ELECOMP CAPSTONE
SUMMIT
TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

SAInt™ Dashboard

Security **A**rticles of **I**nterest for Awareness, Outreach, and Actionable Intelligence

AEROCYONICS

Team Members: Bella Johnson (CPE), James McDermott (CPE)

Technical Directors: Daniel DiMase ('89), Bronn Pav | Consulting Technical Director: Jamie Gagnon (ELECOMP '22)

Project Motivation

The objective of this project is to create a SAInt™ Dashboard for Aerocyonics, Inc. that will provide the customer with a taxonomy of threats according to their industry. This project motivation comes from the scarcity of the product. Some companies do have tools similar to the SAInt™ tool in that they organize threats and provide solutions. Aerocyonics objective of this project is to provide affordable options to companies that might not fully understand the need or value of tools like this. The SAInt™ Dashboard will be an economical option for companies to keep up on cyber-news, and it will change the way so many companies understand the magnitude and importance of cybersecurity.

Key Accomplishments

Aerocyonics Inc. wants to create a software for their subscribers of the weekly Articles of Interest that will offer a more organized search through threats and solutions that specifically pertain to the user. The tool will be an online UI that is user friendly and searchable. The SAInt™ tool is written in Python and the block diagram is displayed on the right. The information below further explains each part of the tool.

Read PDF: Aerocyonics, Inc. currently provides a service called the Weekly Security Articles of Interest. The subscribers of this service get a new PDF document every week filled with links to the most current cybersecurity news. The SAInt™ tool reads this PDF document every week.

Text Sanitation: Once the tool reads the Article of Interest PDF, the SAInt™ tool then uses a algorithm to detect URLs and strips all other text from it. It stores these URLs in a list to be passed to other scripts.

URLs: The SAInt™ tool grabs each URL from the PDF and stores them all in a single list to be utilized for the following functions.

Extract Text: The SAInt tool analyzes the text of an article to determine where in the taxonomy it belongs. To get the text of an article, the SAInt™ tool uses a Python package for parsing HTML documents, Beautiful Soup.

Frequency Analysis: The taxonomy of the SAInt™ tool is comprised of top tier categories and subcategories. The team utilized AI tools to create a complex list of keywords for each category and subcategory to be able to perform frequency analysis on an article. The count of occurrences of keywords for each category determines the correct category for a given article. The results of frequency analysis are displayed on the right. The subcategories of a given article are determined once the top tier categories have been declared.

NLP: To create a Natural Language Processing (NLP) program for the SAInt™ tool, the team utilized an NLP library that specializes in dealing with large texts. This NLP library provides an accurate percent similarity between two articles. The NLP library also allows for text to be processed, which removes any punctuation, pronouns or stop words from the article's text. The downside of using the library is the long runtime due to the amount of articles in the SAInt™ database.

Excel: Every week, the Aerocyonics Security Articles of Interest includes hundreds of articles about the current cybersecurity news. The SAInt™ database of articles can be displayed in excel documents, which allows programmers to understand and visualize the data and function of the SAInt™ tool.

Mitigations: To get the mitigations for a given threat, the SAInt™ tool first needed to declare the specific threat of a given article.The articles can be categorized by these threats. Then, we used a webscaper to get all the mitigations for each cyber security threat from security databases. Once each mitigation was gathered, we could match them up with their corresponding threats. Since the articles are already categorized by threats, now we can provide a list of all the threats the article covers along with providing mitigations for each of the threats. This is an automated process, so all the new articles that are included in the weekly articles of interest will have the threat type detected and mitigations for the threat provided to the users.

Web User Interface: After studying many web development methods, the team decided to save on time and use an open source template from Github. The team was able to run the web UI locally and display the results of the SAInt™ tool by editing the HTML files of the template. Most of the data of the tool is displayed in a table where each row includes the release date, categories, industry, mitigations and URL of a given article.

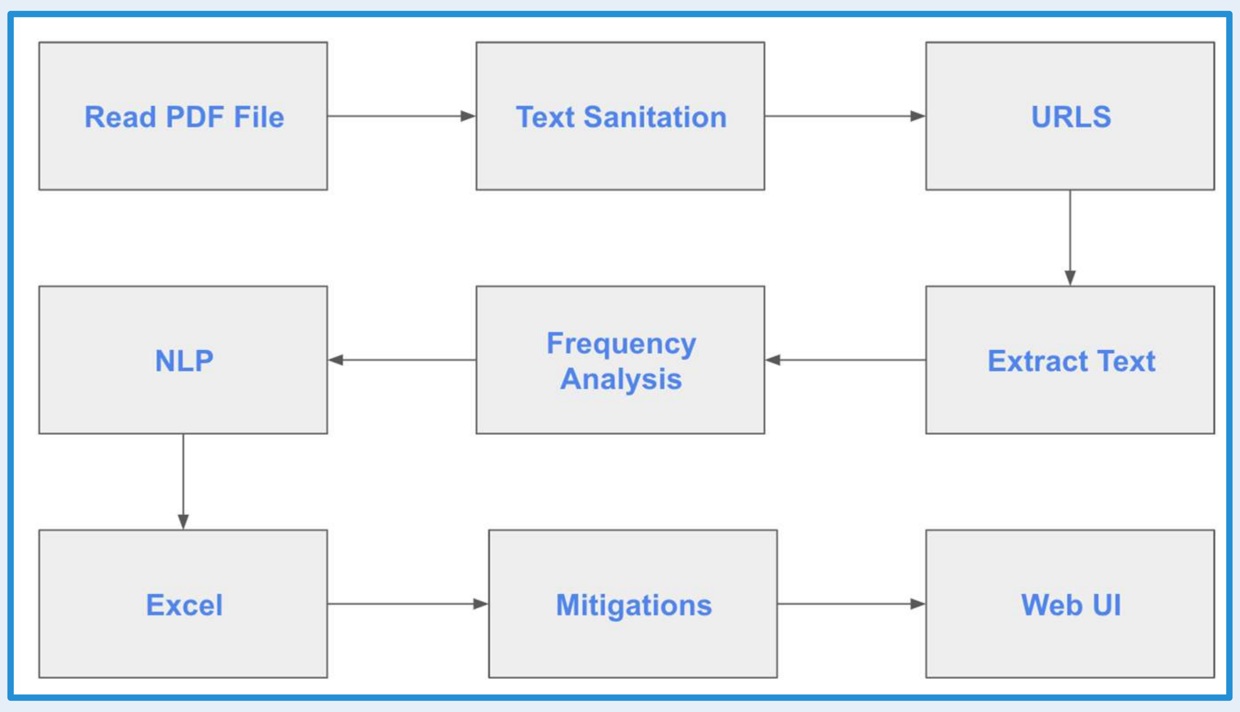
Anticipated Best Outcome

The best anticipated outcome of the project is to create the SAInt™ Dashboard software that scrapes source articles and provides up-to-date information and actionable mitigations to the user. The software should perform frequency analysis of the threat articles using machine learning to create the taxonomy, and also be able to scrape several databases for actionable intelligence for these threats. The SAInt™ TRL(Technology Readiness Level) started at 2, and our ABO specified the success of this project would achieve a TRL of 5-6.

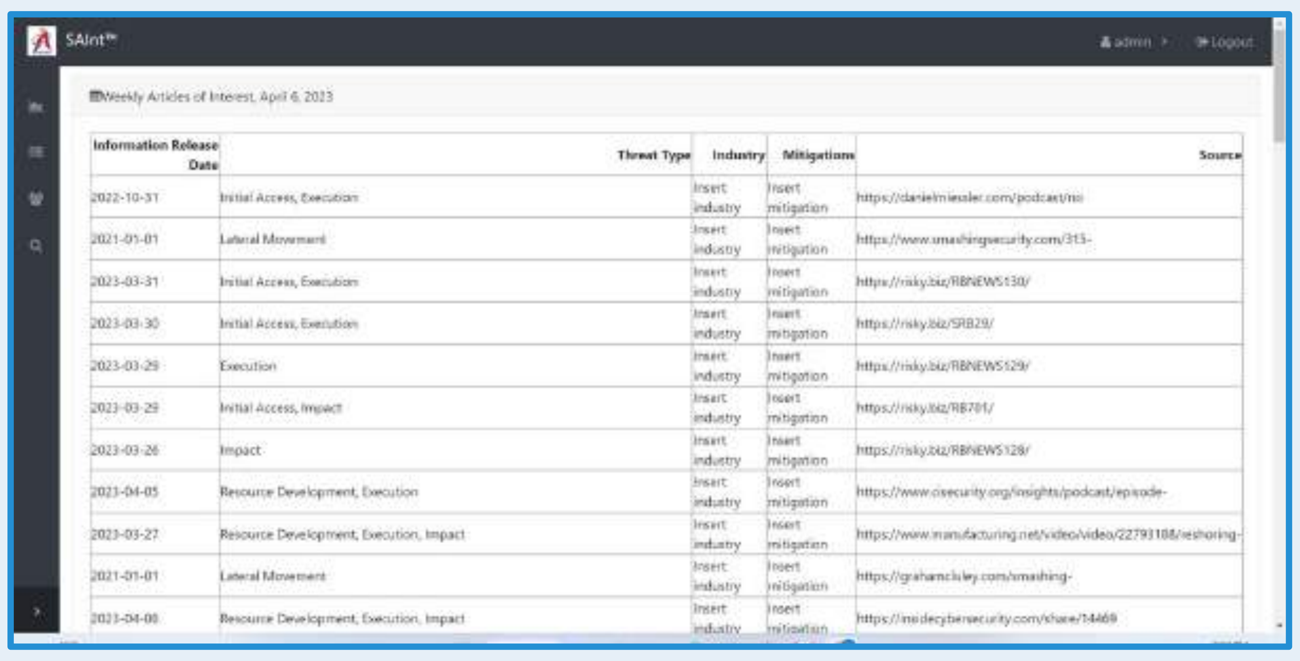
Project Outcome

The ABO was successfully achieved by the team. The SAInt™ tool organizes articles of interest into a complex taxonomy with actionable mitigations, displayed on an online user interface. By the end of the project, the SAInt™ technology was at a TRL 6, which was the goal of Aerocyonics for this project.

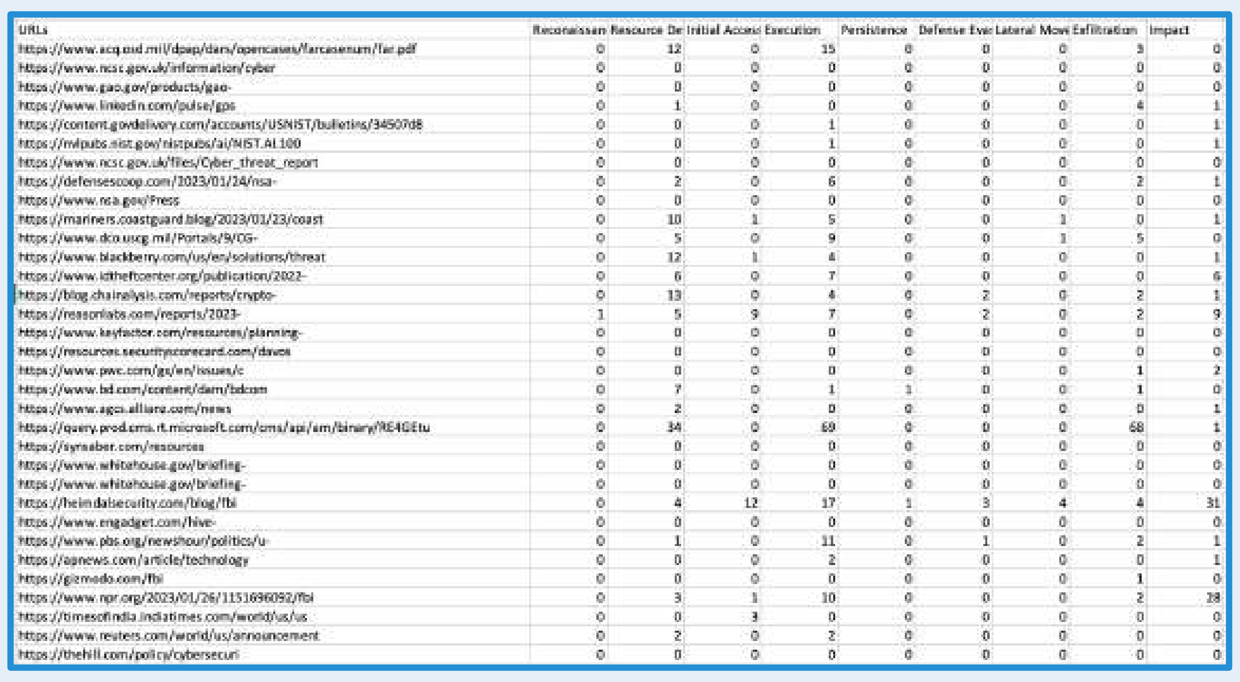
Figures



SAInt™ Block Diagram



Web User Interface



Results of Frequency Analysis in Excel

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MES-OP

Test Operation Integration with Machine Execution System Software

CAMBRIDGE TECHNOLOGY
A Novanta Company

Team Members: Ryan Bradley (ELE), Alec Goldberg (CPE)

Technical Directors: Jonathan O'Hare, Shaan Mitra

Project Motivation

High performance galvanometers involve complex assemblies having numerous operations, many of which are manually implemented with detailed procedures in order to obtain a quality product meeting all specifications. As the latest products push the limits of performance and become more advanced in their design, so too must their manufacturing methods.

Integral to the advancement of manufacturing is the collection of better data. Better data about the manufacturing process means having better ways to measure or observe the product at each successive operation. This includes observing both quality and performance metrics while at the same time making that data traceable to the final product. Implementation involves hardware in the form of digital test and measurement instrumentation, software interfaces for that instrumentation and MES software to tie it all together into a controlled and monitored process.

In this project the emphasis will be on implementing test instruments into their respective operations and integrating that data within an electronic traveler using an MES system under evaluation. One of the instruments is a new laser measuring instrument to characterize thermal bending effects of a subassembly. The goal is to be able to make the instrument operator friendly including a UI and work instructions in the MES interface, as well as having the measured data uploaded to the electronic traveler. This will serve as a proof-of-concept for a new manufacturing line being developed for a new product.

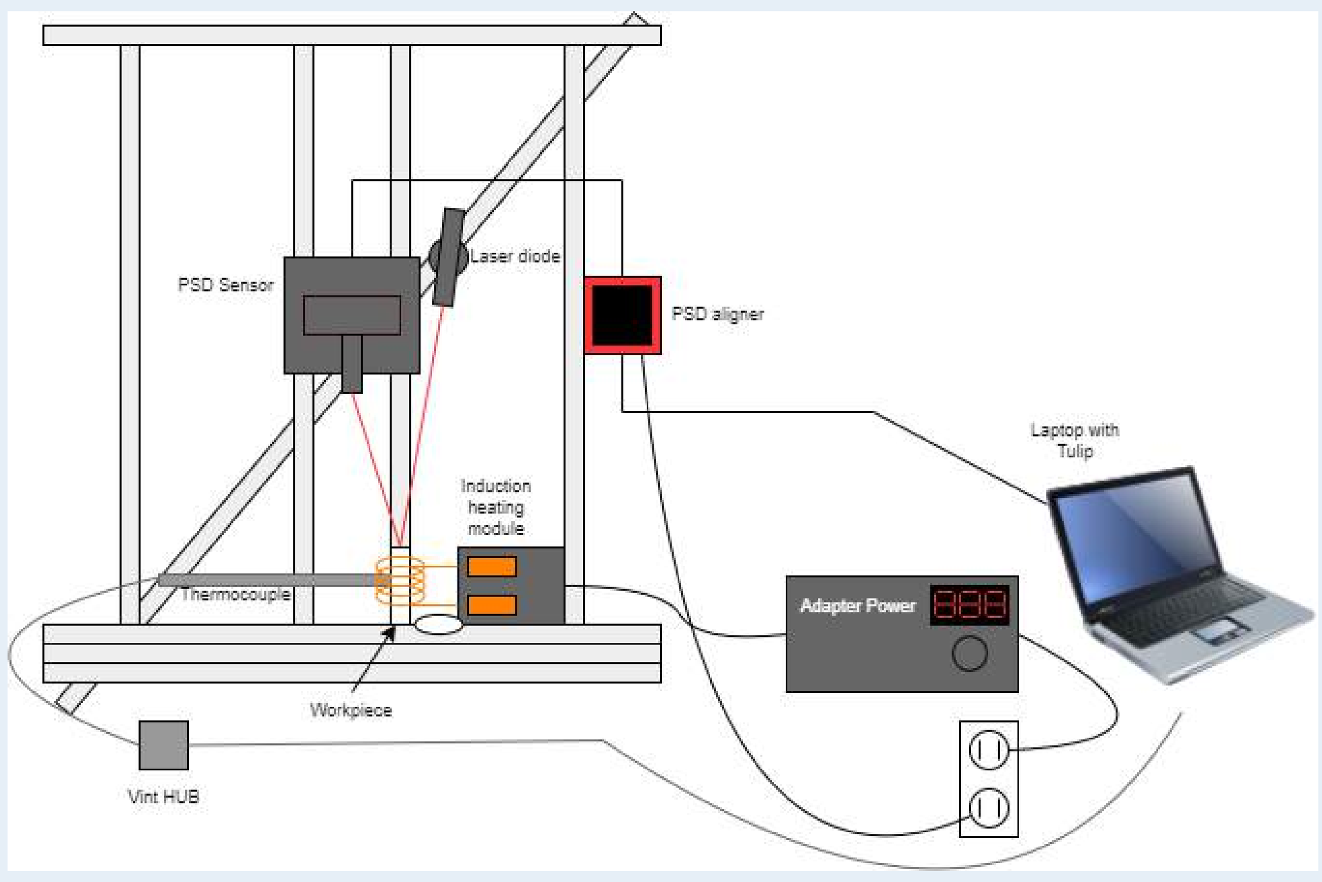
Key Accomplishments

Software:

- Constructed new frame for our testing structure (01/24/23) (20)
  - Stable and vibration free structure
  - X and Y slider for workpiece
  - Adjustable stage for PSD sensor
  - Mount for Induction heater
- Configured and installed Induction heater (01/30/23) (18)
- Configured optimized SQL database connections (02/04/23) (16)
- Programmed a serial number authentication system (02/11/23) (21)
- Function to generate live graph analytics (02/16/23) (22)
  - Saves as a PDF and stored for later analyzation (3/21/22)
  - Highlights big changes with auto zoom feature (3/24/22)
- Improvements to code structure (02/24/23) (22)
- Optimized the code for faster runtime and higher efficiency (2/30/22) (22)
- Function with algorithm to calculate the necessary values to determine the change in position (3/14/22) (19)
- Send testing data to User Interface for Operator to determine if workpiece is faulty (4/1/22)
- Full Process Integration and Completion (4/14/22) (20)

Hardware:

- Completed original testing structure (01/24/23)
- Worked on structure with modification
  - Similar materials used from original structure (01/27/23)
- Material to fix position for the induction heater (02/07/23)
- Integrate inductor to the induction heater
  - Tested for specific specifications
    - Tested voltage (30 mV) (02/27/23)
  - Research to prevent overheating during induction heating
    - Adjust voltage with specific time width to activate the heater (02/17/23)
  - Adjust position involving the laser diode and the workpiece
    - Not unique, but the extruder along with a clamp will stay loosen in case of error (02/14/23 - 02/17/23)
- Adjust voltage from power adapter to induction heater and measure time width from room temperature to 80 ºC (02/24/23)
- Attempted integration with the timer delay module (04/18/23)
- Replace cardboard with a thermal insulator (03/28/23)



Model of Testing Structure

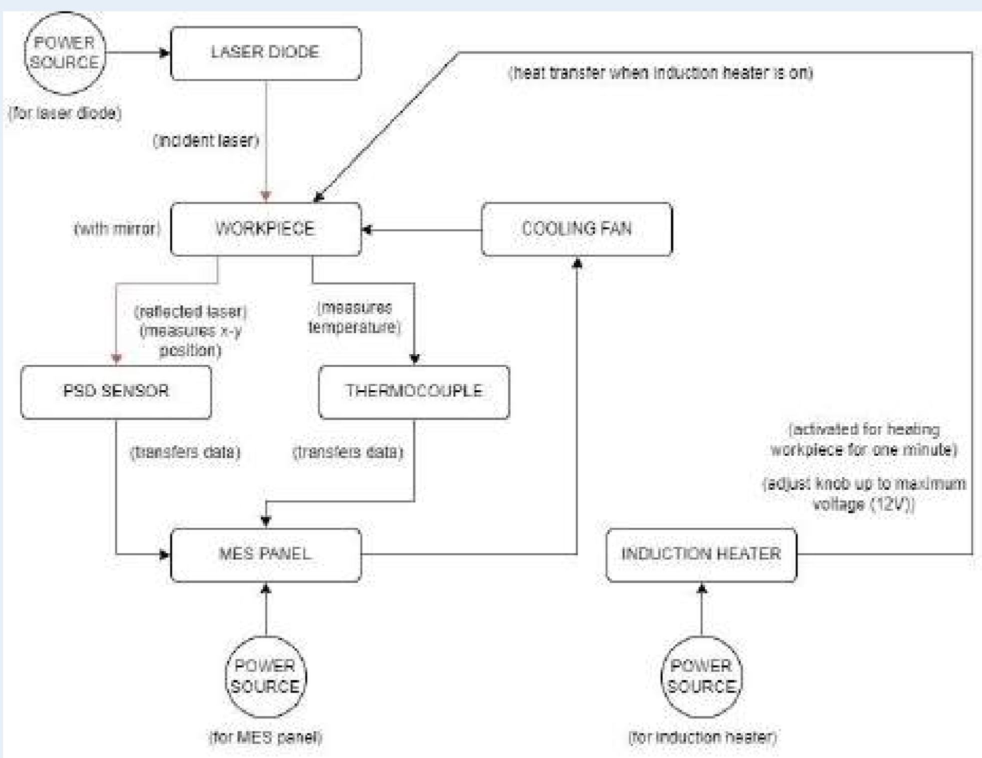
Anticipated Best Outcome

At least two manufacturing operations implemented having the test measurement device described and its associated assembly operation integrated into MES system so that the data is automatically uploaded into an electronic traveler. The best outcome would be to have the measurement devices robust enough for use in a Production environment having their HMIs (human machine interfaces) accessible through the MES UI environment. This will be supported with work instructions and contextual help so that it could be operated with minimal user training.

