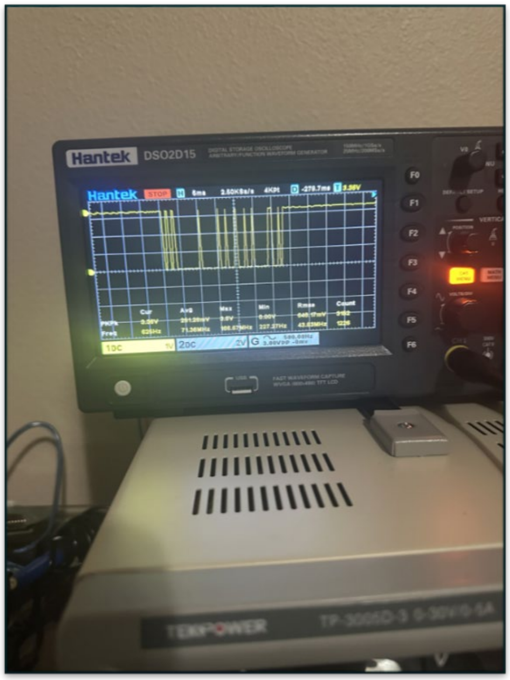

Figure 3: Debugging Setup

This is the primary setup used to debug the PCBs behavior. It is an oscilloscope that has probes that are able to be placed on the individual traces or pins of the PCB, which can be used to observe the signals from the microcontroller or the surrounding hardware. It came in very handy to diagnose issue with our first prototype.

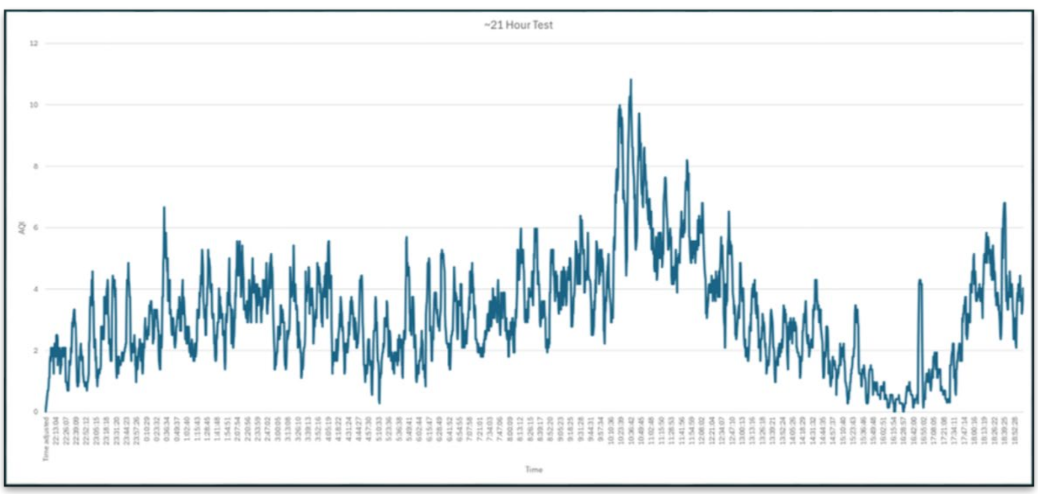

Figure 4: 21 Hour Test Data and Results

This graph displays PM2.5 readings logged by Prototype 2 over a 21-hour period. The fluctuations align with expected environmental changes and showed correlation with local DEQ station data for the same timeframe, validating the sensor's performance.