OpenSense v3 (Group 1)

UCF Senior Design 1 - Divide and Conquer

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2.1 - Motivation and Background:

In today's world, many popular sensor platforms are expensive, closed-source, and not easily customizable. While these systems are powerful, their lack of accessibility creates barriers for those who want to explore how these systems are built and applied in everyday life. This challenge is especially significant in K-12 education, where transparency and affordability are critical for sparking curiosity in technology. To address this, DRACO Labs (Design of Resilient Architectures for Computing) introduced OpenSense, an open-source, customizable, and low-cost sensor platform designed for scalability and educational use. Our project builds on their foundation by expanding the platform's capabilities and developing new features that improve usability and broaden the range of supported sensors.

As students, our team has experienced firsthand the challenges of learning about circuit design and embedded systems with limited, hard-to-access resources. With OpenSense, we want to make these learning materials and tools more approachable and widely available, especially for K-12 educators and students. Our goal is to create a platform that not only lowers technical barriers but also encourages exploration, creativity, and confidence in working with technology. A key part of this vision is enabling users to select their own sensors, making the platform highly customizable to different applications and learning goals. To showcase this flexibility, we chose to develop a custom optical spectrometer as a demonstration sensor. This allows us to highlight how complex measurements can be performed in an adaptable way, reinforcing OpenSense's commitment to accessibility and user-driven design.

Ultimately, our contribution continues the mission of DRACO labs, which is directed by Dr. Mike Borowczak within the University of Central Florida's Electrical and Computer Engineering Department. By improving usability and expanding functionality, we hope to carry forward and expand their vision of making open, educational sensor systems accessible to the next generation of innovators - making their ability to understand, experiment with, and design technology more approachable and engaging.

2.1.1 - Design Features and Functionality

Open Sense is thought to be an open-source sensor platform for a variety of uses, with the ability to customize sensors that you want to read data from, as well as a user-friendly Graphic User Interface (GUI) that will simplify the addition of new sensors. Users are looking for a simplified way to incorporate sensors of their own, without having to directly change the code of the platform. Furthermore, this prevents users from potentially corrupting the coding of the board. This was also something that was noted by Dr. Mike *(Project Sponsor / Mentor),* who felt needed to be improved on. We plan to meet these requests with our design by including the following functions and features in the platform:

1. **WebServer / User-Friendly GUI:** The platform will be able to display sensor data information through a wirelessly connected WebServer that hosts a User-Friendly GUI. The user will use this GUI to add their sensor, select voltages, turn on sensor ports, view

chart data from sensors, and have the ability to download data from a CSV file located in the SD of the board - all in a user-friendly, focused design that makes the platform more inviting for users new to technology.

2. **Long Period Data Collection:** The platform will store continuous amounts of data onto an on-board SD card - *.csv file format*. This allows the user to take in multiple points of data over an extended period of time to then access later. This data will be available to the user for download through the Web Server.

3. **Customizable Sensors:** The platform's versatility is an important part of the market requirements, so it is essential for our board. To increase the variety of sensors that can be used, the platform will take in parameters through the Web Server that will allow the user to implement their own sensor while avoiding the hassle of having to change the main code and reducing the possibility of breaking the code.

4. **Optical Spectrometer Integration:** To further showcase this degree of customizability, our team will design and construct a custom optical spectrometer to utilize with the platform as a demonstration sensor. Spectrometers are typically expensive and inaccessible to beginners, yet they are powerful tools for analyzing light. By including a spectrometer, we bring optics to students and educators and highlight how advanced measurements can be made transparent and customizable with the OpenSense platform.

5. **Sensor Voltage Switching:** Different sensors may require different voltages (3.3 V or 5.0 V) in order to operate and give back accurate readings. In order to increase customizability, this ability to access both voltages is necessary. Our team's version of the Open Sense will account for this by allowing the user to input which voltage they desire to use for their sensor, and the board will adjust the Vcc of the corresponding sensor port accordingly.

6. **I2C and Analog Compatibility:** Three of the ports will be outfitted with Analog to Digital Converters (ADC) in order to increase customizability. This will allow the user to not be limited to I2C and have the option to include sensors that are 3-pin analog sensors - i.e., Light Sensors, Humidity Sensors, Temperature Sensors, etc.

7. **System Life-Span:** The platform will be able to be used in both wired and wireless settings in terms of power supply, allowing for more versatility in educational applications.

2.1.2 - Current Commercial Technologies and Previous Versions

There are multiple companies, such as Vernier and Globisen, that offer products such as this one commercially. Vernier offers support for 10 different sensors and is considered to be very user-friendly and educational. This, however, comes with the trade-off of their product being very expensive, as one package can cost anywhere from around $300 - $1400 for a package with a sensor platform [1]. This makes obtaining one of these sensors less practical for lower-level education classrooms with less funding - this is where the need for the board to be low-cost comes into design specifications.