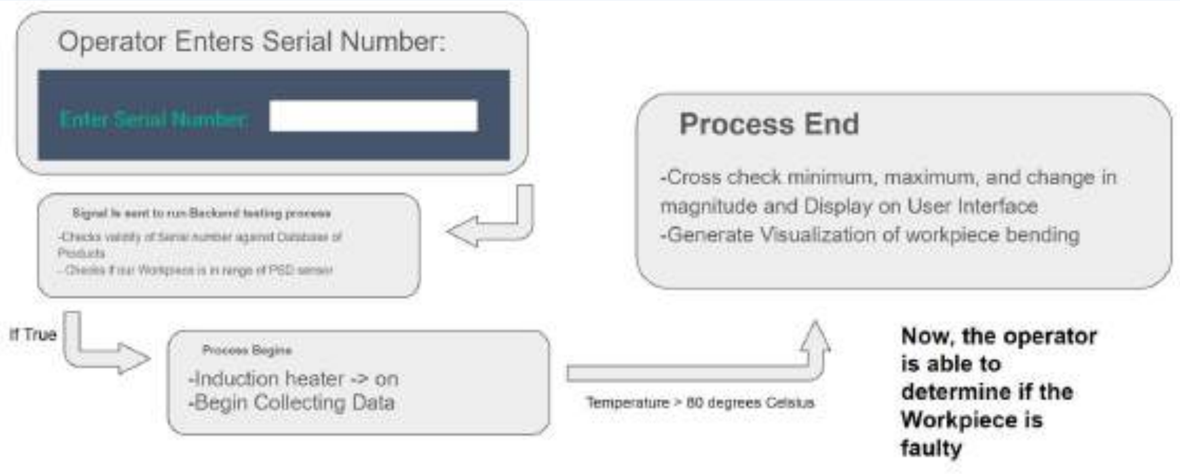
Project Outcome

The anticipated best outcome was not achieved, and it requires extra work to allow the testing structure to improve its efficiency. This includes integration of automation for controlling the heating process and adding codes to advance specific data on the display.

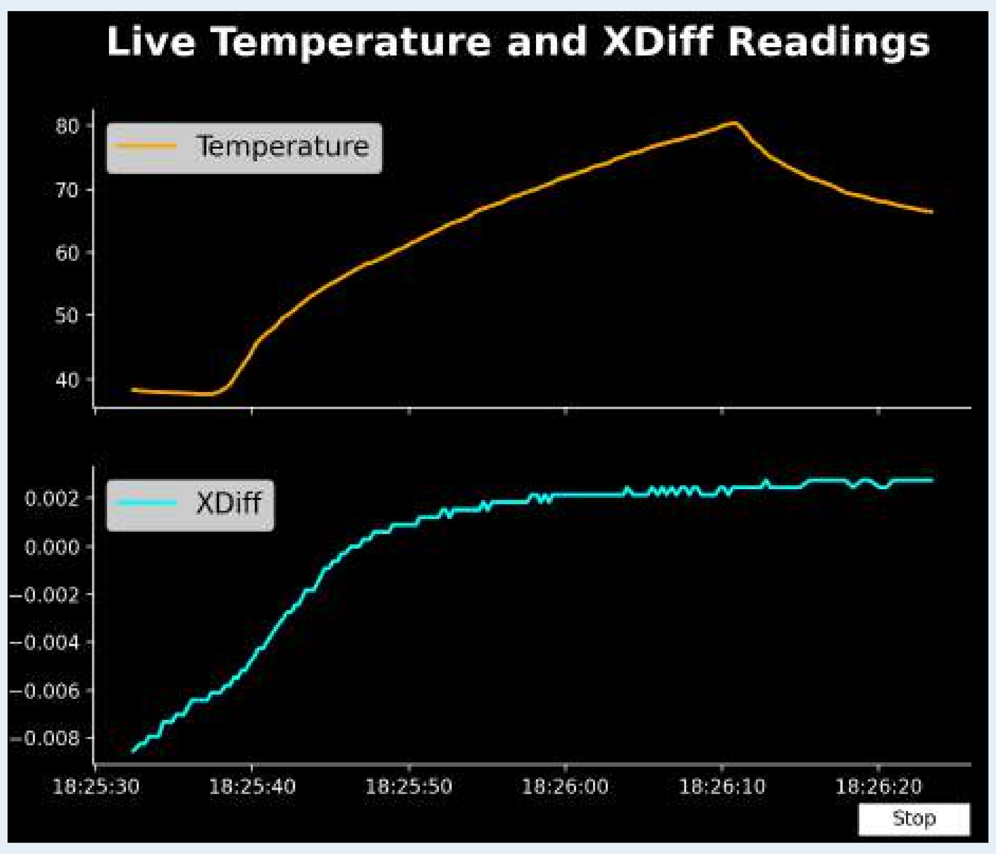
Figures



Flowchart of the Testing Structure



Full Software Overview



Final Results

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Battery Oracle

Battery Machine Learning System (BMLS)

EAGLEPICHER TECHNOLOGIES

Team Members: Cameron Amaral (CPE), Paul Perry (CPE), Santhosh Rajendran (ELE)

Technical Directors: Frank Puglia, Christopher Charron

Project Motivation

Under water, over land, in the air, and out in space; EaglePicher batteries are providing power to the most extreme applications ever conceived. Our batteries are commonly required to deliver high power and energy while exposed to dynamic conditions and over a long service life. While advancements in battery performance develop at a rapid rate, improvements in battery management systems have consistently lagged behind. Leveraging the success of AMBATS-part deux, this project seeks to illuminate the fundamental indicators of optimal battery management through the application of Machine Learning algorithms. The Battery Oracle will lead to advancements in BMS designs, improving the safety and longevity of future batteries. The objective of this project is to develop improved machine learning methods and algorithms to improve the performance of Li-Ion battery management systems for a variety of battery applications. The team will evaluate and select tools for developing machine-learning solutions.

Key Accomplishments

Digital Twin: The Digital Twin is a highly accurate data generation tool for battery data. The initial step of this project was to convert this into Python to rapidly generate data and make any further additions needed for evaluations. Overall, calculations were added for the derivative of voltage with respect to current, better known as resistance, and the derivative of temperature with respect to time. Linear control methods were also implemented to give a more accurate step input for the DV/di calculations.

Battery Storage: To store the damaged cells in a safe environment, they needed to be kept in a lithium-safe bag. In order to keep the cells organized and even safer, an enclosure was designed which keeps the cells in numerical order and separates the defective cells from the working ones for quick setup of the board. The enclosure is made of PETG (Polyethylene terephthalate glycol), which is best used for thermal and chemical resistance.

Mathematical Evaluation Methods: One of the main goals of this project was to see whether a mathematical or machine-learning approach would be better suited for the detection of a faulty battery. The mathematical methods have proven to work well using the implementation of Z-score calculations to detect how far away the temperature of a certain cell is from the average. This usually displays the faulty cells having a much higher sigma above the average.

Data Correlation: As the team gained proficiency in machine learning and the intricacies involved in creating a reliable model, it became apparent that our extensive dataset required careful attention to ensure its accuracy. An essential aspect of this process was determining which features were significant and identifying any correlations that existed between them. To overcome this challenge, a Python script was developed, which facilitated the analysis of various statistical elements, including mean, median, mode, and boxplot for outlier detection as shown in Figure 1.

Machine Learning: Using what we learned from the various forms of data analysis the team worked to create and deploy a machine learning algorithm. The algorithm is capable of taking in large amounts of digitally simulated data, correctly parsing it, and detecting anomaly's / faults within the system as a whole as well as individual cells. The model is able to extrapolate which of the individual cells' features resulted in anomalous behavior. The plan with this is to eventually implement the technology into a real BMS systems which will allow for predictive actions rather than reactive ones ultimately resulting in in safer Li-Ion cell use.

Data Collection with Faulty Cells and Short Circuit: Using this usage profile, data was collected with two faulty battery cells and an external short circuit attached to the cell along with 9 normal battery cells. This data collection shows the depth and accuracy of data coming from the BMS and AMBATS platforms. And being able to detect faulty cells among normal cells. The results of this data were that without any modification to the current PCB, it was not possible to get accurate data for ML. So it is essential to modify the PCB to get accurate data.

Silver Epoxy Batteries for Better Contact: As it was determined from last semester the terminal of the battery connection causes high and varying impedance due to poor area of contact. Also data collection with faulty cells, there was quite a bit of noise in the platform which created inaccuracy in the data and made it hard to differentiate between faulty cells and normal cells. To resolve this unstable contact problem, silver epoxy was applied to the battery contacts and battery holders making it a permanent connection. This will increase the area of contact between battery terminals and battery holders. Figure 2 shows the difference in before and after silver epoxy.

Assembling a PCB and Modified Battery Holders: A duplicate of last year's PCB was assembled and modified with a new battery holder. The sockets used on the battery holder which is used for the PCB to battery terminal connection have a very low resistance of a few milliohms. To hold the battery and socket together, a 3D-printed battery holder was modeled and printed. With this duplicate PCB with modification, we are now able to identify or differentiate between faulty and normal cells, as shown in Figure 4.

Anticipated Best Outcome

The anticipated best outcome for this project is to develop the Battery Oracle machine learning system, applying the lessons learned from the AMBATS program, to identify performance indicators of Li-Ion batteries for specific use cases. Demonstrate the application of the Battery Oracle methods to empirical data produced on the AMBATS and Eagle-Li systems for fault detection and life optimization. In working with Eagle-Li, propose optimizations to BMS designs for applications such as electric vehicles, directed energy weapons, etc., to improve battery safety, performance, and longevity, reducing the risk of batteries in more extreme scenarios.

Project Outcome

The project was an overall success. We were able to correctly demonstrate the application of the Battery Oracle methods to empirical data produced on the AMBATS system for fault detection as well as propose optimizations for the BMS through various improvements. Although the machine learning component was not completely realized, substantial headway was achieved in identifying the most sensitive data, relevant detection models and, most importantly, a data format that did result in the unlearning of detected anomalies.

Figures

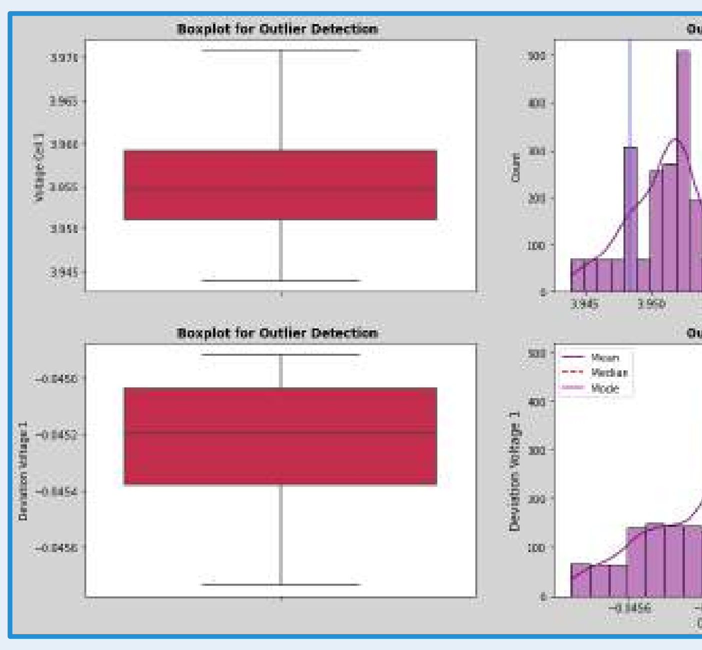

Figure 1: Statistical Analysis: Box and Bar graph plots

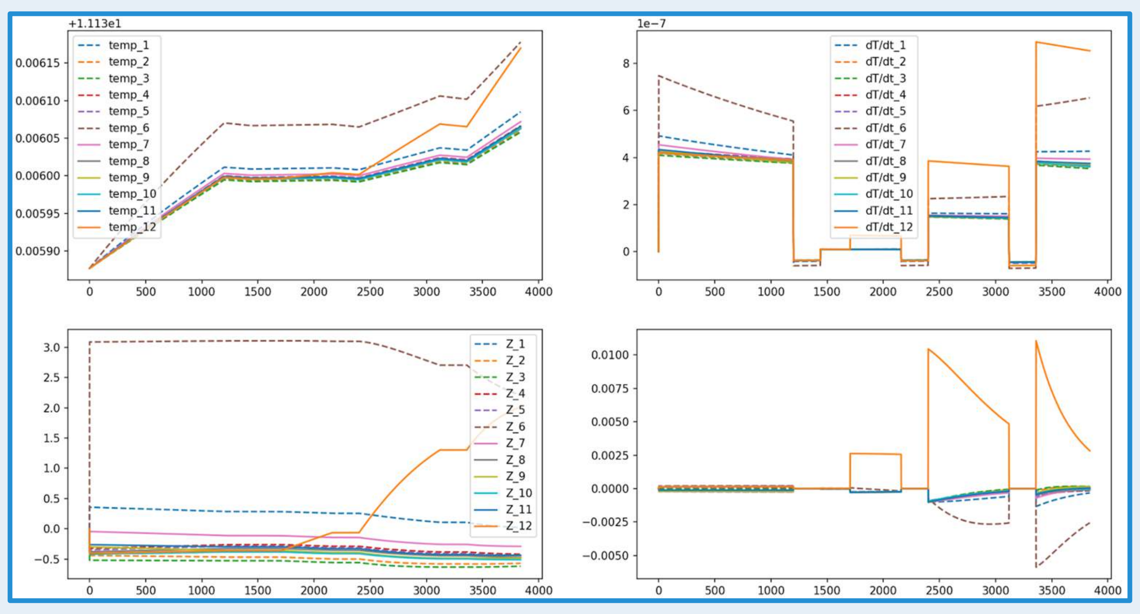

Figure 2: View of the Z-score data for the temperatures.

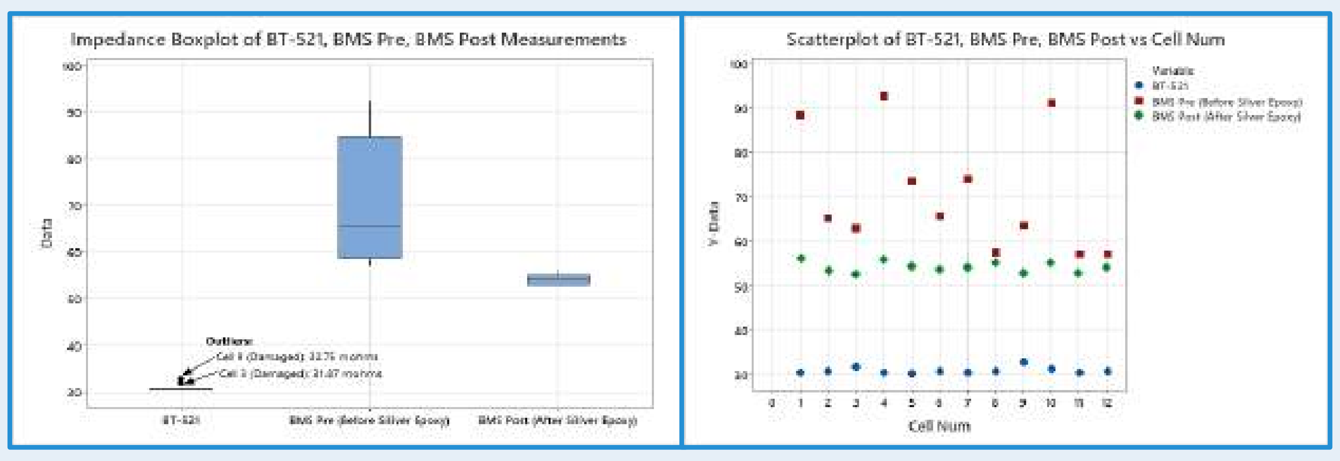

Figure 3: Impedance Plot of BT-521, BMS Pre (Before Silver Epoxy), BMS Post (After Silver Epoxy)

Battery #	Impedance (mΩ)	
	BT-521	BMS (New PCB)
1: Cell #4	32.83	42.83
2: Cell #5	33.8	43.29
3: Cell #6	32.3	40.95
4: Cell #7 (Damaged)	33.4	45.52
5: Cell #8	32.1	41.22
6: Cell #10	32.4	39.45
7: Cell #13	32	41.06
8: Cell #14	32.5	42.13
9: Cell #15	32.1	41.41
10: Cell #16	32.1	41.64
11: Cell #17	31.7	41.47
12: Cell #18	31.9	41.16
Average:	**32.43**	**41.84**

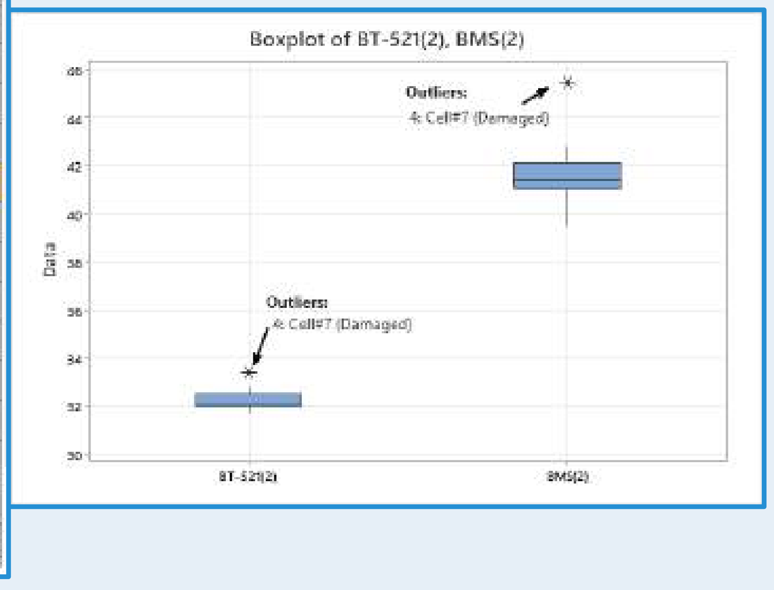

Figure 4: New Assembled PCB BMS Impedance Data

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Eagle-Li

Programmable Discrete Load for an Improved Battery Management Research System

Team Members: Adam Anabtawi (ELE), Benjamin Feeney (ELE), Brendon Lorena (CPE), Peter Martin (ELE)

Technical Directors: Daniel Wertz, Brandon Moore, Frank Puglia, Timothy Kelleher

EAGLEPICHER TECHNOLOGIES

Project Motivation

In today's world, batteries are the backbone of what fuels technology. Many companies will start incorporating Lithium-Ion batteries if they haven't already. The problem with these types of batteries is that they are unpredictable. If not properly charged or discharged, they can cause injury or even fatalities. Our vision is to create better testing procedures for the battery test platform and find new ways to make batteries last longer and be safer for the consumer. Through hard work and rigorous testing, we will make sure to provide the best solution to the utmost of our abilities.

Key Accomplishments

- **Discrete Load Specification Sheet:** Team Eagle-Li created a specification sheet that complies with industry standards to establish a set of rules on what is necessary for the hardware in the creation of the discrete load. The specification sheet lists important key details such as rated power, temperature etc.
- **Discrete Load Automatic and Manual Operation Options:** Gave the user the ability to use the discrete load either manually using a custom front panel or using the team created software with a connected PC to run tests using the discrete load.
- **Discrete Load Active Convection Cooling Solution:** Implemented an integrated active cooling solution that allows the enabled load to dissipate up to 1000W of power from the power devices. The Fischer Elektronik LA17-200 cooling aggregate has been implemented and is designed to ensure cooling for the system even when the high-power channels are active.
- **Remote User Control:** Through a USB interface to an internal Raspberry Pi, a user will have full control over the functionality of the hardware through a software program with an intuitive UI. This software will allow the control of load profiles, manual channel toggle, and be able to view time parameters. (Fig. 2)
- **Temperature Sensing Circuit:** The cooling aggregate that we choose comes with an integrated fan that operates at 24V DC. We implemented a temperature sensing circuit to control the speed of the fan so that it won't run at 100% power, ultimately reducing noise and power consumption.
- **Front Panel:** The front panel (Fig. 3) of the discrete load will consist of many different components to aid the user as well as monitor the performance of the system. The components include LED indicators, an LCD, toggle switches, push buttons, usb connectors, and a rotary encoder. The front panel also has an emergency kill switch which will be used to immediately cut power to the system in the case of emergencies.
- **Designed Resistor Networks:** Due to the high-power draw of the channels, it was important to choose a series of resistors that are able to dissipate the required power by being actively cooled. By choosing a particular set of resistors in series or in parallel, precise resistance was achieved which could also easily dissipate the required power.
- **Discrete Load Channels:** The discrete load has eight separate channels which will be used to discharge the Lithium-Ion battery cells at a desired current value. These channels range from 0.04 to 5.12 Amps and are capable of outputting 256 unique current values by using a simple 8-bit character. The largest current capable is 10.24 Amps, which occurs when all the channels are turned on together.
- **MetCase Enclosure:** We decided to use a MetCase case to enclose the discrete load. The case will come with a front panel which we will create a drill guide for to drill holes in order to mount the necessary components. We will also drill holes to create vents to influence airflow throughout the system.
- **Discrete Load Display:** The discrete load display is a 4x40 character LCD which will communicate with the Raspberry Pi Pico. Our aim was to display the current value being loaded through the Lithium-Ion batteries, as well as the total time discharging the cells, and the current time spent on each profile. Finally, we would like to display whether the system is in remote or local control.

Anticipated Best Outcome

Team Eagle-Li's best anticipated outcome for the project by April 14th, 2023, is to construct a discrete resistive load, code name Pablo, intended to discharge the Lithium-Ion 18650 cells that will replace the BK PWM load. The discrete resistive load will help to answer whether or not the BK PWM load is implementing data that is impeding the data being extracted from the battery management research system.

Project Outcome

Team Eagle-Li did not achieve their updated ABO. Although we do have schematics for all portions of the project, we just never got to order the components and physically assemble the system we fully designed.