Globisen, on the other hand, is a lot more affordable than Vernier [2]. However, it is also a lot less flexible, as it doesn't allow you to swap out or modify the sensors. This greatly diminishes the versatility of the product and doesn't allow users to implement or add a sensor that is niche to their use. Open Sense, as a concept, tries to solve this problem and add more customization to the platform. Our plan is to make it easy for others to modify our project and set up a custom sensor which would allow for more flexibility and data collection depending on the user's needs.

Another example of limited accessibility in commercial technologies is spectroscopy. Companies such as Ocean Optics and Thorlabs sell compact spectrometers that are widely used in labs, but these devices are often expensive, ranging from several hundred to several thousand dollars depending on resolution and features [3]. Other low-cost options, such as Science Buddies DIY spectrometers use phone cameras or repurposed webcameras to make it more affordable and accessible, but lack the ability to be integrated with a broader sensor platform and are limited in resolution and robustness [4]. By incorporating a spectrometer into OpenSense, we adapt the concept into a transparent, customizable system designed for broader access.

Since the project's initial creation in 2014 - 2015, there have been two prior iterations of the OpenSense platform. This was done at UCF with Dr. Mike Borowczak's oversight. In 2015, the project was able to support 13 sensors, display values to a Google Chrome App, and cost about $60.32 for volume production. Their project was also battery-powered and included micro SD card storage. Obviously, this iteration was powerful, being able to support 13 different sensors, but it lacked the customizability for other sensors that were not pre-coded onto the MCU. In 2024, the project was improved upon by another UCF Senior Design group that managed to bring the cost down to $35 and chose to focus on supporting 3 simultaneous sensors in detail. Similar to the version before it, this project was only able to support sensors that were already coded into the MCU [5], [6].

The previous iterations of this project prioritized keeping the cost low over the customizability of the platform. Adding a new sensor would require changing the code, which can cause unintended issues and prevent the device from working as intended. This made the board more complex in terms of adding your own sensors and went against the goal of creating an accessible, user-friendly device for educational and project-based purposes. This necessity for changing the code to add a new sensor is key when it comes to the versatility and marketability of the platform. The goal of Open Sense, according to Dr. Mike, is for the platform to be as user-friendly as possible, encouraging those who do not have a significant background in Engineering or technology to be able to utilize the device with a sensor of their own choice. The platform's design is intended to be an educational tool for K-12 students and educators - hence the importance of the customizability and accessibility, all while maintaining a low cost for volume production. This is where our team hopes to improve upon previous iterations, focusing on the implementation of universal I2C and Analog sensor compatibility - allowing users to use a wider variety of sensors instead of pre-programmed sensors.

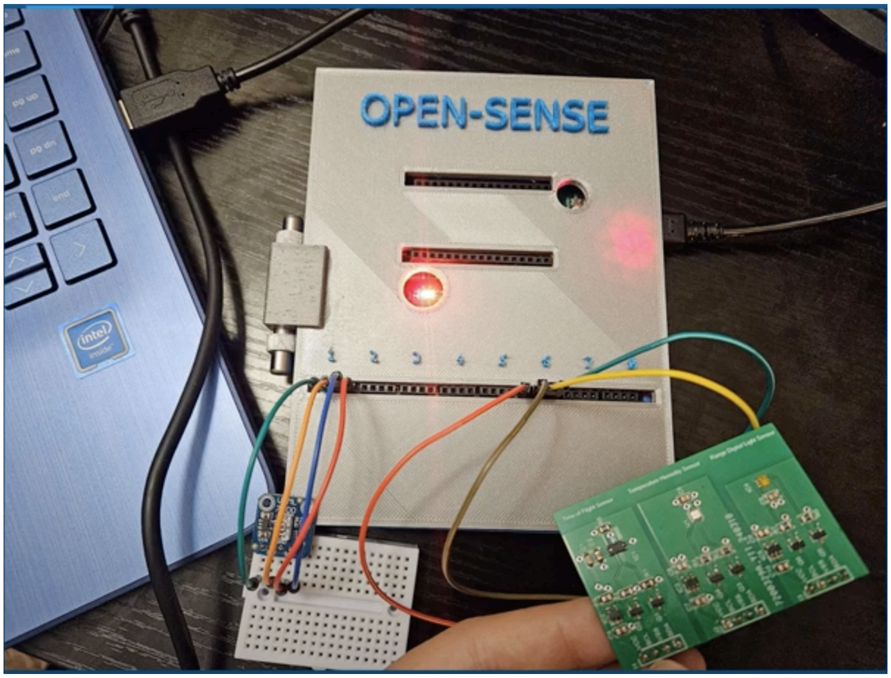


Figure 2.1: *Version 2 of the OpenSense Project*

2.2 - Objectives and Goals

The purpose of this project is to create a low-cost tunable method of collecting sensor inputs in a transparent and reliable manner. The platform is designed to prioritize customizability and user accessibility. The following section outlines the specific goals and objectives our team established for this purpose, split into three categories. Basic goals are the baseline necessities for the project, as detailed by D.R.A.C.O. lab, whereas advanced goals are more complicated but still doable under the scope of the project. Stretch goals would require increasing the scope and necessitate that the basic and advanced goals be completed before these are considered. Similarly, our basic objectives have been assigned the target values that we find realistic. The advanced objectives increase those target values by raising the expectations and introducing added complexity. Finally, the stretch objectives would challenge the team to push the boundaries of cost and usability.