Figures

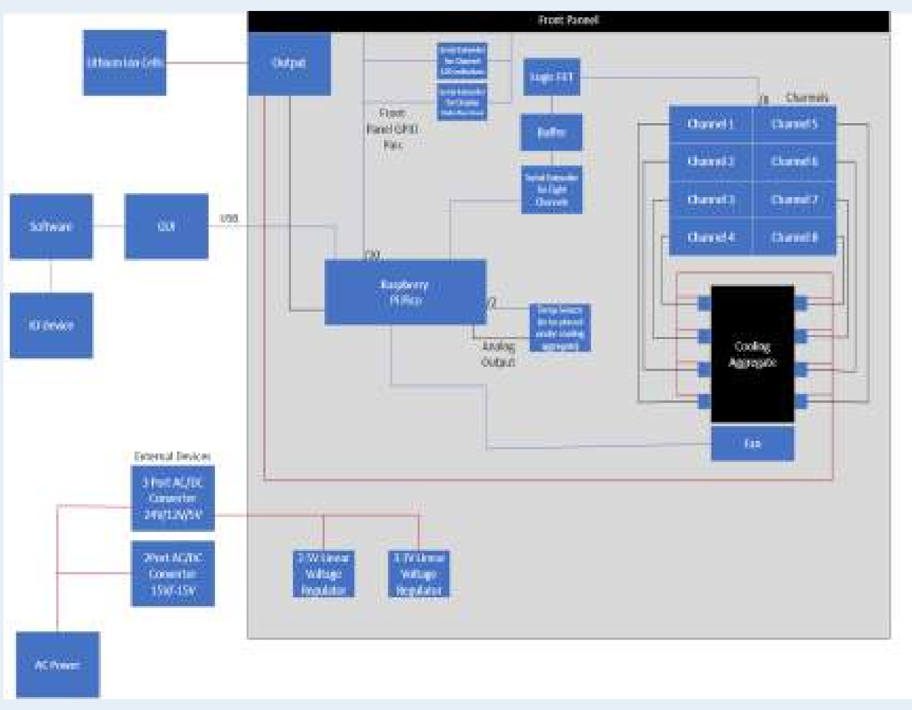

Figure 1: Discrete Load Block Diagram

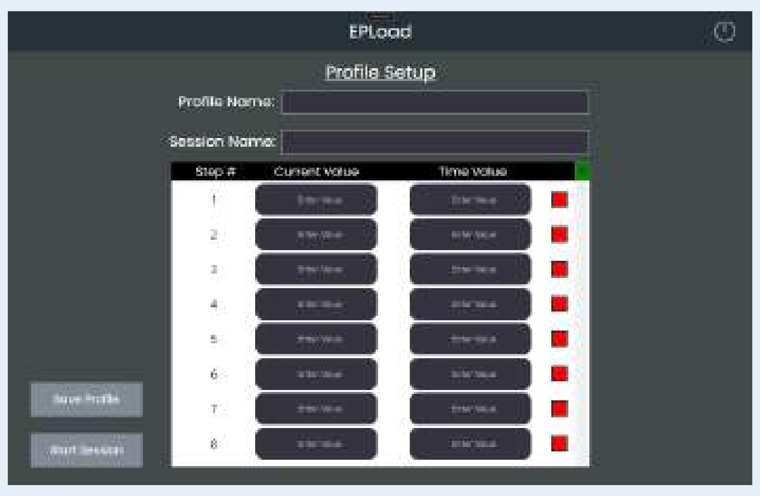

Figure 2: GUI Profile Setup Screen

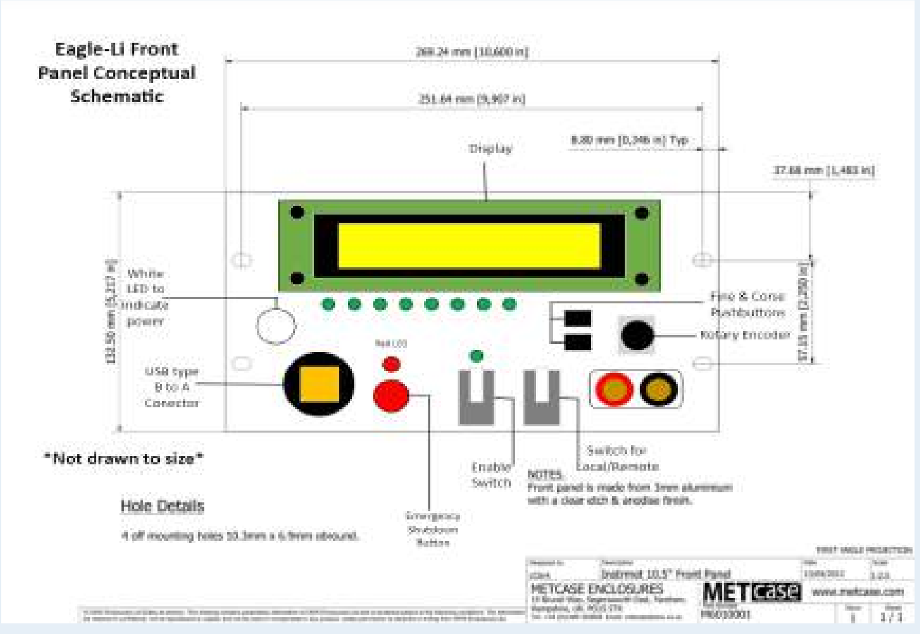

Figure 3: Front Panel Conceptual View

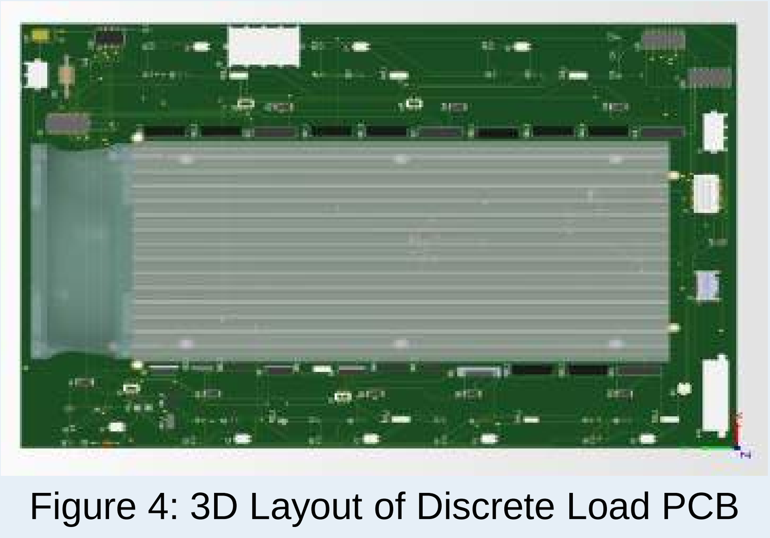

Figure 4: 3D Layout of Discrete Load PCB

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THINK BIG WE DO™

A Multimodal Brain Monitor

An integrated functional near infrared spectroscopy (fNIRS) and electroencephalogram (EEG) headband.

EchoWEAR

Team Members: Gianna Nardini (CPE), Chase Peirson (ELE), Jessica Yang (ELE)

Technical Directors: Dr. Nicholas Constant and Dr. Kunal Mankodiyas

Project Motivation

The study of brain activity has allowed researchers and medical professionals alike to collect data to learn about and sometimes treat different types of cognitive impairments. Current technologies allow for valid measurements of cognition and neural activity, however, often require significant preparation time, including the measurement of head circumference, integrating the electrodes, measuring the quality of electrode-to-skin contact, and lengthy system calibration. The other challenge is patient comfort, as many existing devices use rigid, bumpy electrodes that are uncomfortable for most users.

The development of a multimodal wearable headband monitoring system that could be used by neurospecialists, trying to detect early mild cognitive impairment (MCI) and assess its future trajectory, is the goal of this project. The new brain monitoring technology will be textile based, with the functionality of measuring both the brain's blood oxygenation response (using functional near infrared spectroscopy (fNIRS)), along with its electrical activity (using electroencephalography (EEG)).

Key Accomplishments

- **fNIRS Revision 2 PCB Created:** Developed a new fNIRS prototype that incorporates an Arduino Nano as the microcontroller. This board consists of 5 breakout boards and one main board with the Arduino Nano for a total of 6 boards shown in **Fig. 1**. There are 2 LED driver boards with black silicone polymer to allow for a better measurement of the light signals. The other 3 photodiode boards will also have a color sensor and an IMU (inertial measurement unit) chip. This allows for a 4 channel fNIRS that measures blood oxygenation and deoxygenation levels as well as skin tone estimations, and gyroscope and accelerometer readings. The overview of the fNIRS prototype PCB and all of its components are shown in **Fig. 2.**

- **fNIRS Skin Tone Estimations and IMU:** The fNIRS signals are dependent on the light absorption beyond the skin and skull to obtain a good reading. This means that there are poor readings if skin tone is not taken into account because the light absorption is different depending on the skin pigmentation. To take this into account, there is a color sensor on the PCB that will allow for an adjustment of the light intensity to obtain a good reading. Additionally, there is also an IMU chip on the board to allow for measurements of gyroscope and acceleration to obtain more data about the headband user.

- **fNIRS Firmware:** Currently developing firmware for the fNIRS PCB using an Arduino Nano. The IMU and photodiode measurement signals will communicate with the Arduino Nano using I2C (Inter-Integrated Circuit) protocol. These signals will be communicated to an OpenLog Artemis bluetooth storage and module board using UART (Universal Asynchronous Receiver Transmitter) communication. From there, it will communicate to another OpenLog Artemis board using Bluetooth to allow for signal processing **(Fig. 4)**.

- **Data Collection:** Working in coordination with researchers at Brown University and clinicians from Rhode Island Hospital, data was collected using the "Flanker" protocol, which is a protocol with well known results and identifiable data trends. Both the Brown cap and the EchoWear headband were used in data collection for verification of acceptable data in the EchoWear setup.

- **Signal Processing:** Data collected from the Brown EEG cap is recorded using "BrainVision" software, which was then plotted on and observed in both EEGLAB through MATLAB, and the MNE toolbox in Python. Data collected using the OpenBCI software is saved in a .csv file and was exported into Python for processing to observe the same time series and Epoched plots for verification of the data compared to the stable results given by the Brown EEG cap.

- **Headband Prototype:** Using a flexible fabric material, a prototype headband was made that houses the electrode snap-clips where the textile electrodes are placed for data collection **(Fig. 3)**. This headband leaves room for modifications to include the LEDs and photodiodes that are necessary in the fNIRS data collection circuits.

- **OpenLog Artemis:** Multiple OpenLog Artemis boards are going to be used in this project. During EEG data collection, another Artemis is used to collect the start times for each new task using a push button. It is saved in a .json file to then be used for signal processing. Currently working on communication between two Artemis boards using UART and then bluetooth to send information from one Artemis to the other.

Anticipated Best Outcome

The ABO of our project is the combination of two outcomes, with the first being a miniaturized electronics module for the fNIRS-EEG data acquisition. The entirety of the electronics will be embedded into a single flexible printed circuit board (PCB) consisting of both the analog and digital circuits used for acquiring the fNIRS and EEG signals. The second of the outcomes are the methods for processing the fNIRS, EEG, and head motion data. The on-board data acquisition system will acquire and send the raw data wirelessly to a computer where the signal processing algorithm will be applied on the incoming time-series data.

Project Outcome

The Anticipated Best Outcome of the project was not achieved.

Figures

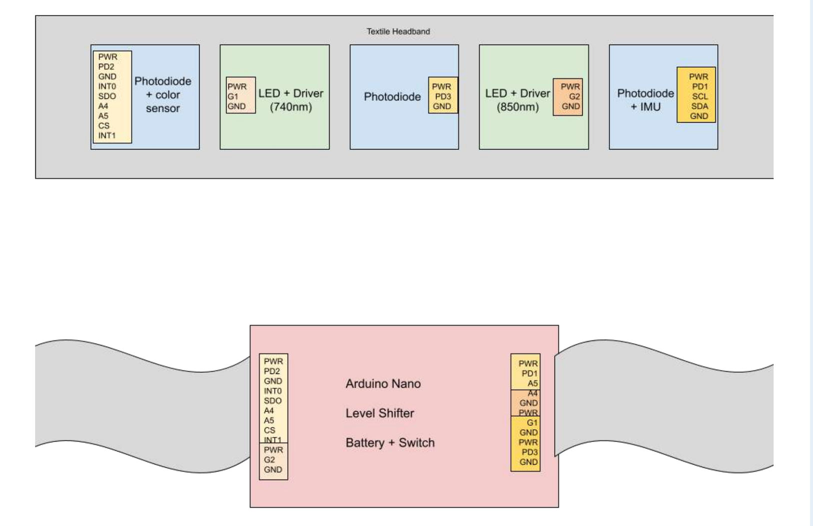

Fig. 1: Overview of the fNIRS Revision 2 breakout boards with corresponding jumper connectors in a textile headband.

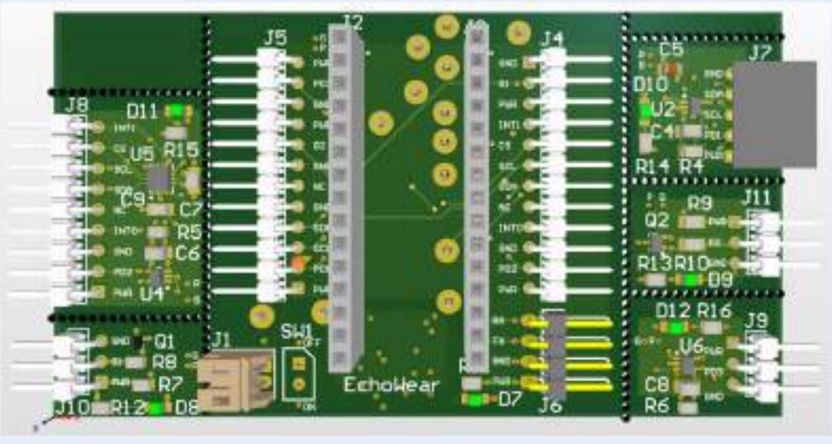

Fig. 2: PCB view of the fNIRS Revision 2 board and its breakout boards.

Fig. 3: Headband design includes a cover over the electrode face, leaving only the exposed metal for contact to the head (EEG). The space left in between the electrodes is where the diodes and photodiodes that will measure the fNIRS signals will be placed.

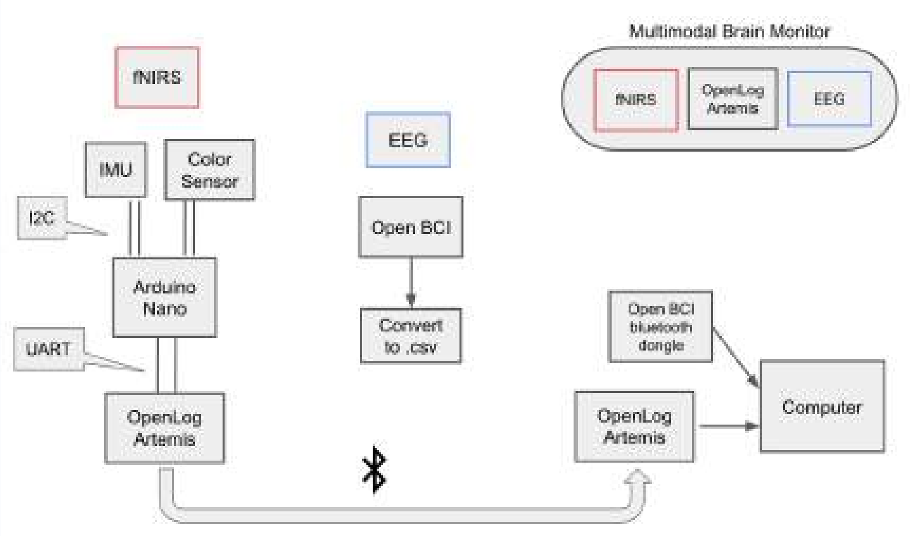

Fig. 4: Block Diagram of Multimodal Brain Monitor headband connections with EEG, fNIRS, OpenLog Artemis and communication protocols.

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ELECOMP CAPSTONE
VIRTUAL SUMMIT
FRIDAY, MAY 8, 2020

THE UNIVERSITY OF RHODE ISLAND

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Advanced AC-DC Power Architectures for Modular Data Center Enclosures

GENERAL DYNAMICS
Electric Boat

Team Members: Adam Silvestri (ELE), Alexis Noriega (ELE)

Technical Directors: Mike Brawner, Tyler Balczun

Project Motivation

This Project will investigate, perform technology assessment and develop simulation models of capabilities for next generation enclave level high voltage direct current power systems for mobile data centers. Mobile, reconfigurable processing enclaves and data centers require stable and reliable high voltage (>400 Volts) DC power. Traditionally, these systems are powered by 3 phase alternating current, and the individual servers/processors convert the ac to dc on a component level vice providing dc directly. We aimed to explore next generation technology and create models of a potential future design. This centralized DC system would allow for component upgrades, provide uninterrupted power, and remain efficient

Key Accomplishments

- **Initial Research of Power Distribution Systems:** Our first priority was to conduct research to become familiar with the concept of a power distribution system. We discovered concepts such as power architectures and the fundamental ideas of redundancy, efficiency, availability and modernization. Along with these comes the type of voltage (DC vs AC) as well as favorable voltage levels to have in our system. We eventually concluded that having a centralized DC system best satisfied all of the important criteria.
- **Research of Specific Power Distribution Components:** Our next step was to start researching the components that make up a power distribution system. These components include:
  - PDUs, UPSs, Circuit Breakers, Transfer Switches, Busways, voltage converters, Power Monitoring, Battery Technology and Cooling Systems.
  - Later in our research, we began to focus on solid state technology, specifically solid state circuit breakers and transfer switches. We believed that this technology had the most area for innovation in the coming years, and was most beneficial for us to research and model.
- **Technology Downselections:** As we moved closer to the actual design and development of our system, it was time for us to select specific components. We chose to use a modified version of Pugh Matrices to keep track of our downselections. We first narrowed down the specific characteristics of our own design, as we had come across many different sources of information. This technology evaluation led us to completing our system concept model.
- **Specific Research on Solid State Technology:** This was the area of technology we spent most of our time researching after our initial data center “deep dive”, as we found it provided the most area for innovation in the mobile data center power distribution system. Solid state circuit breakers and transfer switches were of interest to us, as they are both newer versions of already existing technology in the power distribution chain.
  - These components consist of semiconductor switches, as well as sensing/control and voltage clamping circuits. They provide exponentially faster switching speeds and phase matching capabilities, presenting the opportunity to replace the traditional UPS and battery backup system.
- **System Concept Model:**For our concept model of the system, we wanted to show how each component would be connected and describe what they do. We decided to use matlab to do this, we used various blocks and subsystems to model components such as the circuit breaker, transfer switch, UPS, etc. Then in each subsystem we provided a description of the technology as well as how it worked along with its benefits to our power system. With this we believe we had a detailed concept model of our power system and the technology it utilized.
- **Simulink Simulation Model:** Through our research into solid state technology, we modeled single phase as well as three phase AC voltage systems, to show switching speed and other characteristics of solid state technology.
  - Our main simulation is our three phase solid state transfer switch, with 440V AC voltage. From this simulation model we were also able to pull multiple waveform views that show the extremely fast switching time, of about 100 microseconds.
- **Physical Prototype Model:** With all the information we had gathered from our research, we began planning how to test and model our system. We decided on modeling a static transfer switch as it is one of the most important components in a data center. To do this we will use single phase 115 AC power in order to show accurate results as to how the system would work in a data center. We will also use a perfboard in order to handle the two 115 AC power sources and utilize TRIACs, as well as some switches to allow for the system to transfer between the two sources.

Anticipated Best Outcome

The Anticipated Best Outcome of this Project was to identify emerging technologies/systems and develop simulation model(s) to provide enclave level stable and reliable high voltage dc power. Also to develop a model that can not only provide the required power characteristics but also enable data processing component changes and upgrades while isolating the ac power feed from continual power load rebalancing. Following the system concept model approval, the designers will develop a prototype development plan as well as simulation models showing the capabilities of the proposed system.

Project Outcome

The ABO was met as we made progress through the simulations and physical modeling to meet the initial conditions set in our Anticipated Best Outcome. We have analyzed technology, created multiple iterations of concept models, built simulation models, and begun a significant amount of work on a prototype model that could be continued by a future project.

Figures

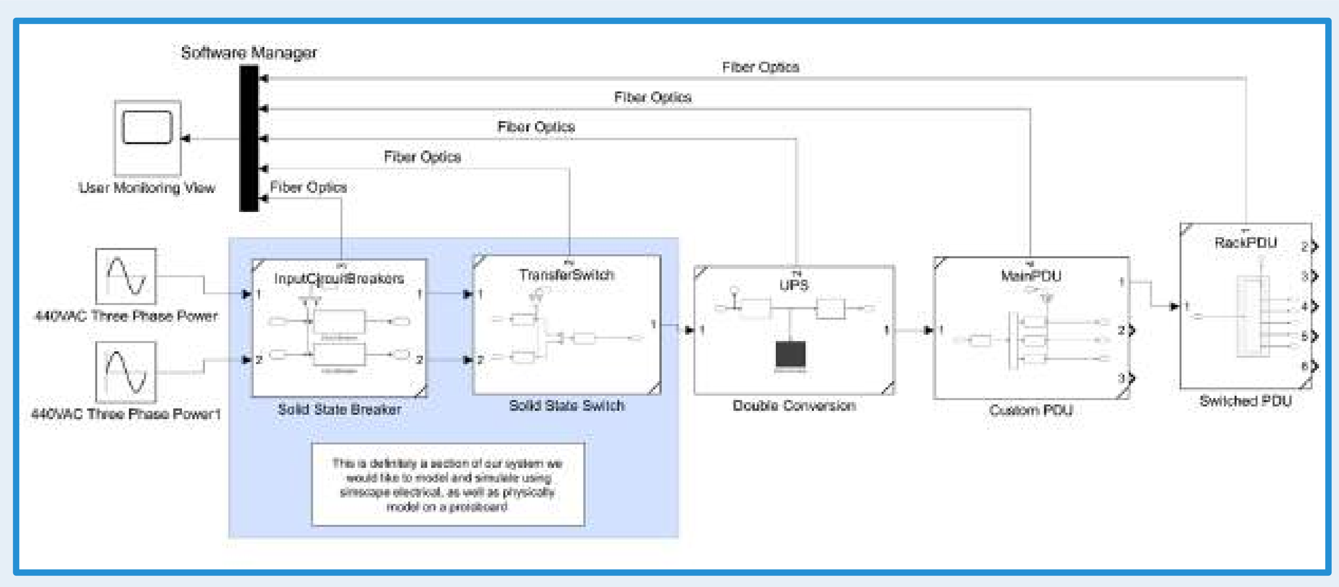


Fig 1: (Above) Concept Model of Entire proposed Power Distribution System, showing component interconnections and power monitoring connections.