2.2.1 - Goals

Basic Goals:

- Design a data logger capable of acquiring and recording outputs from multiple sensors simultaneously.
- Be able to store data from sensors onto an SD card, inside of a .csv file.
- Develop a user-configurable conversion interface to present the information in user-readable units.
- Maintain a minimum of 1 hour of onboard storage for collected data.
- Publish the system and associated documentation under an open-source license to enable community access, collaboration, and further development..
- Design a basic optical spectrometer module to establish proof-of-concept integration with the sensor platform, focusing on accessibility and educational use.

Advanced Goals:

- Integrate a power supply subsystem capable of sustaining continuous operation for a minimum of two hours.
- Utilize a microcontroller to control the data acquisition subsystem and distribute power to connected components as required.
- Create a housing that enables system portability by minimizing weight, reducing volume, and ensuring robustness during transport and deployment.
- Implement the system for straightforward setup to minimize deployment time and required user training.
- Develop a software framework that supports user-defined sensor models, increasing customization and expanding supported sensor options.
- Demonstrate the platform's flexibility by constructing an optical spectrometer capable of resolving distinct spectral peaks.
- Incorporate GUI support for visualizing data in real time, enabling intuitive interpretation for educational purposes
- Ensure a straightforward setup to achieve an easy overall user experience.

Stretch Goals:

- Enable wireless data transmission for automated upload to external devices or storage systems.
- Enable the USB port to power the system and also recharge batteries (*Lithium*).
- Incorporate modular sensor ports to support "plug-and-play" integration and replacement of multiple sensor types.
- Implement spectrometer data visualization tools into the GUI to make optics more approachable for students and educators.
- Develop a cross-platform interface for the visualization of data to ensure broad accessibility and usability.

2.2.2 - Objectives

Basic Objectives:

- Implement a data acquisition system capable of sampling each connected sensor at a minimum rate of 10 Hz.
- Support simultaneous communication between a central MCU and at least 5 sensors over I2C.
- Establish a baseline battery life that will guarantee a minimum of 2 hours of battery life.
- The system ensures that sensor readings achieve a minimum accuracy of 85% in relaying correct values.
- Ensure that the device is equipped with at least one hour of data storage, independent of the sensor type implemented.
- Implement a diffraction-grating-based spectrometer with a single detector to verify integration of custom sensors with the platform and produce basic spectra for educational demonstration.

Advanced Objectives:

- Establish a baseline battery life that will guarantee a minimum of 6 hours of battery life.
- Extend the data-acquisition system to include an intuitive interface that simplifies onboarding new sensors.
- Data collection will be able to store up to 4 continuous hours of data.
- The system ensures that sensor readings achieve a minimum accuracy of 90% in relaying correct values.

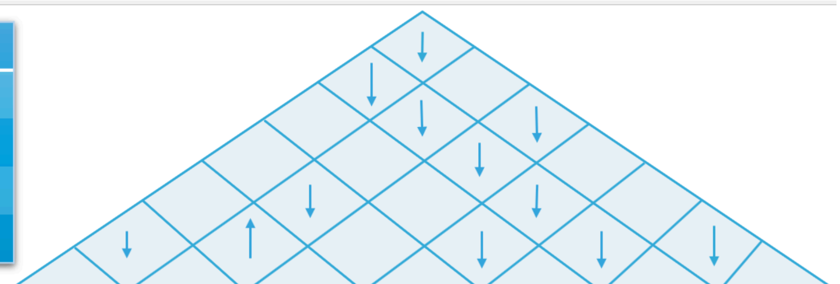
- We ensure that the device is equipped with at least two hours of data storage, independent of the sensor type implemented.
- Utilize an array sensor with an optical spectrometer setup to demonstrate the customizability of the sensor platform.
- Achieve a minimum wavelength coverage of 400-700 nm (visible spectrum) to ensure relevance for education and demonstration purposes

Stretch Objectives:

- Establish a baseline battery life that will guarantee a minimum of 24 hours of battery life.
- Data collection will be able to store up to 8 continuous hours of data.
- Incorporate a custom library that will allow users to input parameters of their own I2C sensor - effectively making the platform functional with any sensor that utilizes I2C communication Protocols.
- The system ensures that sensor readings achieve a minimum accuracy of 95% in relaying correct values.
- We ensure that the device is equipped with at least four hours of data storage, independent of the sensor type implemented.
- Extend the wavelength of the spectrometer subsystem into the near-UV or near-IR to broaden applications.