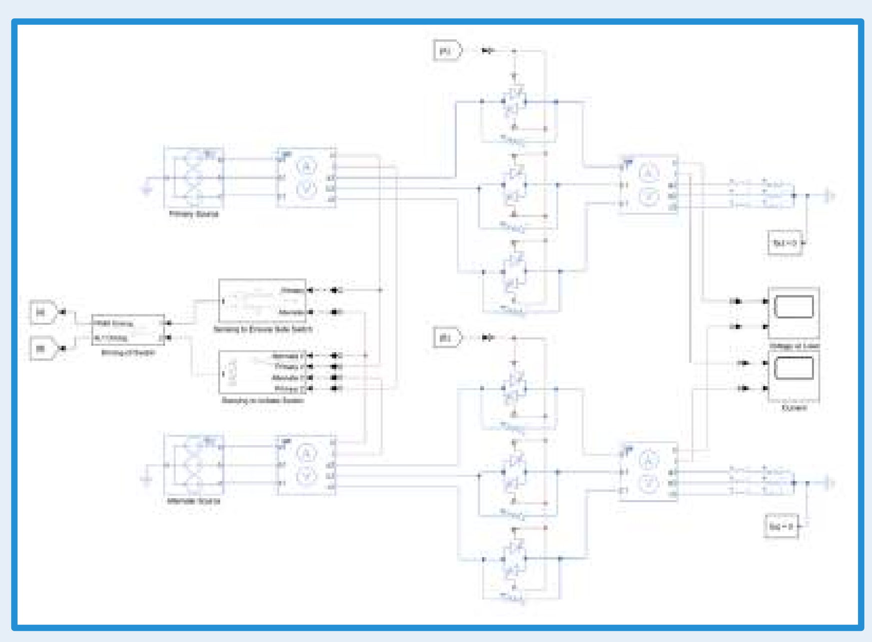
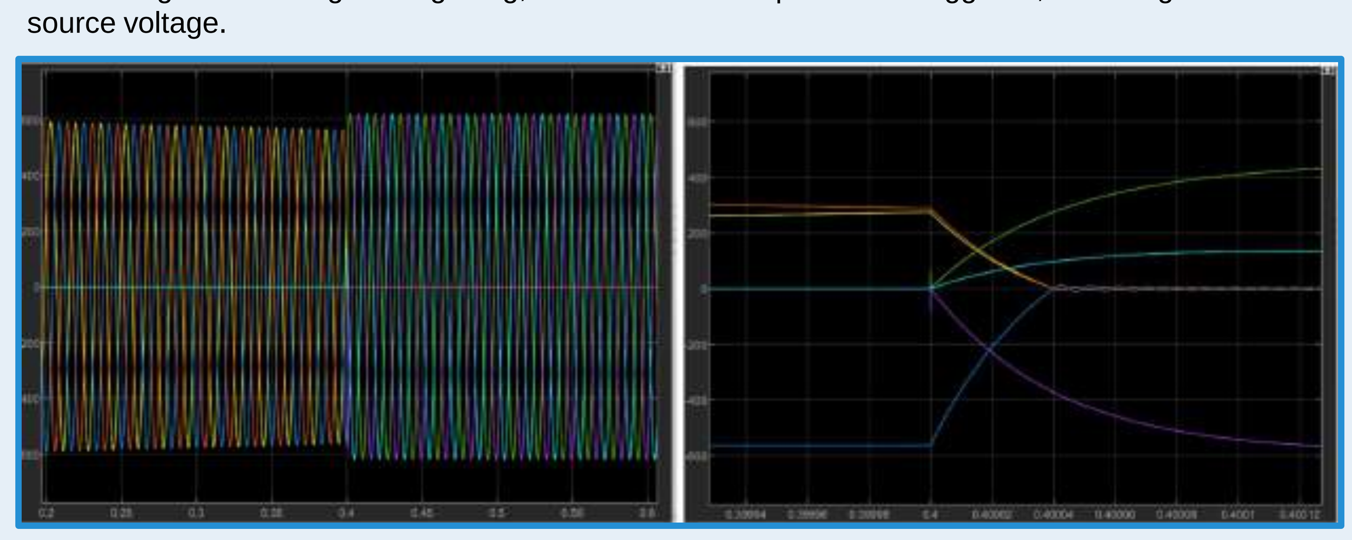


Fig 2: (Left) Simulink Simulation model of three phase solid state transfer switch. Switch operates between a primary and alternate source, with power being monitored at the load and at the source. Simulation also includes control circuit subsystems for sensing of voltage source conditions, as well as driving the Switching operation.

Fig 3: (Below) Voltage waveform of Primary and Alternative sources undergoing a transfer. Primary source begins to undergo voltage sag, and the Transfer operation is triggered, switching to Alternate source voltage.



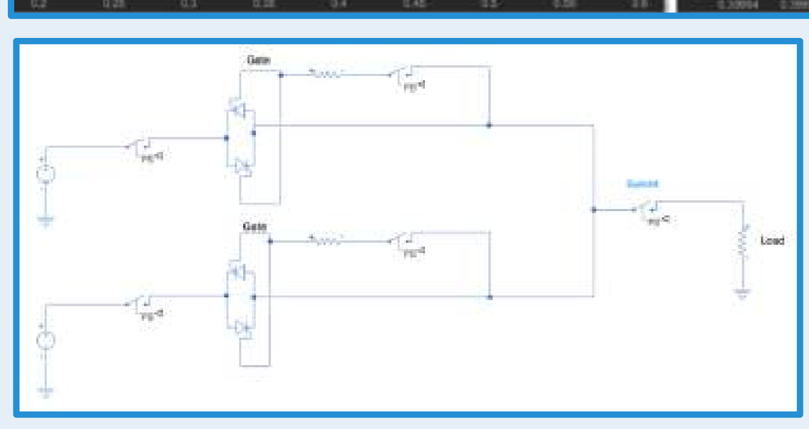
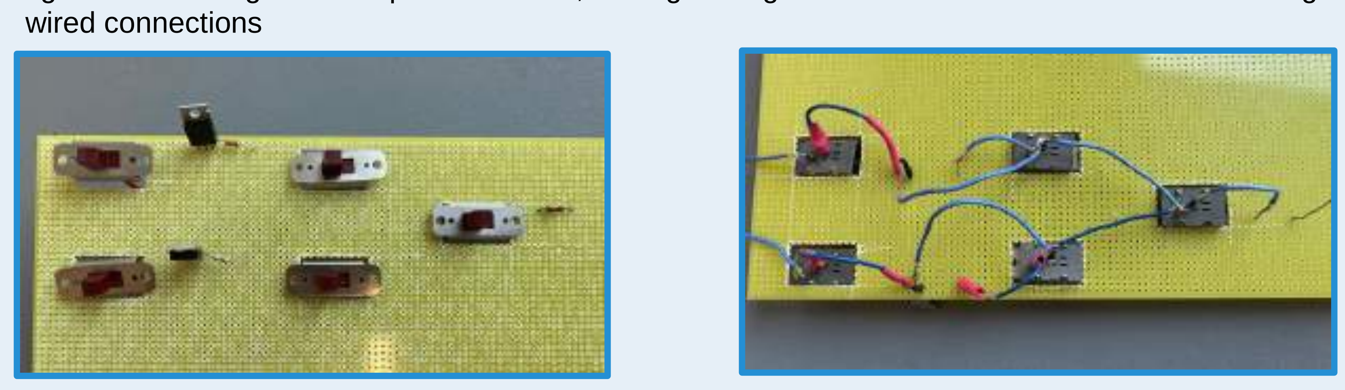


Fig 4: (Left) Circuit architecture model for physical prototype of Solid State Transfer Switch. Design uses two Triacs as a semiconductor switch and a manual switch to turn Triacs on and off.

Fig 5: (Below) Photos of physical prototype model progress, built from simulated circuit model in figure 4. Left image is the top of the model, and right image is the underneath of the model showing wired connections



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ELECOMP CAPSTONE
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TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Low Frequency RF over Fiber Optics

GENERAL DYNAMICS
Electric Boat

Team Members: Antonio Venmahavong (ELE), Brandon Yeh (ELE)

Technical Directors: Michael Brawner and Dr. Charles Jewart

Project Motivation

This project will investigate and assess technology options and develop simulation models of capabilities for conversion and optical routing of Low Frequency RF signals between antennas and radio systems. Next generation optical conversion technology/systems are required to provide the capabilities to enable improved reliability, signal quality and hardware arrangement flexibility. System development to provide a capability that can support a range of frequencies and signal types over varying distances is required. Next generation optical conversion technology / systems for low-end range of frequencies do not exist. The aim of this project would be to develop corresponding systems for this frequency range.

Anticipated Best Outcome

The goal is to identify emerging technologies/systems and develop simulation model(s) to enable removal of traditional coaxial cabling between antennas and radio receivers and replace them with fiber optics for low frequency signals. This capability is not currently available for many low frequency signals. The investigations will include identification and assessment of applicable technologies and components', systems Readiness Level (TRL) and potential risks for maturity of that technology. The Sponsor will provide the required project information including specific frequency ranges of interest and data transport descriptions. An introduction to optical routing of RF signals will also be provided as part of the kick-off meeting. The Sponsor will also provide the required documentation and guidance on TRL determination and mapping and trade study approaches. The Sponsor will provide guidance and operational requirements for student use in the execution of this project. To control the transfer of sensitive information, the Sponsor will utilize commercial system-based information and publicly available oceanographic conditions information.

Key Accomplishments

Key Technical Accomplishments, Research and Findings:

Identified Appropriate Design for a Low Frequency Radio Frequency over Fiber Communication System

We were tasked with identification of an appropriate design for a Low Frequency Radio Frequency over Fiber Communication System. This was done by completion of several prerequisite steps. We compiled a list of interpreted specifications, parameters, and requirements of the design for the project. We created an appropriate project plan that provided a structured and ordered projection of research, design, and implementation tasks for us to do to better track and progress towards completion of the project. We researched existing literature on current and emerging Radio Frequency over Fiber Communication Systems. Then we identified a system design to implement through a down-selection trade study.

Interpreted Design Parameters

We compiled a list of interpreted specifications, parameters, and requirements of the design for the project. This was done through discussion with our technical directors to obtain desired system performance requirements and system operating conditions. We then interpreted this information to form a list of design specifications, parameters, and requirements. This list was used to support decision-making in the selection of potential designs and design implementation to ensure that the design and its implementation worked satisfactorily.

Project Plan

We made a project plan that provided a structured and ordered projection of research, design, and implementation tasks for us to do to better track and progress towards completion of the project. This plan served as a schedule or roadmap which specified dates or weeks for work towards tasks or items to be done. The tasks are specified and ordered so that it would be easy to identify and track progress of work to be done to progress towards completion of project milestones.

Literature Research

We researched existing literature on current and emerging Radio Frequency over Fiber Communication Systems. We studied and researched the following topics: fundamentals of communication systems (amplitude and angle modulation), fundamentals of fiber optics (fiber optic characteristics, E/O and O/E conversion methods), and current implementations and technologies of high frequency RF over Fiber.

Down-selection Trade Study

We identified a system design to implement through a down-selection trade study. This trade study was able to be performed after completion of the interpretation of design parameters and research of existing literature regarding radio frequency over fiber communications systems. Through the down-selection trade study, we were able to identify an appropriate system design that could fulfill design parameters. The specifics of the design are shown in the below description of its implementation.

Implementation of a System Simulation Model

We were tasked with producing a simulation model of a designed end to end radio frequency signal communication system with an intermediate fiber optic link. This overall simulation model is composed of a cascade of major subsystems that each represent effects on the signal throughout its travel through each respective stage of the system. Descriptive models of each subsystem that capture the whole picture of positive and negative effects on the signal are key technical accomplishments towards this overall end to end system simulation model. This simulation model was implemented in Simulink.

Input Signal

We implemented a model that simulates the input signal that the designed communication system will be communicating. For this project, our design had to successfully communicate a binary frequency-shift keyed (B-FSK) signal from an antenna source. We had implemented a model that simulated a clean BFSK signal source. Future work on this model would include simulated attenuation, noise and distortion, which would better approximate the actual received signal from the antenna source.

Electrical to Optical Converter

We implemented a model that described the series of transforms on the inputted signal as it passes through the electrical to optical conversion subsystem. This subsystem simulated the operations of radio frequency (RF) domain preprocessing and the translation of the signal from RF to optical media.

Electrical Preprocessing

We implemented a model that described operations performed on the signal as it passes through the electrical preprocessing stage of the electrical to optical conversion subsystem. For the design we selected, we implemented a model that demodulates the inputted BFSK signal to obtain its digital baseband. This digital baseband signal would then be passed into the device that translate this signal into an optical format. Further work on this model would include simulation of parasitic noise or distortion, as well as signal processing operations as needed, reflective of real-world component counterparts, such as amplification or filtering.

Electrical to Optical Conversion

We implemented a model that described the translation of the processed input signal from RF to optical format. The input FSK signal is first demodulated into the binary message, and is converted into an optical signal via Mach-Zehnder Modulation (MZM). MZM is a form of intensity modulation, in which an optical signal, such as a laser or an LED, is varied in accordance with the amplitude of the modulating signal. This modulation method applies electric fields to a split optical signal, resulting in the optical path lengths to be altered, resulting in phase modulation. By combining the two "arms" with different phase modulation converts the phase modulation into intensity modulation.

Optical Link / Network Model

We implemented a model that described the transformation of the signal as it passes through the optical link. Currently this model describes the attenuation of the signal over the optical link's distance. Further work on this model would include simulation of delay, phase shift, and parasitic noise or distortion.

Optical to Electrical Conversion Rx Device

We implemented a model of specific O/E conversion components, such as an optical amplifier, and a lowpass filter. Further work includes an optical receiver, such as a photodiode, in between the optical amplifier and the lowpass filter. The receiving device used needs to be capable of reconverting the optical signal into the original BFSK rather than the raw binary signal.

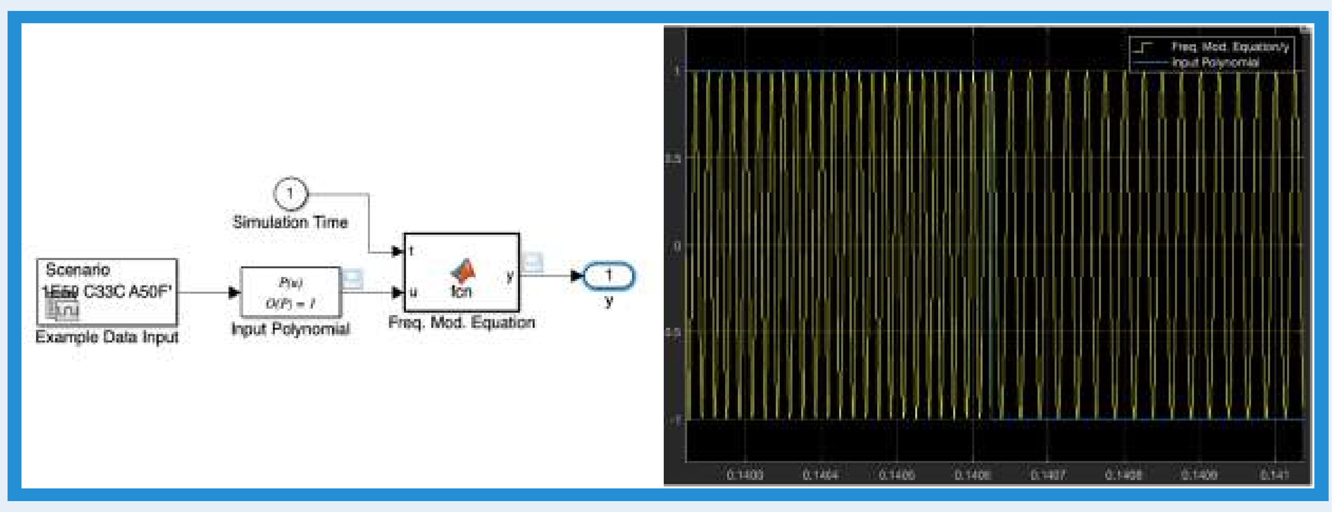
Rx Receiving Terminal

We implemented a model that describes the final receiving terminal that will be receiving the signal. Further work on this model would include functions that calculate and display the simulated resulting bit error rate, bandwidth, eye pattern, and other pertinent information of received signal characteristics or system performance.

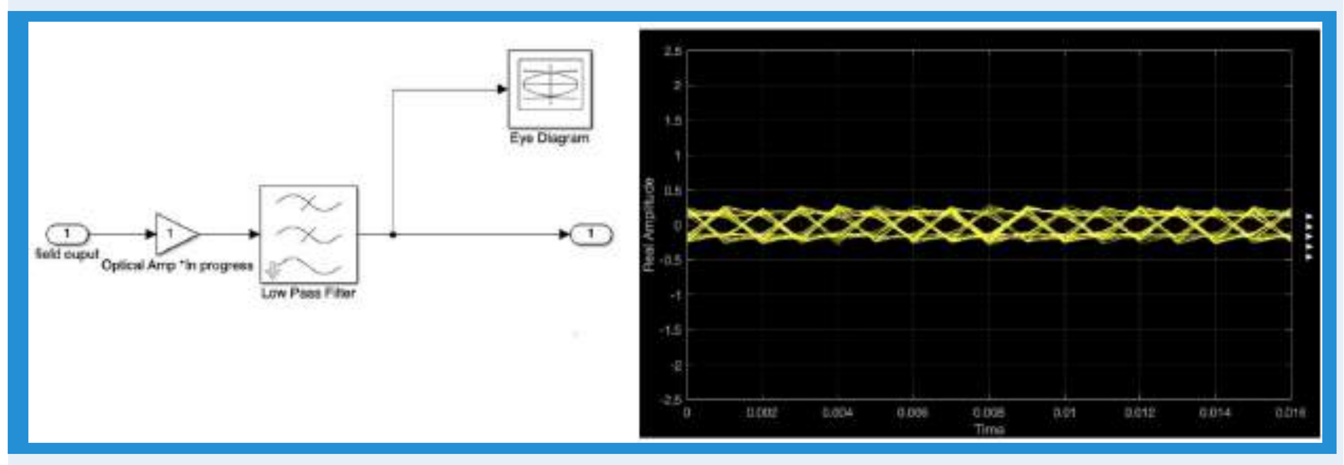
Project Outcome

We were unable to achieve our anticipated best outcome. Our model lacked the Fiber optic cable, Optical to RF conversion, and RF output subsystems.

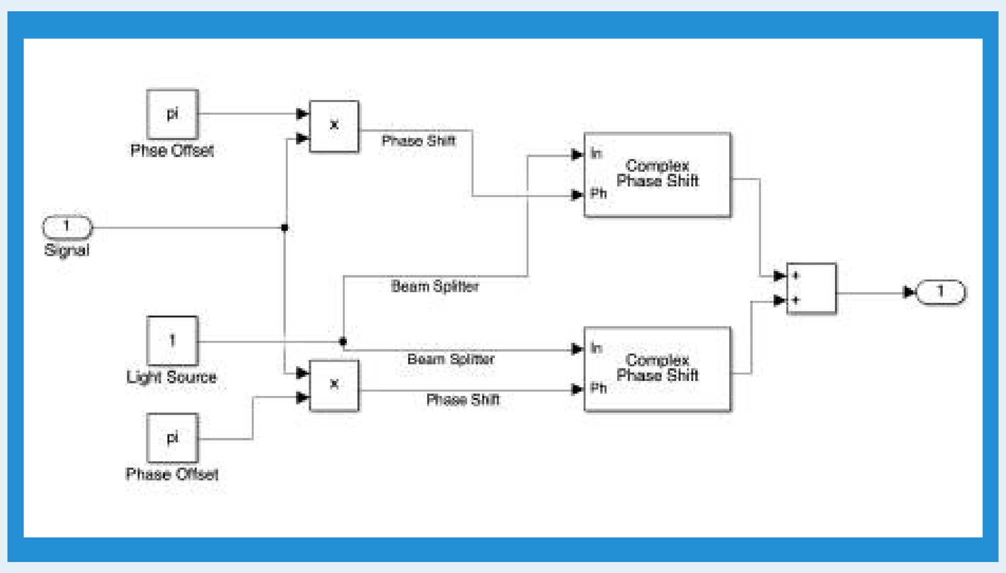
Figures



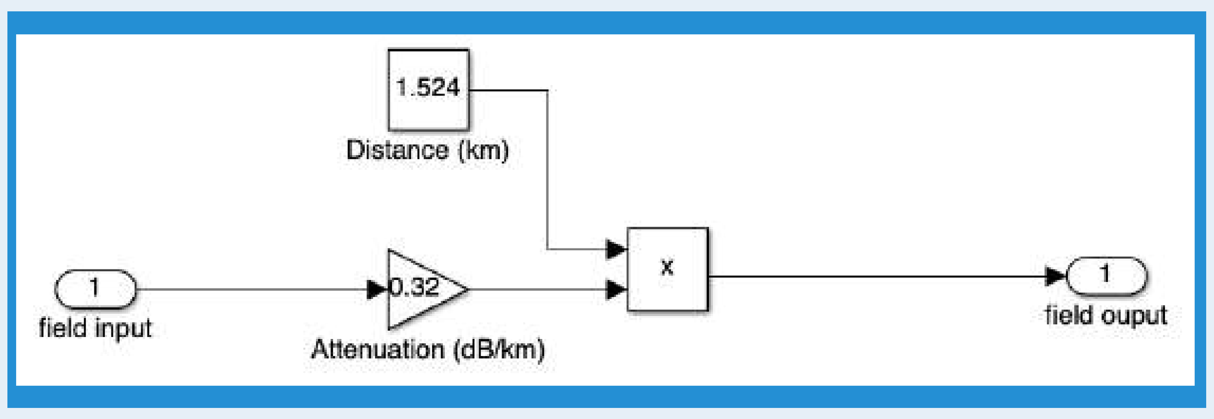
RF Input Subsystem with corresponding output



Incomplete Optical to RF conversion subsystem with corresponding eye diagram



Mach-Zehnder Modulation technique within the RF to Optical conversion subsystem



Incomplete Fiber Optic Subsystem

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TUESDAY, MAY 9, 2023

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ShowController Refresh

Redesign of a dual output, digital signing, headless terminal.

Team Members: Nathan Campano (CPE), Kartik Mohanty (ELE), Andy You (ELE)

Technical Directors: Raymond Leland ('93), Erik Hanley ('05) | Consulting Technical Director: Brenden Smerbeck (ELECOMP '17)

Project Motivation

The lottery is one of the most popular forms of gaming. Many people around the world participate in the lottery in hopes of being the lucky winners of the ultimate prize. One of the key factors to a successful lottery system is a digital signage display. IGT has their own video controller unit (VCU), also known as the ShowController. The current version of IGT's ShowController **(Fig 2.)** was introduced to the marketplace in 2015 and is in need of an update. The goal of this project is to replace the current version of the ShowController with a new and improved version. The new ShowController must meet a set of base requirements defined by IGT. These requirements relate to the resolution, media formats, connectivity, operating system, memory, and storage of the new video controller unit. Once all of these requirements are met, the new ShowController can be released into the market.

Key Accomplishments

Buy vs Build Evaluation:
Research was conducted regarding purchasing off the shelf digital signage devices vs building a device from components. The major factors in this evaluation were the pricing, availability, performance, and matching the requirements set by IGT. The evaluation concluded that there were no off the shelf devices that matched the specification requirements for the ShowController replacement, thus the project has moved onto evaluating components for the building option.

Solution for no mechanical components and passive cooling:
This was a hard requirement for the devices as having no mechanical components increases the lifespan of the devices and lowers maintenance. To resolve this, the replacement ShowController will inherit design choices from the current device. These design choices are, passive cooling through device chassis which eliminates the need for system fans, non-mechanical storage drives (SSD, NVMe), and a fairly low power device that wouldn't require an integrated power supply as it would require a PSU fan.

Key Component Research:
The result from our buy vs build evaluation was that the team would be choosing a building option moving forward. This requires component research and evaluation. The most important component for this device is the Central Processing Unit (CPU) as it dictates almost the rest of the device; board, memory configuration, I/O support. We compared the specifications of multiple CPUs from Intel (2019-2022) to the current ShowController's CPU.

CPU Benchmarking:
Once we narrowed down a few CPU options, we performed benchmarking tests on them. We first did benchmarking tests on the CPU used for the existing ShowController and recorded the results in a spreadsheet. Then, we did benchmarking tests on each of the new CPU options and put them in a spreadsheet as well. After that, we did a side by side comparison of each CPUs results. These results are used in our future price vs performance analysis.

Benchmarking New Boards:
We also performed further benchmarking on new boards: Intel x6413E (BCM), Intel x6425E (DFI), and Intel x6413E (iBase) to evaluate different hardware configurations and to determine our new baseline performance. There were various test ran on this board: Chrome Experiments: WebGL Aquarium/Blobs/Field, Sysbench CPU Benchmark, HardInfo: CPU Blowfish/GPU Drawing, Geekbench, Phoronix-Test-Suite: GPUTest, GLXGears, GLMark 2, stress-ng thermal stress tests, various HTML5 based test and IGT test-shows. These test results (**Fig 4.)** are then recorded in an organized spreadsheet to be used to compare their results with each other. We also re-evaluated the performance of the Intel x6413E using the BCM board which performed much better than the previous x6413E board we tested due to it having either hardware/firmware bottlenecks. These results dictate the final board configuration we will be recommending the IGT Team.

IGT Software/Firmware Integration:
We integrated IGT's custom Linux distribution to evaluate the performance of the Intel x6413E (BCM) and Intel x6425E (DFI) boards. Using IGT's custom test shows which were mainly HTML and WebGL based, we were able to evaluate and compare the performance of each board on the custom software. These test shows consisted of a countdown animation to test the board's ability to smoothly handle multiple pre-generated animations at once, and a simple vector physics test with a varying number of entities to monitor the CPU's ability to maintain a stable framerate, and at which number it started to decrease and lose performance.

IGT Next Generation ShowController presentation/documentation:
We created documentation/presentation on our findings on digital signage trends and potential buy/builds solutions with relevant specifications. This presentation includes our benchmarking results with the various board configurations (**Fig 4.)** Comparing these results we were able to provide recommendations of the configuration going forward for the new generation ShowController. These documents will be transitioned to the IGT team.

Anticipated Best Outcome

The Anticipated Best Outcome (ABO) is dependent on the initial buy vs build analysis of the product. If there is an off the shelf product available that satisfies all of the requirements for the new ShowController, then the ABO is to integrate the device with IGT Platform software and digital media software. If the decision is to build the product, then the ABO is to purchase the necessary parts and develop an engineering prototype device. After software integration has been performed, the product should be transferred to IGT's Engineering Team. Either way, the product should be available in the market by the end of April 2023.

Project Outcome

The ABO was successfully met. The outcome of the project was a set of slides for IGT's Engineering team, consisting of parts to use for the ShowController, as well as benchmarking results.

Figures

Fig 1: Diagram that demonstrates the functionality of the ShowController

Fig 2: Image of the existing ShowController

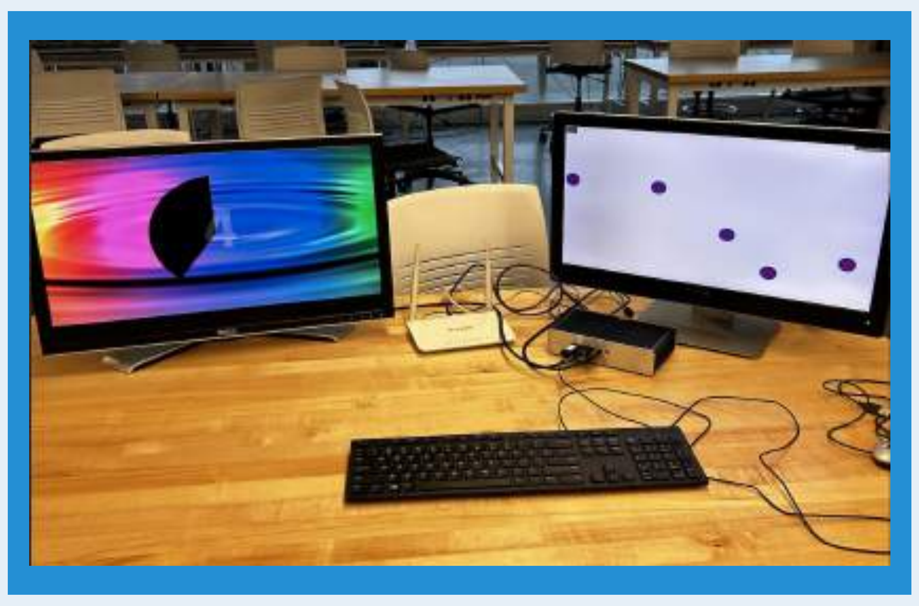

Fig 3: Demonstration of ShowController functionality

SPECIFIC TEST	Atom x6425e Board (DFI) 1x3200 4gb RAM		Atom x6425e Board (DFI) 2x2400 2gb RAM		Atom x6413e Board (BCM)	
Resolution/Output	1920x1080 Single Output	1920x1080 Dual Output	1920x1080 Single Output	1920x1080 Dual Output	1920x1080 Single Output	1920 x 1080 Dual Output
Chrome Experiments: WebGL Aquarium: 30000 Fish	16 - 23 FPS	14 - 19 FPS	26 - 29 FPS	13 - 14 FPS	17 - 20 FPS	10 - 11 FPS
Chrome Experiments: WebGL Blobs 1000 @ 48^3 Resol	46 - 47 FPS	22 - 24 FPS	47 - 60 FPS	24 - 25 FPS	43 - 45 FPS	22 FPS
Chrome Experiments : WebGL Field: Lots	57 - 60 FPS	37 - 39 FPS	59 - 60 FPS	48 - 50 FPS	60 FPS	28 - 38 FPS
Sysbench CPU Benchmark	1793.82 Events/sec		1906.28 Events/sec		1668.85 Events/sec	
Hardinfo: CPU Blowfish	"3.11" Lower is better		"3.02" Lower is better		"3.02" Lower is better	
Hardinfo: GPU Drawing	"4265.15" Higher is better		"5151.09" Higher is better		"4106.53" Higher is better	
Geekbench	Benchmark Link		Benchmark Link		Benchmark Link	
Phoronix-Test-Suite: GPUTest	PDF File		PDF File		CRASH	
Stress-ng --matrix 0 --matrix-size 64 --tz -t 30m	acpitz 26.80 C || x86_pkg_temp 68.50 C		acpitz 26.00 C || x86_pkg_temp 68.00 C		acpitz C || x86_pkg_temp 78.25 C	
Stress-ng --matrix 0 -t 30s --times	Load Average: 1.92, 1.38, 1.41		Load Average: 3.23, 2.66, 1.61		Load Average: 2.44, 1.46, 0.96	
GLX GEARS	60 FPS		60 FPS		60 FPS	
GLMark 2	Score: 1295		Score: 1468		Score: 1911	
Ubuntu: Vector Diagshow 1080p 60FPS CAP	1700 Balls for 25 FPS		1780 Balls for 25 FPS		1600 Balls for 25 FPS	
Gentoo: Vector Water Gradiant CPU Usage	25%~	30-35%	15%	25-30%	25%	33-37%
Gentoo: Vector Diagshow 1080p 30FPS: 30 Balls	25%	50-55%	25%	50%	25%~	55%~

Fig 4: Test board benchmarking results

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TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

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BAMS

Biometric AI Measurement System

in-depth engineering

Team Members: ChangTao Yu (CPE), Whitney Schoellerman (CPE), Noah Nicolella (ELE)

Technical Directors: Bill Matuszak and Dave Helms | Consulting Technical Director: Brenden Smerbeck (ELECOMP '17)

Project Motivation

Wearable technology is currently a billion-dollar industry that is expected to continue expanding. Data from these smart devices have already been used to optimize athletic performance and have great potential to revolutionize future workforce performance and quality of life. In-Depth engineering has begun to explore whether information from biometric devices can also be used to optimize the performance of computer-based tasks.

The objective of this project is to create a successful proof of concept that proves that biometric data can be collected and reveal correlations that can be used to train machine learning models to predict operator performance. The ability to understand and predict operator performance would benefit many organizations significantly by providing insight into how to optimize personnel while improving quality of life.

Key Accomplishments

Biometric AI Measurement System (BAMS) Research and Acquisitions: Research was done into various methods, devices, and software to be used for extracting and collecting different types of biometric and performance data which could reveal data correlations that could be used to train a machine learning model with the ability to predict operator performance levels. Hardware and software choice options with strong customization capabilities were prioritized when the final parts of the data collection system were chosen and ordered. **(Fig.2)**

Design and Assembly of Data Collection System: The resulting BAMS data collection system is comprised of both hardware and software that work together to synchronously collect biometric and performance data in real-time and store it into properly formatted files. **(Fig. 1)**

- **Hardware:** Three hardware devices were chosen for BAMS: Fitbit's Inspire 3 health and fitness tracker, a custom-built Galvanic Skin Response (GSR) sensor, and an infrared head tracking device.
- **Software:** Each hardware device required interfacing software to collect and store data generated by testing sessions
- **MouseTracker:** Our own program using a Python library, initially using the Winput library to record the mouse current location with a frequency of 1 millisecond per set of data. Afterward, find out that the First-Person-Shooter (FPS) games tend to constantly reset your mouse's current location which will provide useless test data. With the help of our technical director, Winput library switched to pyautogui which is able to track the change of mouse locations (delta x and y). First-Person-Shooter (FPS) games do not limit the change of mouse locations and are able to give more interesting data by how much the tester moved their mouse and in what position they moved.
- **Keylogger:** Our own program using the Python library Winput, is able to record all the keyboard movements. In First-Person-Shooter (FPS) games, this data is not so valuable.
- **FitBit API:** A custom python program was created that would interact with FitBit's API to access and collect relevant data collected by the Fitbit trackers worn during data collection sessions.
- **Screen Capture:** Our own program uses a Python library, using the function ImageGrab from pyscreenshot library, that takes a picture of given X and Y location relative to screen resolution at a rate of one picture per second. This program is able to take the score and accuracy of the current tester from the AimLab game.
- **TeraTerm:** A free program that is able to take port data, reads recordings and give them timestamps. It is very useful for our Galvanic Skin Response (GSR) data collection.
- **OpenTrack:** A piece of free and open-source software that tracks three IR LEDs worn by the user and uses trigonometric algorithms to determine the yaw, pitch, roll, x, y and z position of the user's head.
- **AimLab:** A free program from Steam that is able to simulate lots of First-Person-shooter (FPS) games' scenes for users to practice, and it also has a powerful creator studio for creating game scenes. It is our premiere source of data collecting.
- **AimTrainer Clone:** A 2D 'clone' of AimLab developed in-house to simplify the mouse tracking process and collect additional metrics, as AimLab limits the amount of data we can collect to what is on the screen.
- **.bat opener:** A .bat Windows command file that is able to one-click install all Python libraries that a user needs and also one-click open all test software which significantly reduces the time for test sections.

Data Processing Programs: We wrote a series of scripts that processes the incoming biometric and performance data for model training. Unprocessed data can contain time-points without values, extraneous values of 0 inserted into the data, and duplicates that can throw off the model. Our data processing suite ensures that the data training the model is accurate and formatted correctly. **(Fig. 1)**

Correlation Analysis: Using a program called RapidMiner, we were able to quickly and effectively construct correlation matrices to plan our model development and training. Although we did not successfully train a model, a future team will be able to use our correlation matrices to develop a model. **(Fig. 3)**

Preliminary ML Model Training: Towards the end of the project, we began to train a preliminary model to test our concept. We used the Keras and PyTorch library to accomplish this and chose a Temporal Convolutional Network (TCN) model on the advice of our technical directors. **(Fig. 1)**

Anticipated Best Outcome

The anticipated best outcome of this project is a successful proof of concept for a system that can measure the relationship between operator biometrics and operator performance on a CBIS. Data will be collected using video games in place of CBIS applications and biometric sensors and then analyzed for strong correlations which could be used to train a Machine Learning model to classify operator performance based on operator interactions within video game environments. The resulting BAMS prototype could be used to help create ML models to predict and improve the performance of operators of CBIS systems for air traffic control, power plant operation, sensor processing, and unmanned vehicle control.

Project Outcome

Despite being unable to achieve full model training, our findings demonstrate the feasibility of constructing and training a model utilizing the available dataset. Thus, we have successfully met the ABO requirements. Our work lays the foundation for future teams to build upon and create a functional product.

Figures

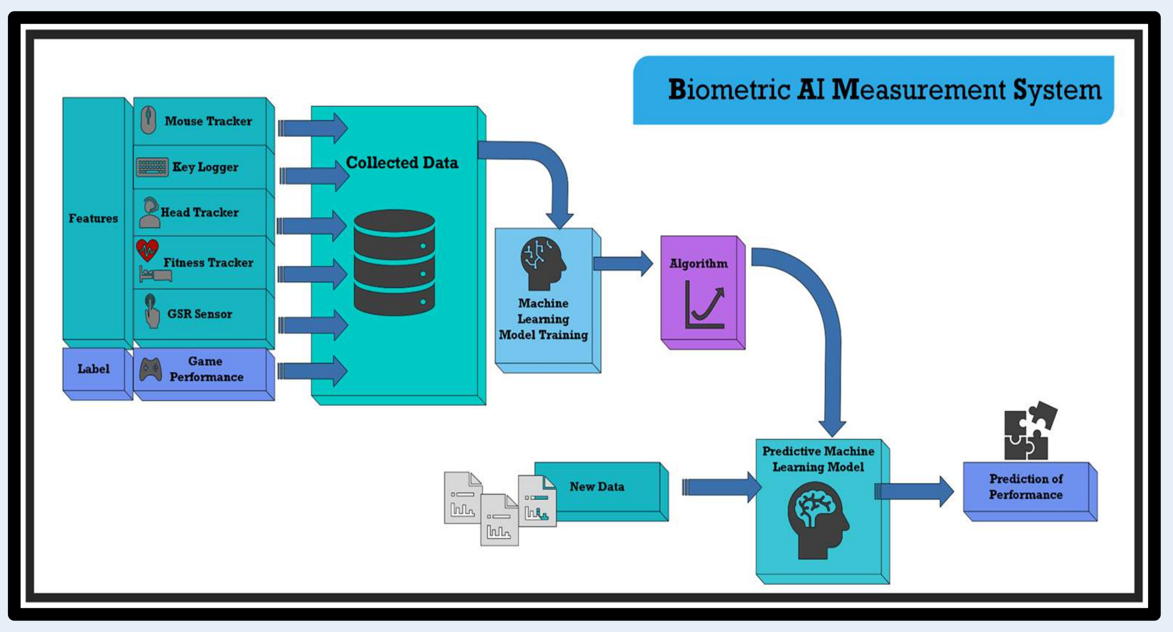

Fig.1: Block Diagram of full BAMS System

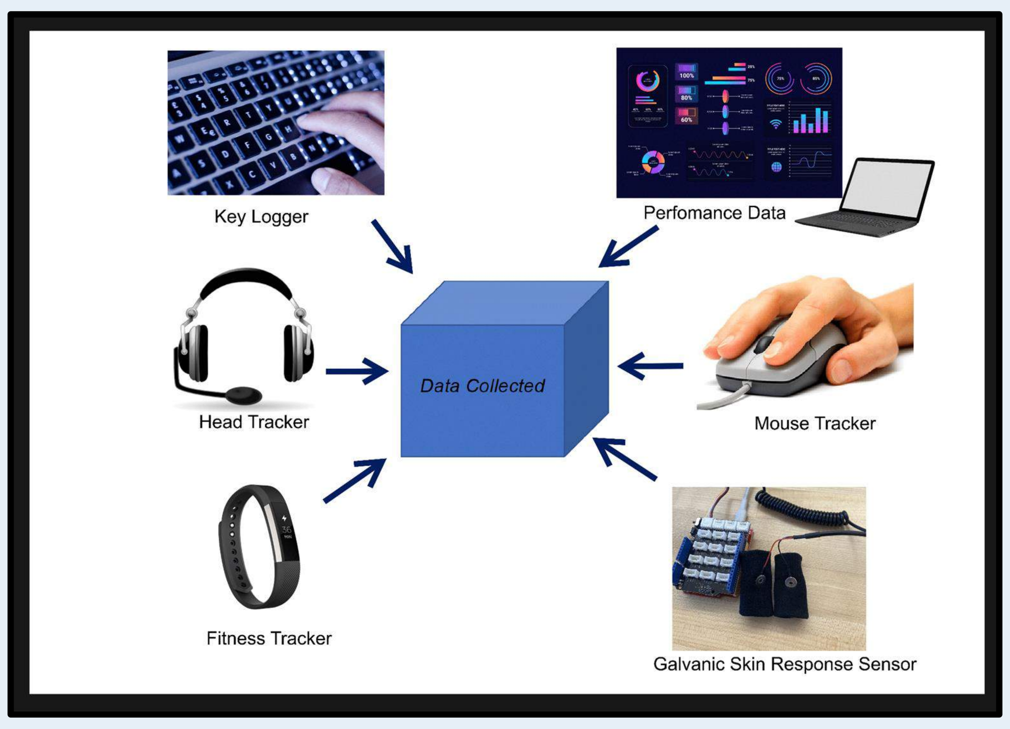

Fig.2: Overview of initial BAMS Data Collection Components

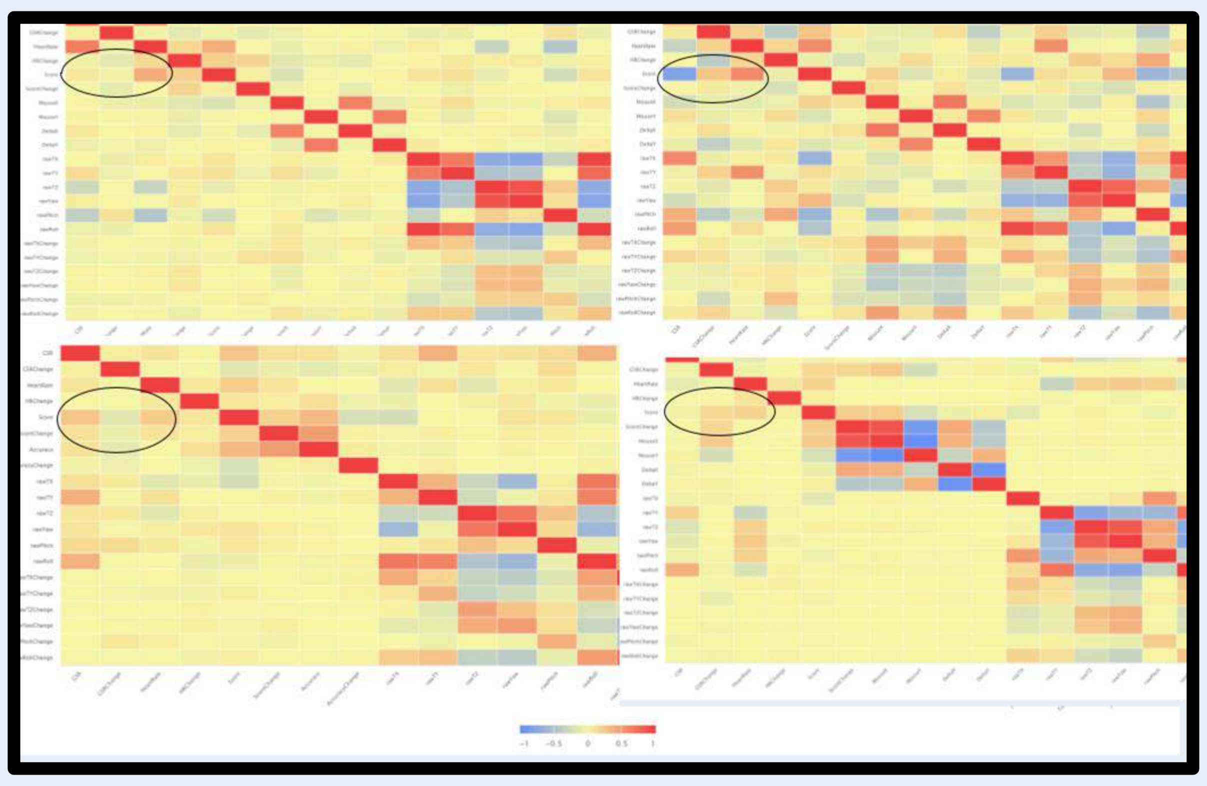

Fig.3: Heat Maps of Generated Correlation Matrices
(Consistent correlations involving score and heart rate are circled)

ELECOMP Capstone Program Director: Professor Harish R D Sunak

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NAVAL UNDERSEA WARFARE CENTER NUWC DIVISION NEWPORT, RI

Contactless Underwater Battery

Contactless Recharge/Discharge of UUV Battery

Team Members: Tucker Snow Girard (ELE), Isaiah Idelfonso-Plourde (ELE)

Technical Director: Peter Nickerson

Project Motivation

The project motivation stems from the issue with wireless power transfer, not only over the air, but also the ability to transfer this power underwater. This would allow naval submarines to launch unmanned underwater vehicles for reconnaissance and provide methods to deal with threats undetected or distract threats away from the master vessel of the main naval submarine.

The project investigates the new technology of contactless underwater discharge and recharge of an unmanned underwater vehicle battery. The ability to discharge/charge without pulling the vehicle out of the water is very beneficial for the unmanned underwater vehicles capabilities.

Key Accomplishments

Research: We began the project by researching key technologies related to this project: such as wireless power transfer, resonant inductive coupling, litz wire, unmanned underwater vehicles, coil design, 3D printing, circuit design, and battery design.

Wireless Power Transfer: Transmission of electrical power without wires as a physical link. In a wireless power transmission system, a transmitter device, driven by electric power from a power source, generates a time-varying electromagnetic field.

Resonant Inductive Coupling: The coupling between two wires can be increased by winding them into coils and placing them close together on a common axis, so the magnetic field of one coil passes through a region of space to the other coil. Coupling can also be increased by a magnetic core of a ferromagnetic material like iron or ferrite in the coils, which increases the magnetic flux.

Unmanned Underwater Vehicles: Known as underwater drones, these are submersible vehicles that can operate underwater without a human occupant. These vehicles may be divided into two categories: remotely operated underwater vehicles (ROUVs) and autonomous underwater vehicles (AUVs). ROUVs are remotely controlled by a human operator. AUVs are automated and operate independently of direct human input.

Rectifiers and Inverters: Key component in circuit design. Converts power from AC-to-DC and DC-to-AC.

Nickel Metal-hydride Batteries: We have utilized a nickel metal-hydride battery to recharge and discharge power. This battery was cost-effective for the use in our design. A more expensive and suitable battery would be a lithium-ion battery, due to their higher energy density, better performance under cold temperatures, and less susceptible to the memory effect.

Coil Design and Simulation: We designed two coils in an underwater environment using Ansys Maxwell Electronics and are currently simulating two different coil designs to find the best results. These coils generate the magnetic field that power is transmitted through using resonant inductive coupling. See **Fig 2.** for the coil simulation output.

Circuit Design and Simulation: We have started designing our wireless power transfer circuit and are currently simulating it trying to get our desired results. The circuit design contains inverters and rectifiers using full bridge diodes, inductors, and capacitors to make a practical wireless power transfer circuit.