2.2.3 - House of Quality Diagram

Correlation	Symbol
Positive	↑
Very Positive	↑↑
Negative	↓
Very Negative	↓↓



	Engineering Requirements	Data Storage	Sampling Rate	Sensor Accuracy	Battery Life	Dimensions	Cost	Sensor Support
Marketing Requirements	Polarity	+	+	+	+	-	-	+
User friendly interface	+	↑	↑	↑	↑↑	↑	↓	↑↑
Customization	+	↓			↓	↓	↓	↑
Affordability	+	↓↓	↓↓	↓↓	↓↓	↓	↑↑	↓
Portability	+	↓		↓	↓↓	↑	↓↓	
Battery Life	+	↓↓	↓↓	↓↓	↑↑	↓	↓↓	↓
	Target Requirements	≥ 1 Hour	≥ 10 Hz	≥85%	≥ 2 Hours	≤ 200 cm^2	≤ $60 per Board	≥ 5 Sensors

Figure 2.2: *House of quality diagram*

2.3 - Specifications

Table 2.1 - System specifications table

System Specification Table		
Specifications	**Description**	**Target Values**
Unit Cost	The platform should have a low cost per unit for volume	< $60
System Lifespan	The device should be guaranteed to support data collection over a set period of time	≥ 2 hours
Sampling Rate	The platform should be able to record multiple points of data over time	At least 10 Hz per sensor
Data Storage	The device should have enough storage to gather significant data for analysis	≥ 1 hour storage
Sensor Accuracy	The sensor should collect data accurately	Accuracy ≥ 85%
PCB Dimensions	The PCB should be made to fit in a compact/portable housing	$\leq 200cm^2$
Sensor Support	The platform should be able to support 5 or more sensors	≥ 5 Senors
Spectrometer wavelength range	The spectrometer should be able to plot a spectrum consisting of at least the visible wavelength as well as some UV wavelengths.	300 - 800 nm

Table 2.2 - Component Specifications table

Component Specifications Table			
Component	**Parameter**	**Description**	**Target Values**
Battery	Discharge Time	The battery should be able to power *X* amount of sensors over the desired time period	≥ 2 Hours
MicroSD	Storage	Data should be able to be stored on a MicroSD card - done so that files are not too bulky, but also store the necessary sensor information.	≤ 1 Gb
MCU	Response Time	MCU should have a good response time in	< 1 second

Component Specifications Table			
		regards to user input from the Web Server, as well as incoming sensor data	
Sensors	Accuracy	Sensors will be able to gather data within a certain margin of error	±5 units of measure
LEDs	Status Accuracy	LEDs should be able to accurately display to the user the current status of the platform (active sensor ports, active voltage, heartbeat of the device)	95%
Power Mux	Vin Switch Accuracy	Power Mux is used to switch Vin from 5.0V and 3.3V - this needs to be done with accuracy to get proper readings from the sensors	95%
Mirrors	Focal length	The mirrors should have a focal length of 25 mm .	25 mm

2.4 System Block Diagrams

2.4.1 Hardware Block Diagram:

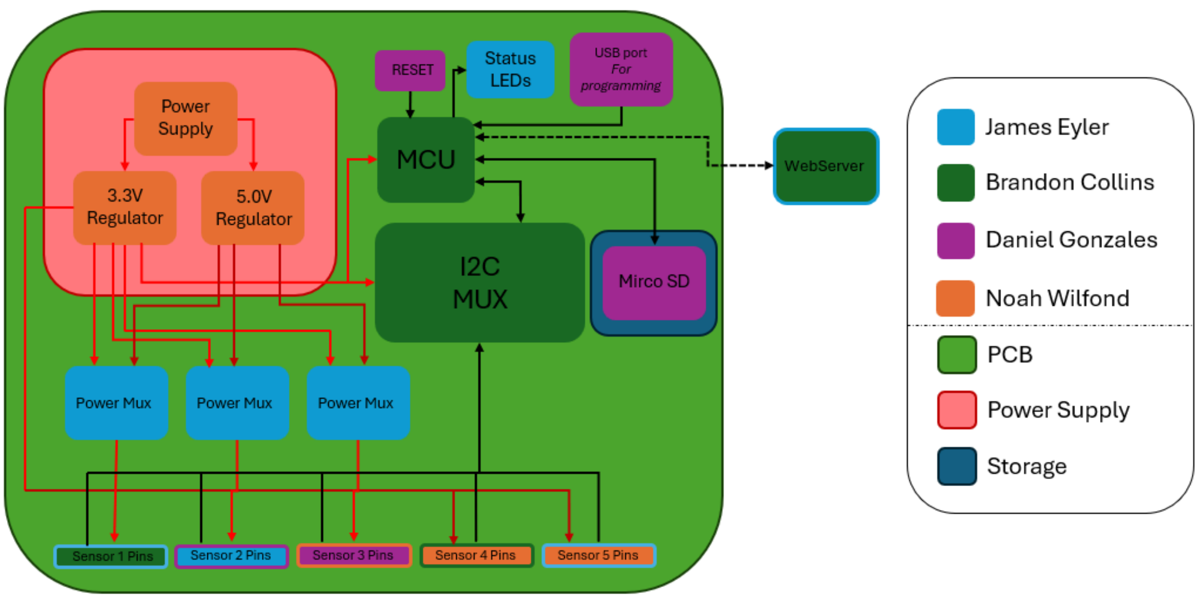


Figure 2.3: *Hardware Block Diagram*

Figure 2.3 illustrates the hardware block diagram for the system. At the center of the design is the MCU, which is the main component for data collection, processing, and communication. The power supply connects to two voltage regulators: a 3.3-volt regulator for the MCU and the lower voltage peripherals, and a 5-volt regulator for components requiring a higher operating voltage.