Ferrite Cores: Our team had the plan to implement ferrite cores. However, due to their expense and properties, we decided to not utilize them. Our team spent a week deciding on this possibility. We ultimately decided that, although ferrite cores are useful, they are more useful to assist in blocking inside and outside electromagnetic interference from nearby objects.

3D Printed Coil Housing Assembly: Our team utilized TinkerCAD to design and implement a coil housing assembly. This allowed for the coils to be structurally set up to wirelessly power transfer in a safe and efficient manner. This design and learning took around two weeks to complete, allowing for a fully functional printed design.

Potting Material: Our team has planned on utilizing the MG 8800 potting compound to seal the currently constructed coils. This will be utilized if the coils are able to transmit wireless power over the air, then we can conduct ocean environment testing and will require the use of the potting compound.

Litz Wire: Our team had ordered what we thought would be the required litz wire for the coil design. However, the coil that was ordered was stranded wire and not useful for the coil design. Our team then ordered the correct litz wire, which was then soldered to the stranded wire to create a connection between the coils and the circuits.

Circuit Construction Assembly: We have created the physical circuit prototype using the schematic used for our circuit simulations. See **Fig. 4** for the circuit assembly completed.

Coil Construction and Housing Assembly: We have completed the antenna coil housing assembly. This will allow the circuits to transfer wireless power between the DC provider and battery. See **Fig. 4** for the coil assembly completed.

Prototype Development: Once the circuit and coils were assembled, we connected the coils to the circuit and began testing our prototype.

Prototype Testing: To test our prototype we used a multimeter to ensure that the voltage, current, and resistance readings are within the expected range for the circuit. We also used an oscilloscope and ran a transient analysis on the circuit. See **Fig. 4** for the prototype assembly testing.

Anticipated Best Outcome

Our group anticipates a working prototype that provides a manageable power monitoring system that allows wireless power transfer to and from the two coils provided. Allowing, for the recharge of the batteries, wirelessly, in an over the air environment. This would be an indicator that wireless power transfer is functional in an ocean water environment. With this indicator, a future team of students could continue our progress and improve our current coil and circuit design.

Project Outcome

Our group created a wireless power transfer prototype with litz wire coils with an inverter and rectifier circuit, successfully completing the prototype design. However, we did not meet the final goal of creating a working wireless power transfer prototype that is submerged in an underwater environment.

Figures

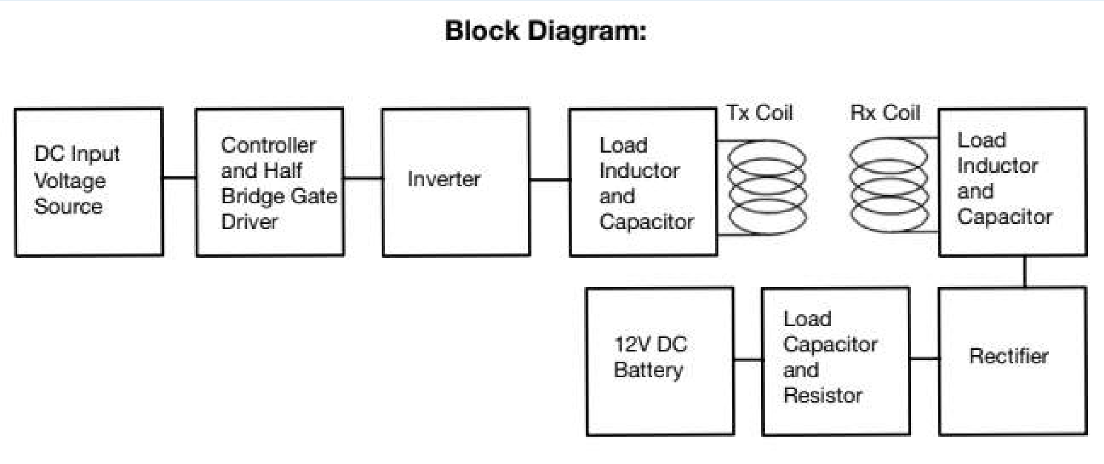

Fig 1: Bi-Directional WPT Block Diagram

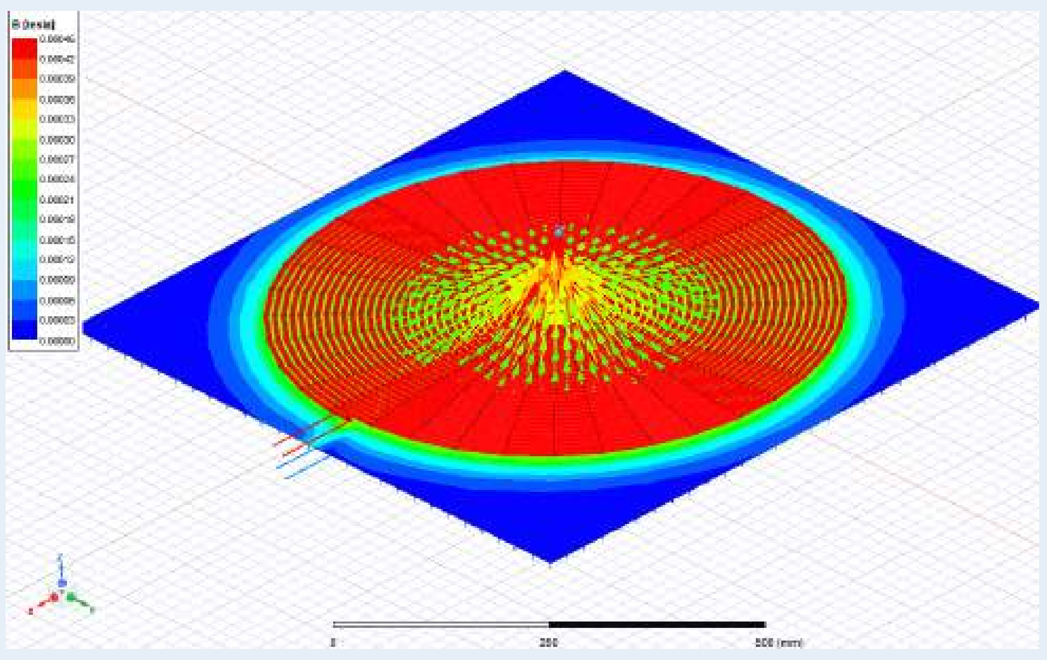

Fig 2: WPT Coil Simulation

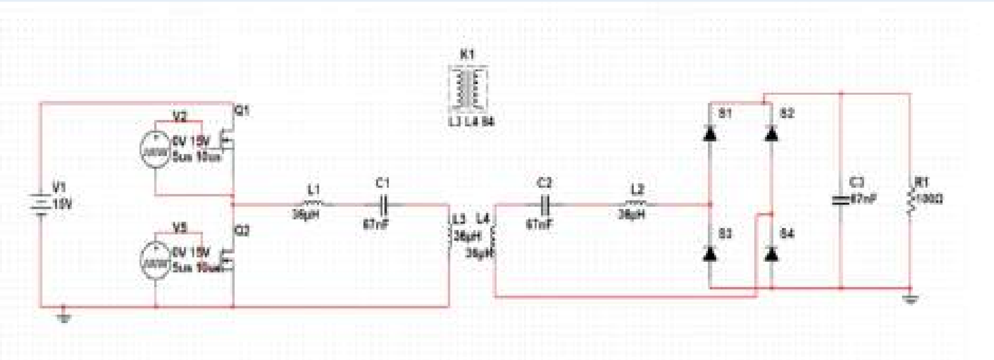

Fig 3: Circuit Design

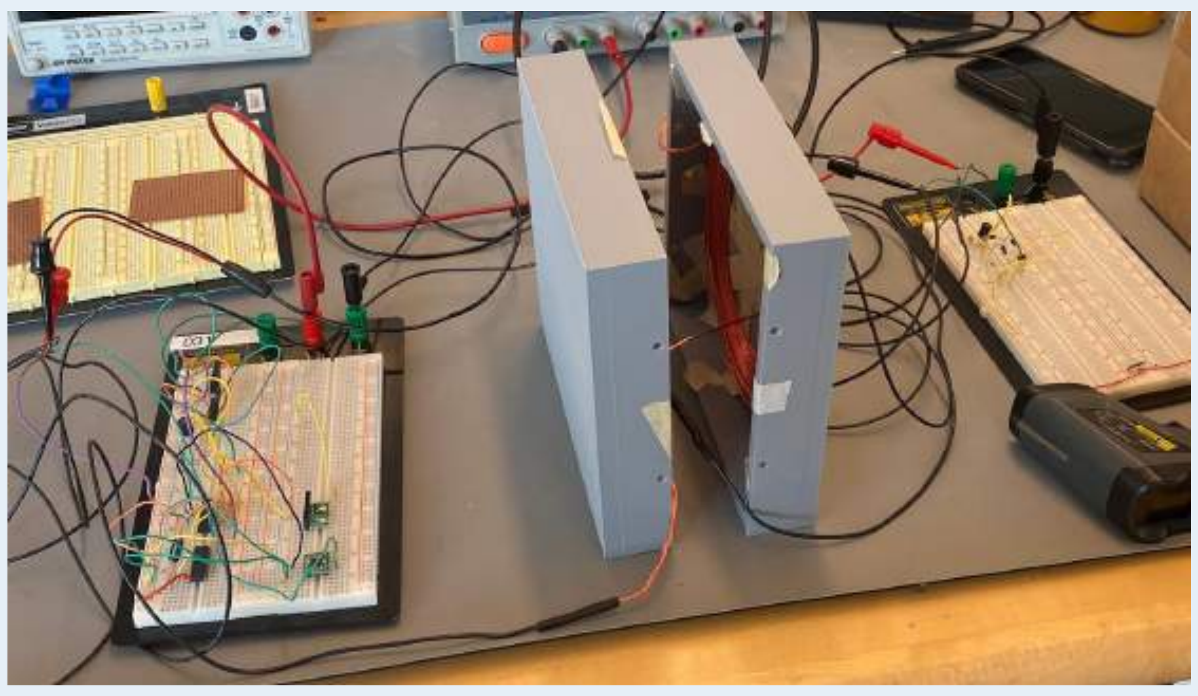

Fig 4: Prototype Design

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Piezoelectric Energy Harvesting

Applying piezoelectric materials to harvest sound energy underwater.

Team Members: Sean Doherty (ELE), Matthew Duke (ELE)

Technical Director: Reid Billings

Project Motivation

UUVs are mission-based systems that can carry instruments and sensors to monitor, inspect, and navigate underwater environments. However, the number one limiting factor of a UUV is its power capacity, keeping its mission limited in range and duration, often as little as 24 hours. Mission durations can be extended using underwater power stations, but these have yet to be implemented commercially as they lack practical power generation sources.

Our project wants to apply **piezoelectric material** to an underwater application that will provide power by converting underwater sound energy into electrical energy. Harnessing sound energy through the piezoelectric effect is the focus of this project. By harnessing the mechanical stress induce by the low frequency underwater noise that is propagated throughout the water, we may have the ability in the future to charge the UUVs batteries and provide power for other applications without the use of external power cables and other power generations sources.

Key Accomplishments

Piezoelectric Research: The Piezoelectric effect is when certain materials generate an electrical field in response to mechanical stress. In our case, the stress applied to the material will be amplified sound waves that can hopefully generate enough power to be stored in a capacitor. But because this is an underwater application that won't be relying on any sound frequencies other than low-frequency ambient noise coming from all directions, our piezo material needs to be of a certain composition that favors lower mechanical factors. Therefore, we are considering a **Lead Zirconate Titanate** based piezo (known as **PZT**) because of its larger dielectric constants and lower mechanical factors. This means higher electrical output in response to lower resonance requirements, a perfect recipe for underwater sound energy harvesting.

Sound Propagation and Sonar Research: We have gathered enough information to have a basic understanding of how sound propagates underwater and to what degree is it most prominent. Having background information on how the speed of sound underwater can vary at different temperatures and depths is going to be helpful in determining our real-world application to this project. For example, a good project experiment would be to determine which underwater location will have the largest concentration of noise present at the sea bottom. Places such as busy boat marinas will be ideal for sound energy harvesting due to the amount of sound propagation that will occur in the shallower waters

Custom Piezoelectric Transducer Design: We determined which physical design of the ceramic piezoelectric material will be the most applicable to our project. We considered either doing a spherical design or a cylindrical design. The spherical design would've given us a more omnidirectional transducer but piezoelectric spheres are more expensive and harder to manufacture. We went with the Cylindrical design which will give us the best array for picking up the sound frequency.

Sound Data Research: We researched available sound data produced produced by small prop driven underwater vehicles as a reference for what frequency we could expect to be produced by our Diver Propulsion vehicle (DPV) since the the data for our vehicle was unabible and outside our expertise to obtain. Based on sound date from other underwater propulsion systems we estimated what the frequency our piezo-transducer will resonate with.

Piezoelectric Resonant Frequency: The resonance (Q value) of our transducers required had to be within the bandwidth of the Frequencies produced by the diver propulsion vehicle. The radial resonant frequency was given for each piezoelectric cylinder which are 11 kHz, 42 kHz, and 51 kHz.

Fabricating Transducers: Components include two end caps, two neoprene gaskets, and the piezo cylinder which are all sandwiched together using a bolt and a lock nut. We also used neoprene rubber as gasket material and clear silicone for sealing any gaps. We encapsulated the entire transducer in a polyurethane so that it can be sustained underwater and remain completely dry while not affecting overall resonance. In total we constructed six transducer.

Researching Parts for PCB Design: This was a crucial part which led to our team being able to start constructing the PCB. Finding a chip that could do everything we needed in one was essential. This chip (LTC 3588-1) can bring our low voltage output and boost it up to something that we can use to power an Arduino Pro Mini. The Pro Mini is a chip that will allow us to connect a bluetooth module (HC-06) and read the data output through the Arduino software.

Designing PCB: Designing the PCB which is a critical component to our project. This PCB has a chip which acts as a rectifier and buck converter to take our low voltage output from our piezo and turn it into a voltage in which we can power a microcontroller. Once we gather enough voltage to power our microcontroller we will be able to monitor the data being received through a Bluetooth chip which will also be connected to the board.

Anticipated Best Outcome

The anticipated best outcome of this project is to develop a piezoelectric underwater sound energy harvesting model that will feature a resonator, piezoelectric material, AC/DC rectifier, DC/DC converter, and a Micro-capacitor. This prototype will be intended to be tested and possibly support a proof-of-concept. We would like to make the prototype exhibit the sound energy harvesting capabilities of converting sound energy into power via the piezoelectric material.

Project Outcome

We did meet the goal of fabricating six different physical piezoelectric transducers and successfully designing and soldering a PCB. However, We did not meet the goal of connecting the transducers with our circuit board design and testing its capabilities in the water alongside our underwater vehicle

Figures

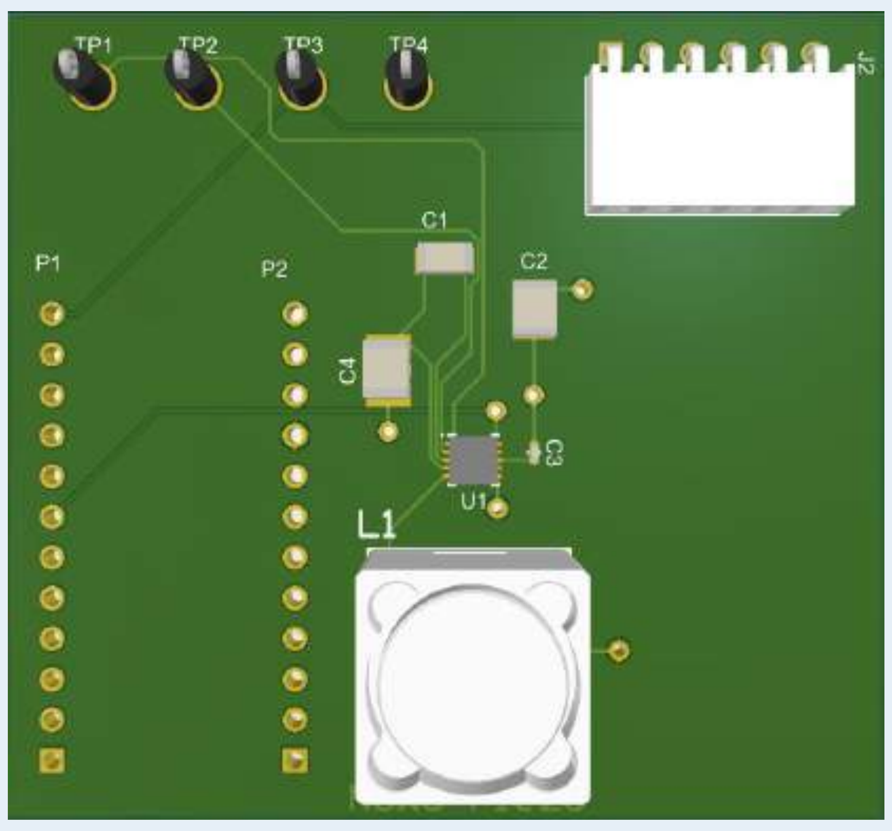

Figure 1: Our PCB model

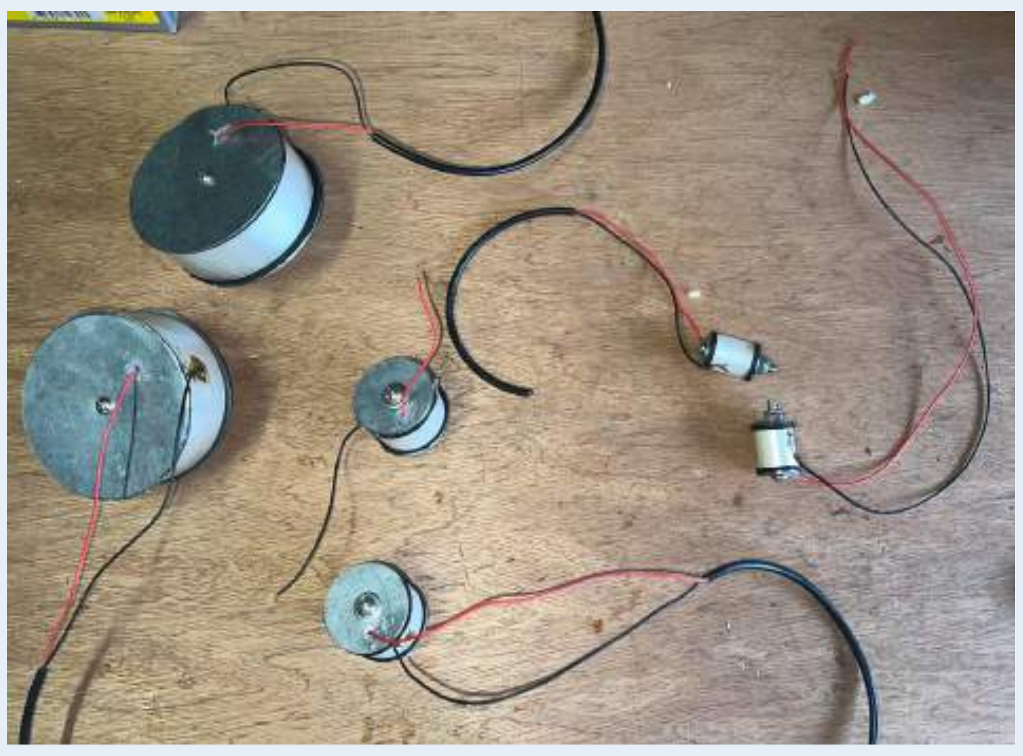

Figure 2: All assembled transducers

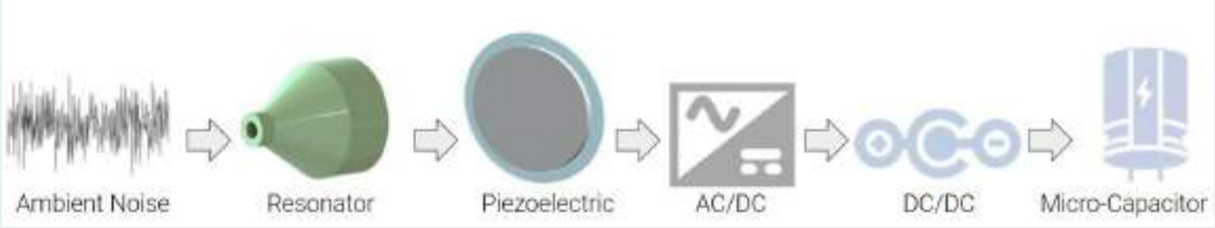

Figure 3: Schematic of sound energy Harvesting process

Figure 4: Our Diver Propulsion Vehicle (DVP)

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TUESDAY, MAY 9, 2023

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Annunciator

Phoenix Electric Corp.

Team Members: Nicholas Costick (ELE), Daniel Wilkins (CPE)

Technical Directors: Sandro Silva ('02) | Consulting Technical Director: Mike Smith ('01)

Project Motivation

Phoenix Electric Corporation believes there is a gap in commercially available annunciator products. An annunciator panel with a plethora of customization options and custom software for user configuration would provide an exciting breakthrough into the market. By creating a first party solution, reliance on other manufacturers is significantly reduced which helps guarantee a product unmatched by competing solutions. Careful design and component considerations can also bolster the reliability and quality of an annunciator, both of which are strong motivators in the market. Additionally, the ability for the user to cater the product to their specifications increases the use case exponentially. This results in a low barrier of entry, and a highly customizable device capable of reaching the mass market. By creating such a product, Phoenix Electric expands their diversity and share in the electronics market, furthering the goals and aspirations of the company.

Key Accomplishments

Virtual Annunciator: Alongside a complete overhaul of the graphical user interface, a virtualization of the Arduino faceplate was implemented (Fig.3). This allows the user to project the panel on multiple displays and to test other features with greater accuracy. The Virtual Annunciator is also seamlessly integrated to the board customization, providing a new and fluid experience.

Embedded Code Rewrite: To make accommodations for the growing needs of the Annunciator platform, a complete rewrite of the embedded code was necessary. An overhaul using object-oriented programming and dynamic data structures provided room for growth and future development.

Alarm Sequences: Using the framework provided by the embedded code rewrite, the 7 new alarm sequences were developed to meet industry standards. The embedded code rewrite provided both a massive improvement in sequence memory usage and ease of development, making room for further additions if necessary.

Modbus implementation: To integrate the Annunciator into an existing network the Modbus communication protocol had to be implemented into both the GUI and the embedded code. This would allow the product to seamlessly integrate with existing systems without further modification, helping expand its potential market impact by reducing the initial cost of entry.

LED Brightness Analysis: The LED brightness of the current prototype annunciator was insufficiently dim. New resistor values were calculated in accordance with the datasheet to achieve a normalized luminosity of 20mA per LED.