In addition, the MCU relies on a USB port for programming and debugging during development. A reset button and LED indicators are also connected to the MCU to provide user interaction and system feedback. Each sensor will have a green LED to act as a visual aid for sensor operational status.

Sensor integration is achieved through a combination of power multiplexers and an I²C multiplexer. Sensors 1–3 connect to the MCU through individual power multiplexers, allowing for selective power control and isolation of each sensor. Sensors 4 and 5 are connected via the I²C multiplexer, enabling efficient communication over a shared bus to avoid address conflicts. This arrangement allows the system to accommodate both analog and I²C sensor types while maintaining flexibility and scalability.

The MCU also controls communication with other peripherals in addition to the sensors. A microSD module is included for local data logging, enabling sensor values to be stored directly on the system. A USB Type-C port for programming and charging the on-unit battery. The MCU we chose offers wireless connectivity to act as an access point for the web server connection between the board and the client.

2.4.2 Software Block Diagram

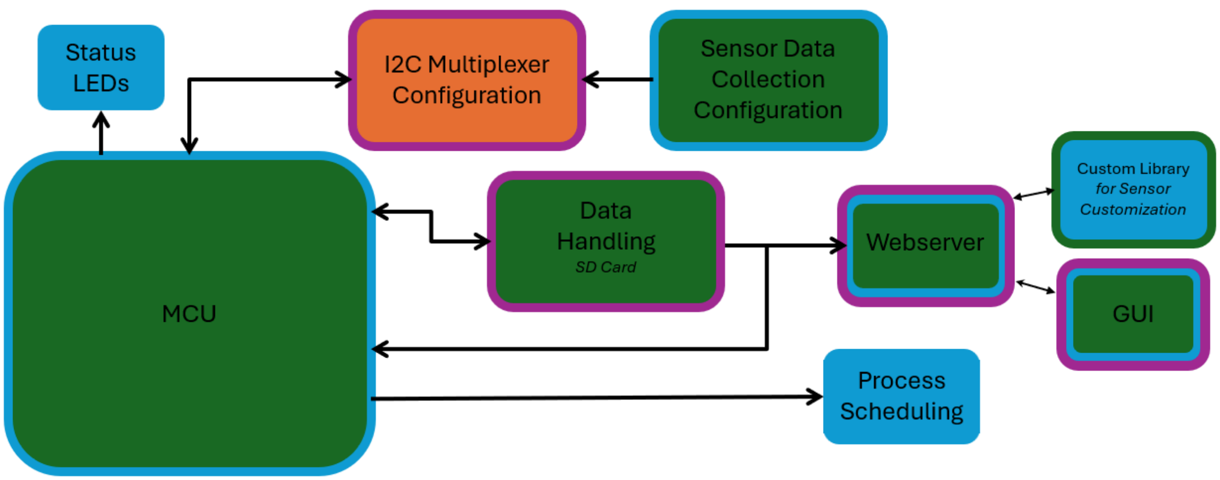


Figure 2.4: *Software block diagram - uses the same legend as hardware block*

Figure 2.4 portrays a proposed software block diagram that establishes a clear and efficient data flow between the system's sensors and the web server GUI. Sensor modules will collect raw values and transmit them to the MCU. The MCU will serve as an access point and forward the data to the data handler, which is responsible for organizing and transmitting the information to the custom web server. To improve system reliability and reduce complexity, the communication pathway uses a direct Wi-Fi connection between the MCU and the server, eliminating an outside factor like an intermediary router. Once the server receives the data, it is processed through a custom sensor library and integrated into the graphical user interface (GUI). The GUI enables users to configure sensor parameters and visualize sensor outputs in real time. This architecture prioritizes reliability, ease of integration, and user accessibility, aligning with our project's goals.

2.4.3 - GUI Design

Our GUI is designed with the main focus of user versatility and customization, built in a way that will allow users to do a lot more with their own sensors than in previous versions. Our GUI offers several important features for customizability, such as the ability to select their sensor's compatible voltage and, most importantly, the ability for the user to input their own sensor's parameters in order to add their sensor to the platform without the need to access the main code. *Figure 2.5* shows an early-stage diagram of what the GUI will look like and also highlights the functionality of the interface.