12V to 9V Redesign: Because the Arduino uses an inefficient form of voltage regulation, power is wasted bucking down 12V to its 5V operating voltage. By supplying 9V instead, less power is wasted and the system becomes more efficient.

Memory Upgrade: The formerly selected memory IC operates on 3.3V, which requires a level shifter for integration into our predominantly 5V system. The FM25W256-GTR was selected to replace it, which operates on 5V, and doubles our memory capacity.

Power Converter Design: A converter schematic was generated and COTS parts were selected to fit the input/output specifications. After testing the prototype via a breadboard configuration, the design was implemented into the Circuit Maker software to build a PCB (Fig.1).

Buzzer Redesign: Former, panel mounted buzzer solution was bulky and complicated. Instead, a board mount solution was found to be much better suited for this application. It eliminated the need for a connector and panel design considerations for mounting (Fig 2).

Main Board Redesign: Many changes were made to the main board to improve fit and functionality. These changes include cutting out a larger portion of the board to guarantee proper clearance for the new USB pigtail Arduino solution. In addition, a fourth push button was added to allow for an alarm silence option, and a new board-mounted buzzer solution was implemented. Finally, the board's layout was overhauled to accommodate the new memory solution, and to better separate the RS-485 components from the fiber components for clarity (Fig 2).

Display Board Update: The display board has been changed to accommodate the new resistor solution found from the LED brightness analysis. In addition, the board's resistor and routing layout was redone to improve buildup and visual appeal.

Anticipated Best Outcome

The ABO is an annunciator panel capable of monitoring up to 48 channels for faults. These faults will be handled with one of the seven on board alarm sequences. Accompanying the board will be a graphical user interface capable of showcasing a front-end virtualization and configuring the stored parameters. The Annunciator will also house a custom power supply designed to convert 120 VAC or 125 VDC input to 9VDC and 5VDC power rails. An updated display PCB will contain a brighter and more consistent LED solution. Additionally, the redesigned main PCB will integrate a larger FRAM chip, a new panel interface connection, and be capable of MODBUS and fiber communication.

Project Outcome

With strong coordination and excellent direction from our technical directors, our team was able to achieve the ABO for the project. All the requirements given at the start of the year, and even some additional features, were delivered to Phoenix Electric Corporation.

Figures

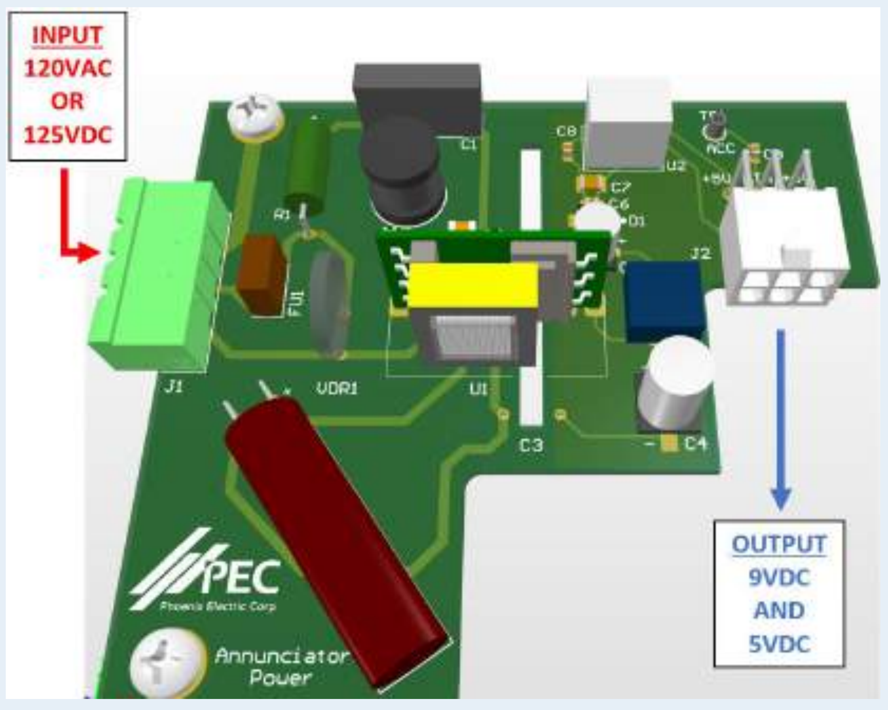

Fig.1: Power Converter PCB Design.

The final version of the PCB power converter. It takes in either 120VAC or 125VDC as input, and outputs voltage onto two separate rails.

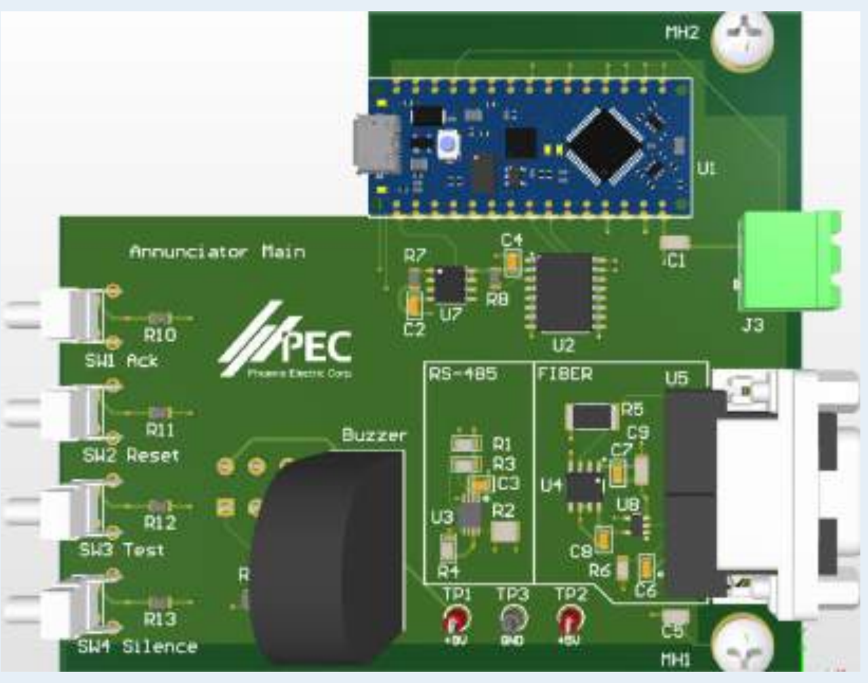

Fig. 2: Main Board PCB design.

The final version of the PCB Main Board. This version houses a new board mounted buzzer design, a new 5V FRAM solution, and an additional pushbutton

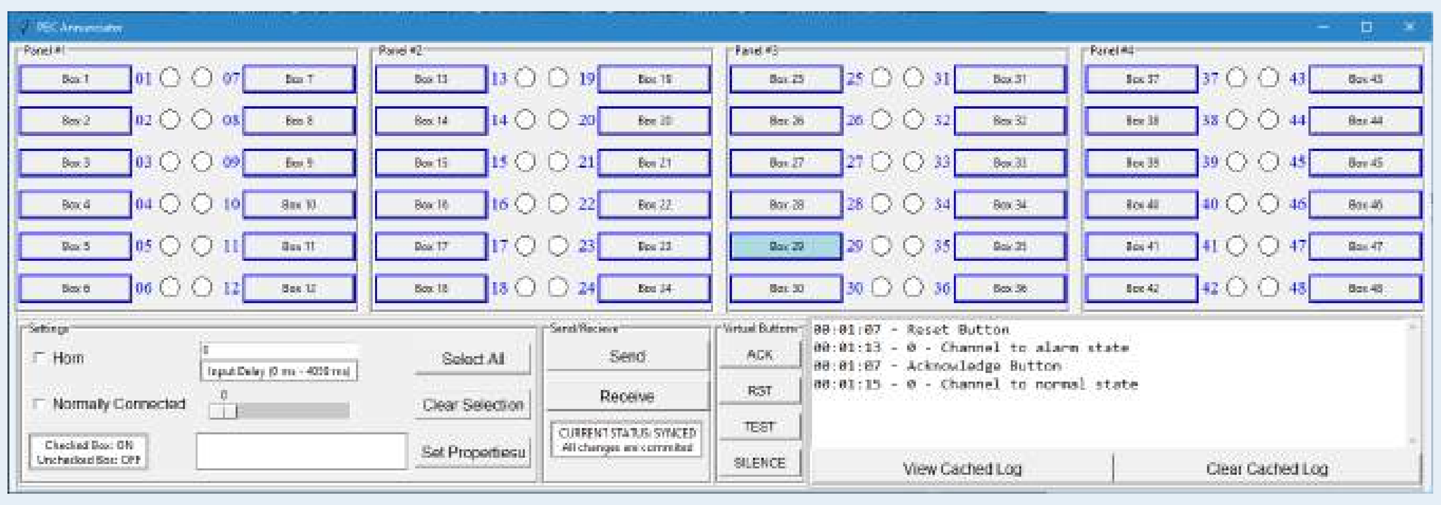

Fig. 3: GUI for the Annunciator

This is the virtual Annunciator developed to configure and maintain the product, according to the customer's needs. It features a live time representation of the annunciator faceplate, several customizable features for each of the channels, and an area to display the device's activity logs.

Low Level Biosignal Acquisition

Team Members: Hannah Morrissey (ELE), Jayden St. Germain (ELE

PISON

Technical Directors: Tanya Wang, Jonathan Eagle

Project Motivation

Pison Technology has engineered a wristband with electrodes on it that reads bio signals from the body and communicates them to a cell phone application. This company's focus is on neural interfaces that fixate on gesture recognition and translating data from the body's natural physiological electricity into interpretable results.

We are working to get a fully functional circuit in LTspice to send various signals through and reverse engineer it to get the outputs that we want. When collecting these gesture related bio signals, one of the most crucial components is to attain the most accurate, representative signals while filtering out all other background noise. It is important to understand how signals will be received from the body, how they can be processed in the device and then converted into data that makes sense.

Key Accomplishments

- **Build analog circuit in LTspice**
  - We were provided with a schematic with all of the circuit components and were tasked with building the circuit and finding all spice models we would need on the internet.
- **Find a suitable instrument amplifier to put in spice model**
  - Had to view the specs of the amplifier provided, then find a similar amplifier that could replace it with a spice model.
- **Sensitivity Analysis of Circuit**
  - Changed values of different components in the circuit to see how the output changed.
- **Circuit Characterization**
  - Tested how the voltage would change through each component/buffer/amplifier in the circuit and observe what putting different inputs would do. *Figure 1*
- **Component research and familiarization**
  - Learned how to review data sheets and get familiar with the specs of each part that to be used as well as what they do.
- **Created bode plots for cutoff frequency**
  - Used spice commands to calculate the frequency cutoff of the circuit that we had constructed. *Figure 2*
- **Familiarized with pizza board and test circuit**
  - We were given the physical board and learned what each part of both boards did.
- **Learned how to use spectrum analyzer**
  - Learned from supporting TD how the spectrum analyzer works and what it does. *Figure 1*
- **Familiarized with understanding noise**
  - Did research on what noise is in terms of electronics.
- **Soldering parts onto test board and pizza board**
  - Improved soldering techniques and would make repairs to the PCBs when soldered joints cracked or came apart. *Figure 4*
- **Finished noise testing**
  - Connected circuit to spectrum analyzer in multiple configurations, given a 20 mV_{PP} input at 300 Hz, as well as grounded input and tested the noise. *Figure 3*
- **Identified problem during continued testing**
  - Replacement wires were too big for board. *Figure 4*
- **Did research on possible solutions to problem and looked at amazon for parts.**
  - Looking to see if we could find suitable BNC cables for testing.
- **Started training with Fusion 360 by Autodesk**
  - Started by trying to figure out how to edit Pison's PCB model of the Pizza Board.
- **Did research on guarding**
  - Looked into what guarding is as well as looking at a specific data sheet that was provided that shows how it is typically implemented in PCBs.
- **Drafted possible designs for redesign of the Pizza Board for testing**
  - Brainstormed several new designs for a test board, one with BNC connectors and one with spring contact connectors.
- **Continued Fusion 360 training**
  - Fusion 360 is can be difficult to learn as there are not many up to date resources available to learn from. Watched introductory tutorial videos and then created a simple example PCB circuit to continue the learning process.

Anticipated Best Outcome

The best anticipated outcome for this project is a developed system that can filter out all ambient noise coming from wires, cell signals, etc. and pick up on our bodies biosignals which are a very low voltage. This will be achieved with the help of the LTSpice simulation as well as testing on the physical circuit.

Project Outcome

We achieved the LTSpice simulation as well as some testing of the physical circuit but overall, we have not met the Anticipated Best Outcome as we do not have a finalized system.

Figures

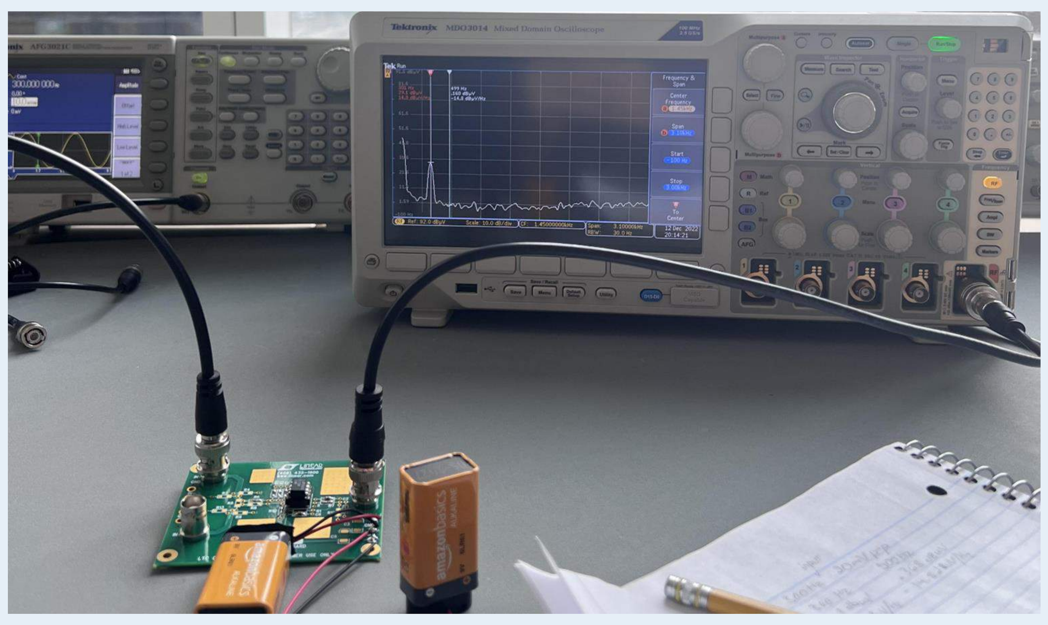

Figure 1: Testing the Demo Board

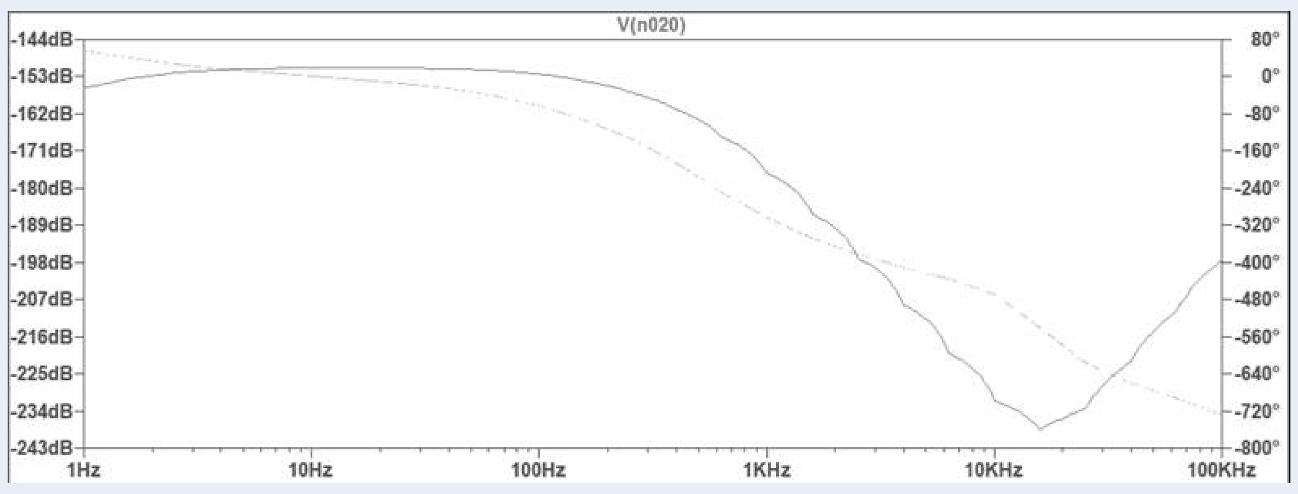

Figure 2: Frequency Cutoff Bode Plot

Component Being Tested	Input Grounded		Sin Input (20mV PP @ 300Hz)		
	300Hz	500Hz	300Hz	500Hz	Units
Function Generator hooked straight to spectgrum analyzer	NA	NA	15.1	0.368	dBuV
	NA	NA	-0.0367	-14.8	dBuV/Hz
Just Test Board	1.65	0.559	32.2	0.655	dBuV
	-13.5	-14.4	18.2	-14.1	dBuV/Hz
Just Pizza Board (Channel 1)	0.586	-0.487	13.2	0.238	dBuV
	-14.3	-15.2	-1.15	-14.6	dBuV/Hz
Both Test Board and Pizza Board in Series (Channel 1)	1.13	-0.0411	36.1	-3.63	dBuV
	-13.9	-14.9	21.1	-18.6	dBuV/Hz
Just Pizza Board (Channel 2)	14.3	5.89	5.06	0.714	dBuV/Hz
	-0.271	-8.43	-10.3	-14.3	dBuV/Hz
Both Test Board and Pizza Board in Series (Channel 2)	40.6	20.3	40.2	-3.08	dBuV
	25.6	5.25	25.3	-15.9	dBuV/Hz
			Frequency being looked at on spectrum analyzer		

FIgure 3: In-Circuit Noise Testing

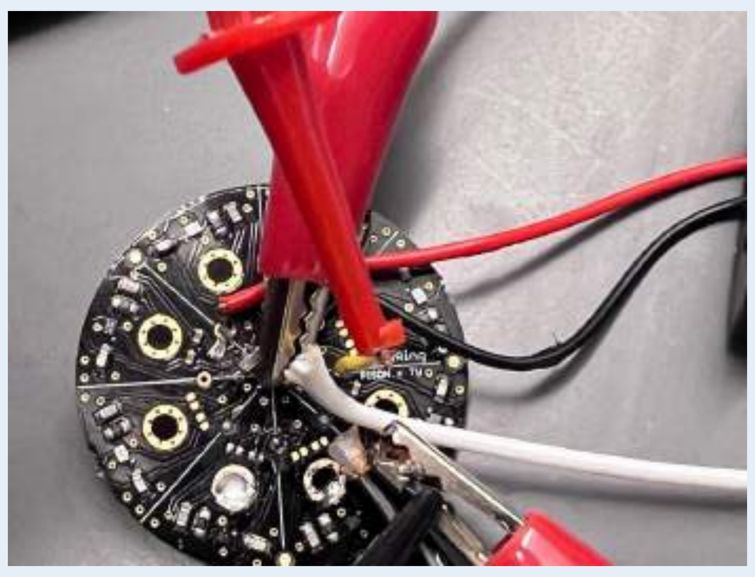

FIgure 4: Testing the "Pizza" Board

ELECOMP CAPSTONE SUMMIT
TUESDAY, MAY 9, 2023

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Crisis Data Relay

RDSI

Team Members: Jonathan Pollard (CPE), Matthew Cordeiro (CPE)

Technical Director: Bruce Torman

Project Motivation

RDSI has strong connections with local Public Safety efforts, such as the Rhode Island Office of the State Fire Marshal. RDSI's President, Mr. John Evans, is a volunteer Fire Chief for the Town of Lyme, CT, and has close relationships with first responders for fire and emergency medical service situations. The incident management sector has a constant need for new technology, and organizations within that sector have received little innovation to their tools in the recent years. Designing and developing an application for firefighters will be beneficial in bringing the departments toolset up to modern day needs. It will also allow for firefighters to quickly receive information on the dangers they face and hopefully from a little safer distance by using the camera. The successful outcome of this project will have a lasting impact on the incident management sector and opens the door for further development of similar applications for Emergency Medical Service, Police, Security, or Military needs.

Key Accomplishments

● **Backend Research**: Once tasked with creating and developing a mobile application
based on the Emergency Response Guidebook (ERG), it was evident that we would need a database that was not only expandable but also reliable. We researched various database packages and styles before deciding on using ObjectBox for storing the ERG's information in our applications database.

● **Database Implementation**: Using ObjectBox, we were able to insert data from the ERG into a backend database for our prototype application. We were able to implement how to store the ERG in a way that allows our created database to be changed or updated by any programmer for future maintenance and development. In the database all data is stored by entity, we have a Chemical entity **(Fig. 3)** which stores all the placard ID's with their associated GUID number and chemical name. Other entities that we stored are a Guide entity for the orange pages evacuation distances, smallIsolation and largeIsolation entities to cover the entirety of Table 1 in the ERG, Table2 entity for table 2 information, and TableThreeIsolation entity for table3 information. After the user supplies the placard ID the application is able to use all of this stored information to return any possible needed information for the incident at hand.

● **Camera Interface**: After Research the camera package was used to interact with the on device camera. This allows for previewing the camera screen to the user and letting them take a picture with it. The camera package also supports zooming in and out while previewing and taking the picture. Once the picture is taken it is stored on the device and the image path can then be retrieved for later use. This interface is needed in order to capture the image of a placard **(Fig. 4)** so that the ID number can be extracted from the Image and used later.

● **Text Recognition**: Using the Google ML Kit package in flutter allows for text to be detected from an image and stored in a string. This allows the application to pull the 4-digit ID number off a placard and use it as a key in the backend database.

● **Manual ID input**: Created a text controller to read and store manually inputted ID numbers from the user on the application screen. When the user selects to manually input the ID they are prompted on where to enter the 4-digit ID number

● **Prototype Application**: Over the course of the year, we developed a Flutter project that would automate all of the functionality of the ERG flowchart, which is what a firefighter would need to navigate through once arriving on site at an incident involving a placard **(Fig. 2)**. This application starts out with a warning as well as the appropriate numbers to call if two placards are involved. After this the app guides the user to either take a picture of the placard or manually enter the ID themselves. Once the user confirms the picture
taken or manually enters The ID, the 4-digit number is read from the image or entered
text and is used as a key to search the database. The app will then guide the user through the functionality of the ERG to get all pertinent information. The flow of how this information is given to the user mimics the ERG flowchart **(Fig. 1)**. This application will show the user the appropriate evacuation distances based on the placard scanned, as well as Isolation and protective action distances from table 1 and table 3 if applicable for that ID number, and the hazardous chemical gas this material will turn into when reacted with water again if applicable for that ID number.