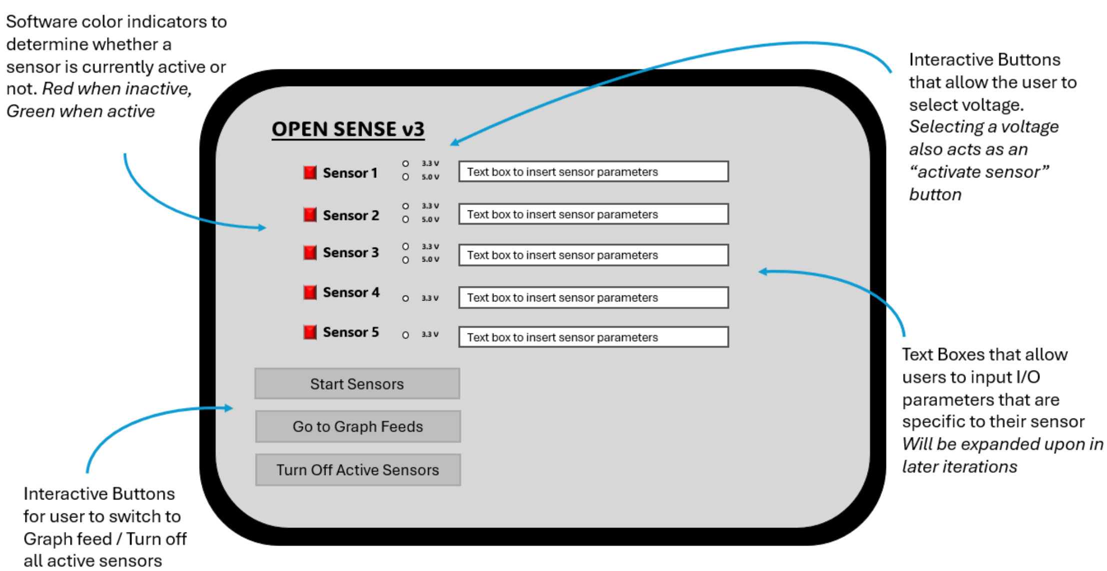


Figure 2.5: GUI Front Page Design

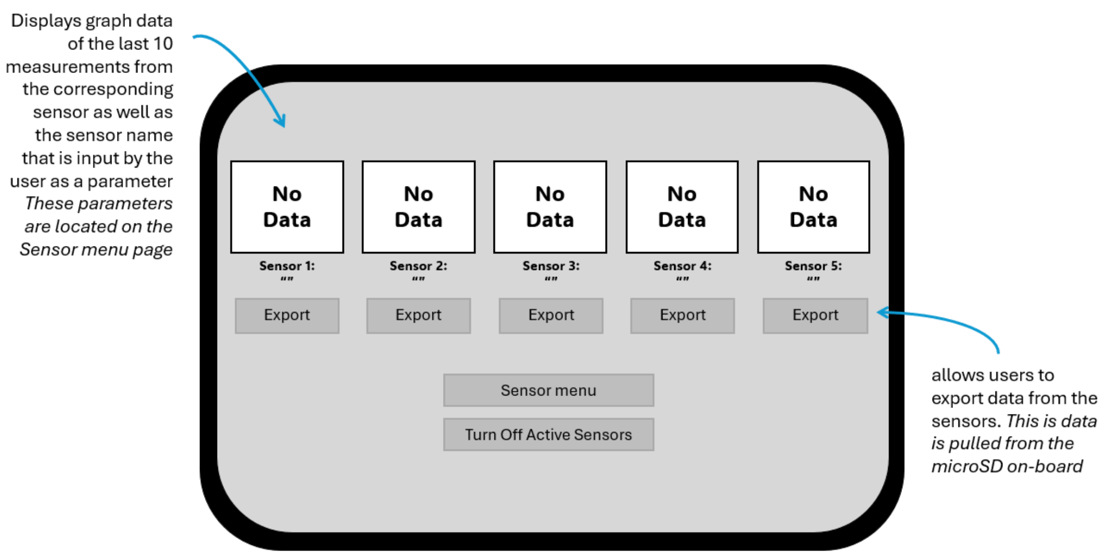


Figure 2.6: GUI Graph Page Design

2.4.4 - Prototype Illustration
Our Prototype illustration highlights the main features that our project offers. There are five available sensor ports, three of which vary in I²C and analog sensor support. In addition, there is a port for programming and charging the device, an On/Off switch, and a MicroSD card port. *Figure 2.7 and 2.8*: The 3D model below is an early rendition of what our finished product will look like.

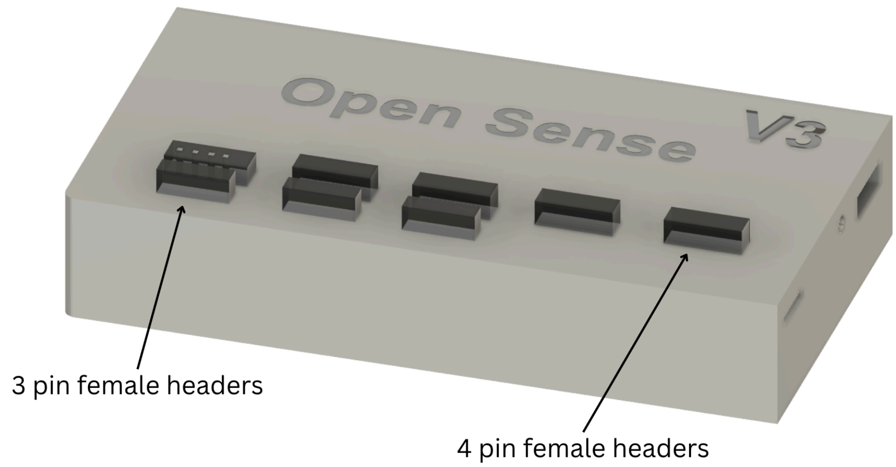


Figure 2.7: Front view of prototype

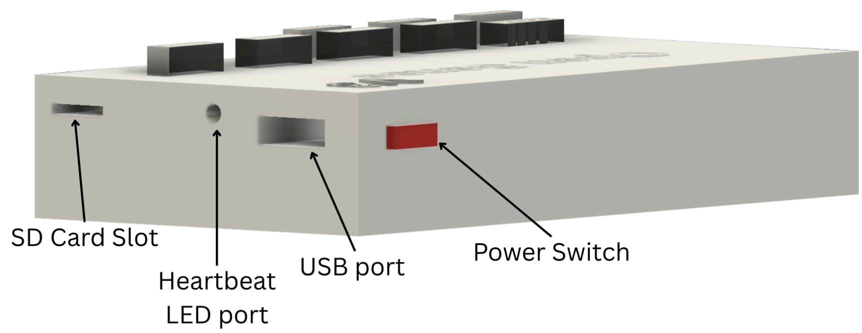


Figure 2.8: Back view of prototype

2.4.5 - Custom Optical Sensor Design
In addition to the other sensors that will be used to demonstrate the functionality of our platform, our group wanted to include a custom-built sensor to showcase the customisability that is central to our goals. For this, we have decided to incorporate our own custom sensor - a light sensor that uses a broadband irradiance spectrometer to measure the power across the sensor of the ambient light rather than using a regular power sensor for the light to include a. The design our team has chosen for this spectrometer is the Czerny–Turner spectrometer design due to its effectiveness over a large wavelength span with no chromatic aberrations [7]. This spectrometer uses two mirrors and a diffraction grating. Light entering the aperture is collimated by the first mirror, then dispersed into its wavelength components by the grating. The second mirror focuses these separated wavelengths onto the array detector, where our platform collects and processes the data. This is shown in *Figure 2.9*.

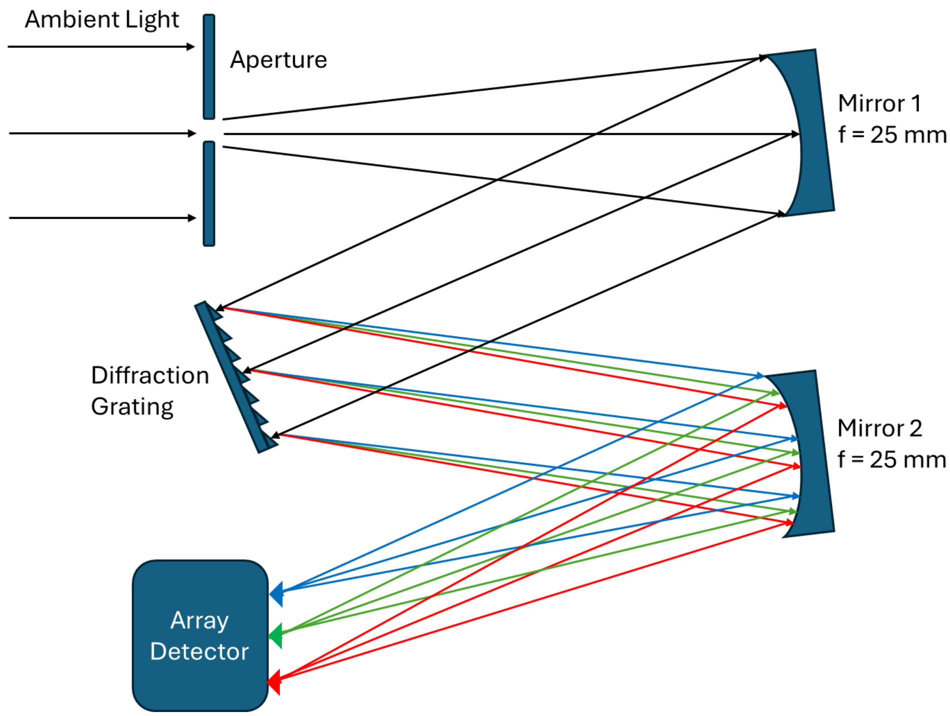


Figure 2.9: *Czerny-Turner spectrometer diagram.*

Chapter 10 - Administrative Content

10.1 - Budget

This project is sponsored and funded by D.R.A.C.O. Labs. To ensure responsible use of this support, one of our design goals is to keep the system low-cost; with that being said, the group has agreed upon a maximum budget of $600. This amount accounts for the total cost of our project, including prototyping, fabrication, testing, and revisions. The budget allows room for error, however, with careful planning and resource management, we are confident this target can be achieved. A $60 figure is the goal for cost per device in regards to volume production after creating a successful platform. This budget is inspired by our first bill of materials and past iterations of this same OpenSense project. As previously mentioned, one of the main intentions of the platform is to be low cost, so keeping this number by volume around the cost of previous versions, if not less, is an important design constraint to consider.

10.2 - Bill of Materials *(Tentative)*

Table 10.1- Bill of Materials

Component	**Part Number**	**Qty.**	**Unit Price**	**Total Price**	**Vendor**
MCU	ESP32-WROOM-32E	1	$10.00	$10.00	DigiKey
I2C MUX	TCA9548APWR	1	$1.41	$1.41	DigiKey

POWER MUX	TPS2117	3	$1.33	$3.99	DigiKey
ADC → I2C	ADS1115	1	$5.12	$5.12	DigiKey
MicroSD Slot	DM3AT-SF-PEJM5	1	$2.66	$2.66	DigiKey
USB-C port	12401610E4#2ACT-ND	1	$1.19	$1.19	DigiKey
RED LEDS	SML-D12U1WT86	3	$0.12	$0.36	DigiKey
YELLOW LEDS	LTST-C191KSKT	5	$0.15	$0.75	DigiKey
GREEN LEDS	LTST-C170GKT	5	$0.10	$0.50	DigiKey
Reset Button	PTS645SM43SMTR92	1	$0.32	$0.32	DigiKey
Micro SD card	2648-SC1629-ND	1	$8.93	$8.93	DigiKey
3.3V REG Chip	TPS63805	1	$2.71	$2.71	DigiKey
5.5 REG Chip	TPS63806	1	$1.16	$1.81	DigiKey
Concave Mirrors	CM254-025-P01	2	$70.88	$141.76	ThorLabs
Diffraction Grating	GR13-0305	1	$83.58	$83.58	ThorLabs
Array Sensor	2156-TSL1401-ND	1	$5.09	$5.09	DigiKey

10.3 - Project Milestones

Table 10.2 - Project Milestones

Project Initialization				
No.	**Milestone**	**Description**	**Start Date**	**Anticipated End Date**
1	Finalize Project Idea	Group meets in person and discusses project idea, routes of success, etc., and decides on project path	8/18/25	8/26/25
2	Meet with Mentor	Group meets in person with Dr. Mike Borowczak - *project mentor* - to discuss project path and inquire about additional goals he has set for the project	8/26/25	9/2/25
3	Divide and Conquer Report	Complete the first 10 pages of the final document (DNC Report)	8/26/25	9/5/25
4	Divide and Conquer	The group will meet with the Advisors to	9/8/25	9/8/25

	Meeting	discuss the project path through the DNC report		
5	Divide and Conquer Revision	Group takes feedback from Advisors and makes necessary adjustments to the project path	9/8/25	9/12/25
6	60-page draft	A 60-page draft is generated for the final paper	9/12/25	10/31/25
7	60-page draft revision	The group takes feedback and makes necessary adjustments.	10/31/25	11/7/25
8	120-page report & demo	Final Paper and Demonstration of the project idea and the project path	11/7/25	11/25/25

Project Fabrication				
No.	**Milestone**	**Description**	**Start Date**	**Anticipated End Date**
1	Major Component Selection	The group decides on what major components will be the best fit for the project path	1/5/26	TBD
2	Design Schematic	Group develops a design that will best work for the project path	TBD	TBD
3	Design the front end of the application	The group will begin working on the application that will send and receive the sensor values	TBD	TBD
4	Order Prototype	Group orders the designed PCB and test to see if it works as expected and what needs to be improved	TBD	TBD
5	Refine Design	The group will redesign the schematic based on how	TBD	TBD
6	Meet with advisor and sponsor	The group takes feedback from Advisors and makes necessary adjustments to the project path after showing them the prototype	TBD	TBD
7	Order the refined version and test	The group will take all the feedback and improvements to order the final PCB and test it, and make sure the application also works	TBD	TBD
8	Finish the paper	The group will finish writing about everything we have experienced with the project	TBD	TBD
9	Final paper and presentation	The group will submit the final paper and present our finished sensor to the review board	TBD	TBD

Appendices

Appendix A - Reference

[1] "Science Probeware & Experiment Software for Teachers.," Vernier. [Online]. Available: https://www.vernier.com/product-category/

[2] "GlobiSens – Next generation science data logging," GlobiSens. [Online]. Available: https://globisens.net/products/

[3] "Spectrometers," Ocean Optics. [Online]. Available: https://www.oceanoptics.com/spectrometers/

[4] "Making a Cell Phone Spectrophotometer | Science Project." [Online]. Available: https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p100/chemistry/make-a-cell-phone-spectrophotometer

[5] "Senior Design Group 21." [Online]. Available: https://www.ece.ucf.edu/seniordesign/fa2023sp2024/g21/index.html

[6] *erebus-labs/sense_platform*. (Aug. 21, 2025). C. Erebus Labs. [Online]. Available: https://github.com/erebus-labs/sense_platform

[7] "Spectrometer Configurations: Littrow, Czerny-Turner and More," Ossila. [Online]. Available: https://www.ossila.com/pages/spectrometer-optics