Anticipated Best Outcome

Design and develop a prototype phone application that will allow the user to take a picture of a placard and display all the information and hazards the user needs to know associated with it. Using the prototype phone application, demonstrate that the needs are met for the end user and determine if additional functionality is required to accommodate all the end user's needs. Identify and highlight additional areas of the incident management sector like Emergency Medical Services and Police which may require a similar application, using the original prototype as a framework for specialization.

Project Outcome

The Anticipated Best Outcome of the project was achieved. A prototype phone application has been created which will allow the user to take a picture of a placard and display all the information and hazards the user needs to know associated with it. The project still has the potential to grow further with more implementations of needs of first responders.

Figures

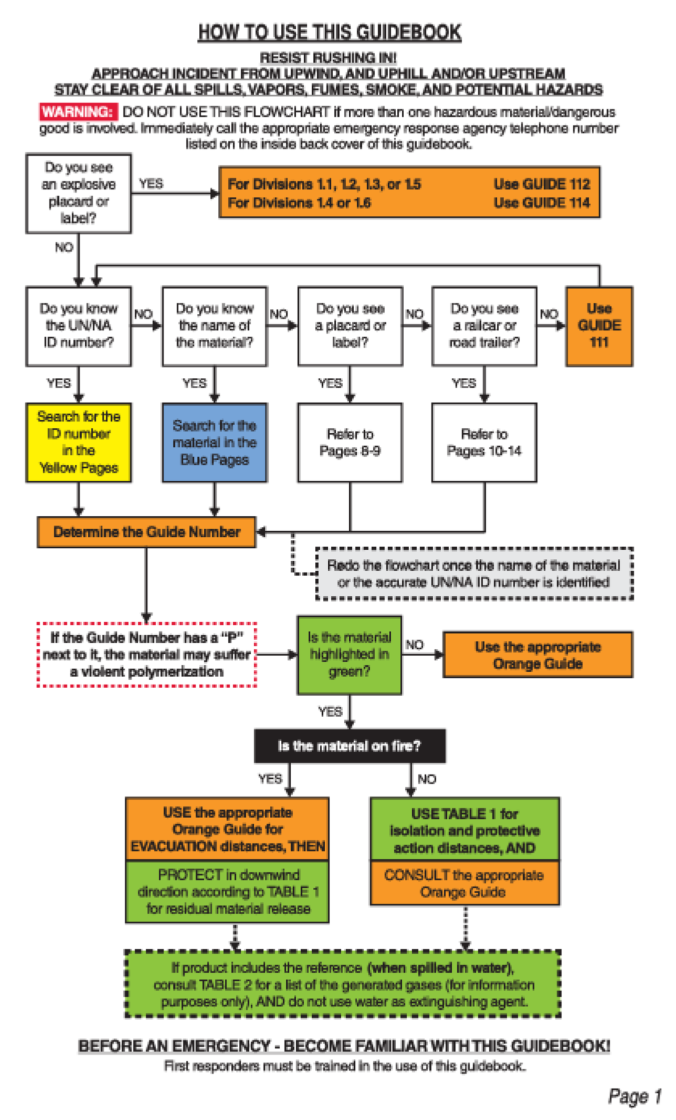


Fig. 1: ERG Book Flowchart

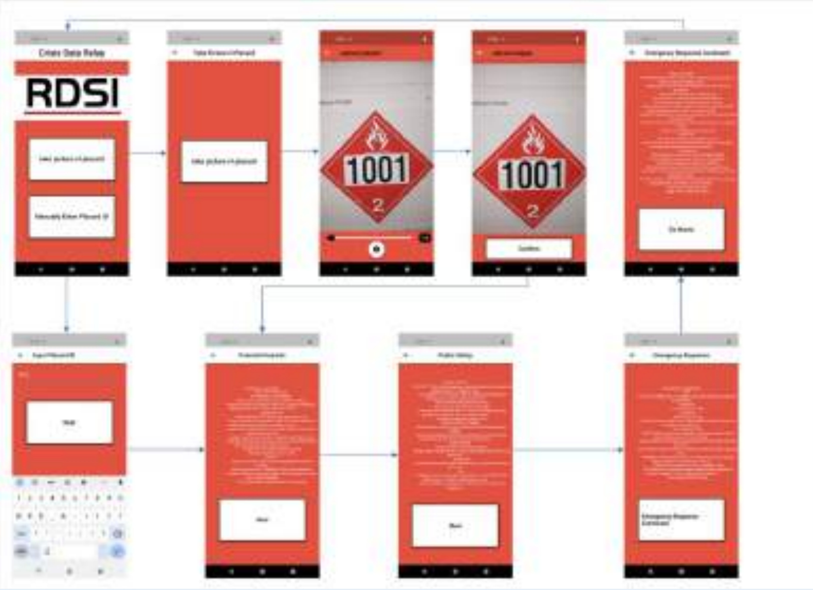


Fig. 2: Prototype Application Example Usage

```
Chemical(
    placID: 1104, guideNum: 129, poly: false, chemName: 'Amyl acetates')
1104  129   Amyl acetates
```

Fig. 3: Coding Snippet from Database

Fig. 4: Placard with ID Number 1162

ELECOMP CAPSTONE SUMMIT
TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Submarine Network Fault Prevention

Team Members: Rudy Reyes (CPE), Thong Nguyen (CPE)

Technical Directors: Matthew Pistacchio & Matt McAdams

Project Motivation

The US Navy fleet, and especially its Submarine Fleet, heavily depend on its ability to reliably communicate with other operational environments. With so many adversaries worldwide, all trying to breach our communication protocol around the clock, it is paramount that the network remains secure to ensure constant communication in case of emergency. This, however, is not possible without a resilient network infrastructure to connect all the sub's components together, such as when a SONAR detection needed to be communicated with the vessel's Combat System to determine the correct course of action. To achieve this, the project focuses on the issue of network fault prevention and analyzing the condition in which a network, especially a switch, can fail by using modern day concepts and knowledge of data science, specifically pattern recognition, to a network dataset to identify and report evidence conclusions on the factor that led to the point-to-point connection being compromised.

Key Accomplishments

The team has completed an exploratory data analysis paper, which includes preliminary findings and insights into the chosen UNSW NB-15 SNMP data set. The unparsable data was cleaned up and checked for any missing key data points. In addition, the team also removed all data point with zero as it would have been able to have a great impact on the project.

Another significant technical accomplishment was figuring out how to implement a port bandwidth utilization calculation. This calculation was used to assist in identifying the bottlenecks that was affecting the system's performance.

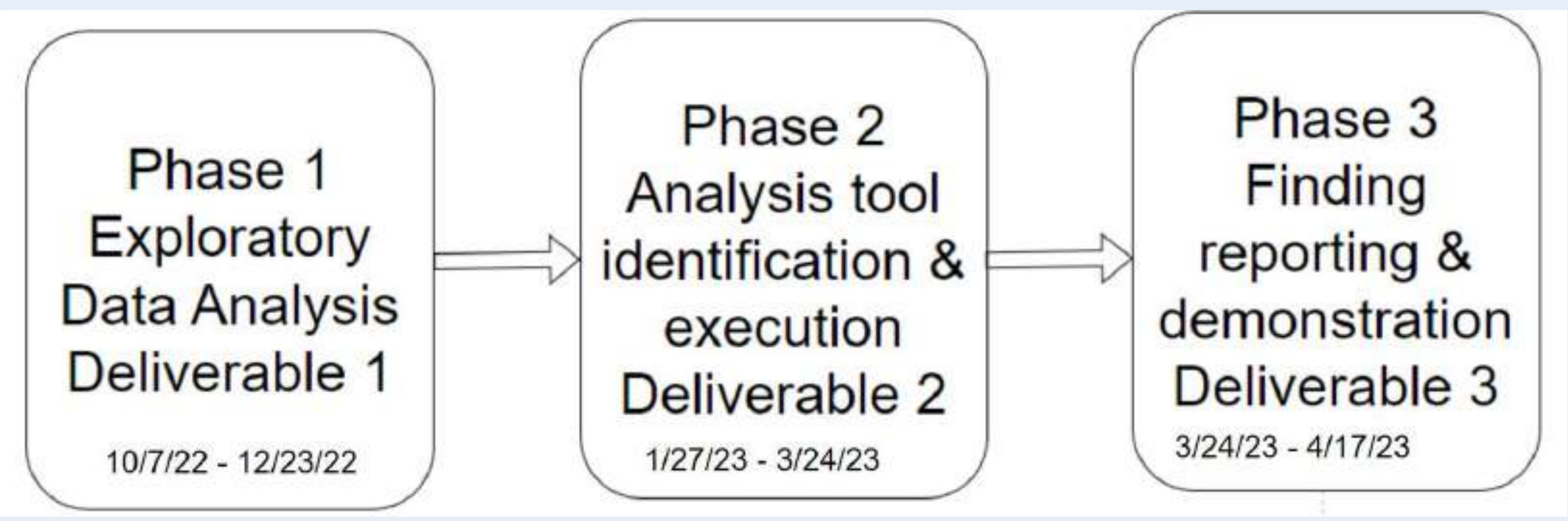
The team had completed a demonstration presentation, showcasing the project's capabilities and key features. Finally,
the team composed a forma white paper, which presents the project's methodology, research and findings.

To showcase the relationship between utilization and jitter, the team implemented a moving average function of 5000. in figure 1, we can see that The patterns of network utilization increasing having a positive(increase) in jitters is observed here. However, there are noticeable "spikes", which could potentially be explained by normal network demand and usage as they are not continuous unlike an attack like DoS, which is designed to load up the network constantly. Note that there is a short spike of both jitter and utilization at the very beginning, also probably due to all the devices within the network exchanging information at the same time when the whole network "turns on". note that some time jitter will rise before utilization and other, utilization will increase first, both they always increase within a short time frame of each other. this
suggest that while one does not "caused" the other, there is a deeper correlation between jitter and utilization.

Figure 2 is a plots between input packets counts and packet drop, colored coded by attack vector and the blue line represent polynomial regress (that came out to be a case case of polynomial regress with degree of 1, in another word, a linear regression). a clear linear trends can be observed between packet count and packet drop, this made the r^2 value for the regress to be very good. using this regression, we can now determined either the packet drop or packet count, even outside the range of provided dataset using the equation Y=0.5263*X

The last figure highlighted the trend between bandwidth utilization and packet loss over time. it is very clear that the higher the utilization, the more packet loss occurred. Furthermore, these two somewhat follow an exponential trend, i.e. from 20% to 40% utilization, there are little jump in packet loss, but from 60% to 80% utilization, the amount of packet loss doubled. it is important to note that all of the data point with high packet loss are shown and all of the data point occurred after 25000 second, the time where malicious attacks started to happen.

In summary, the study found that higher input utilization resulted in higher jitters and packet loss, with jitter remaining acceptable up to 70% utilization but quickly becoming unacceptable as it approaches 80%. However in some cases, jitter remained low despite increasing utilization, this may be due to attacks coming from external sources. Packet loss on the other hand, showed a linear relationship with utilization from 0% to 80%. In the beginning of network operation, both jitter and utilization were high due to device exchanges, but quickly dropped as exchanges calmed down. There is a nominal independence between jitter and utilization, meaning one can increase without causing an increase to the other, resulting in a network with high jitter and low utilization, or vice versa.



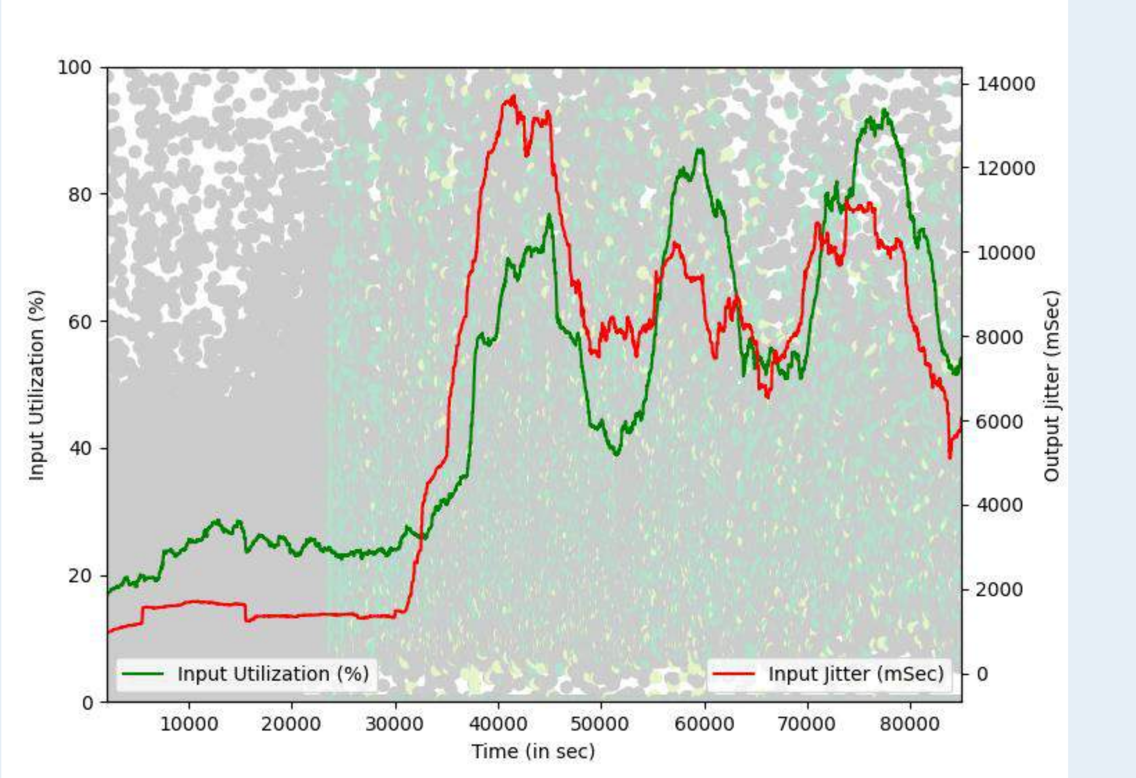
Anticipated Best Outcome

The final deliverable will consist of two parts, the first is the analysis of curated data that would simulate that of a submarine communication system and finding similar characteristics this code then uploaded into GitHub for ease of access by the public to either improve upon or draw inspiration from. The other part of the final deliverable is the White Paper in which we formally describe our research and findings, we will also have comments about alternative machine learning models and how that could be used for the same data set for better accuracy.

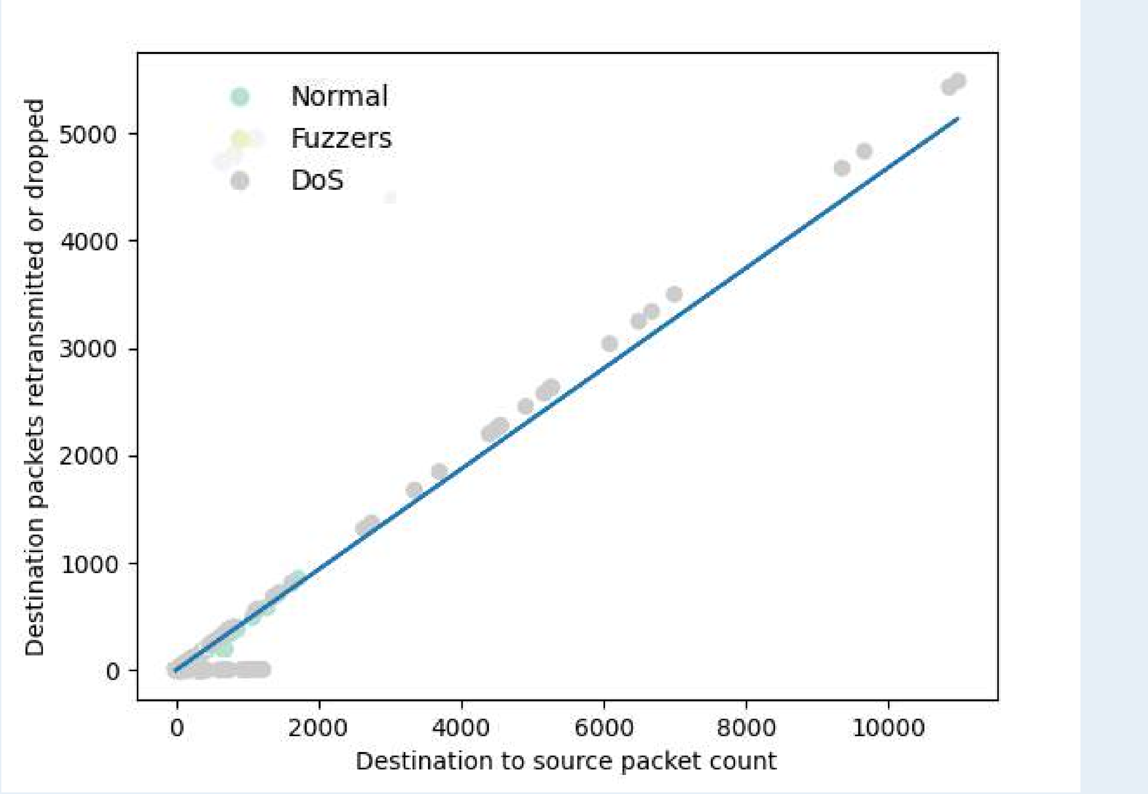
Project Outcome

The Anticipated Best Outcome was achieved as the team was able to analyze curated data from publicly available datasets and identify some network characteristics that can lead to and be caused by switch failures and highlighted them using appropriate graphs.

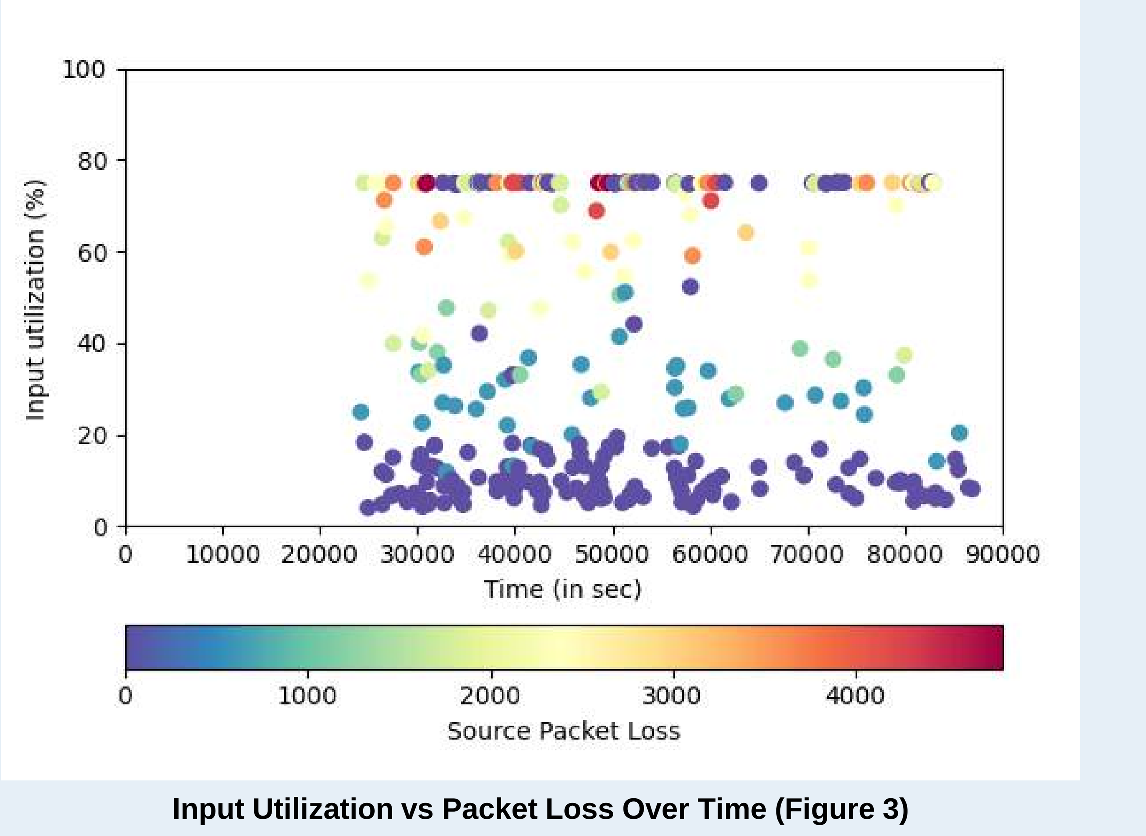
Figures



Output Utilization vs Loss Over Time (Figure 1)



Input Utilization vs Packet Loss Regression (Figure 2)



Input Utilization vs Packet Loss Over Time (Figure 3)

ELECOMP CAPSTONE SUMMIT
TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Project Socket Steward

Smart Power Monitoring & Disconnect System

SOUTH COUNTY GADGETS

Team Members: Brian Bissonnette (ELE), Liam Brennan (ELE), Logan Brooks (ELE), Samuel Isaacson (ELE), Olugbenga Olufasola (CPE), Andrew Ribeiro (ELE)

Technical Directors: Jamie Murdock BSEE URI '84 | Joe Gundel MSCPE FAU '10

Project Motivation

The goal is to design a prototype of a consumer plug-in smart power monitor and disconnect to prevent electrical hazards and to also let consumers safely utilize appliances without needing to abide by strict, and sometimes unusual, safety requirements and measures that most either are unaware of or just ignore for convenience. The hazards this product aims to protect from and prevent are; house fires, ignitions, electrocution shock, surges, and appliance damage.

By creating this product, it seeks to challenge the current industry standards that allow for cheap, faulty, and down-right dangerous devices to go to market and get used by the unsuspecting and trusting users. Through the social features of the product, its secondary goal is informing the general public who utilize the products of hazard that it actively prevents, letting the users know what happened, letting them know what was prevented, and knowing how to take care of the issue for the future, without becoming an inconvenience or annoyance.

Key Accomplishments

- **Fault Demonstration Bench**: Creation of a demonstration board to simulate various active faults that are not triggering the circuit breaker, a ground fault, or an arc fault. These faults or failures are most common in residential homes with either outdated wiring, or appliance cords. (**Fig 1**)

- **Wiring / Connections:** Successfully wiring all components correctly. **(Fig 4)**
  - **Temperature Sensing:** Creation of four voltage dividers using thermistors and 10kΩ resistor for temperature sensing. Voltage divider output is converted to Celsius. Temperature sensing located at the hot and neutral terminals on Eaton receptacle, at the head of the Socket Steward plug, and an ambient temperature sensor.
  - **LED Reader:** Creation of two voltage dividers using phototransistor, which outputs voltage based on illumination from the LED's on the Eaton receptacle. This output is inputted into an analog-to-digital comparator, which sends 3V when the output of the voltage divider passes threshold to communicate with the Adafruit board via a digital extender board.
  - **RMS Voltage Sensing:** Voltage sensor connected in parallel with Eaton receptacle to evaluate voltage coming from home outlet.
  - **RMS Current Sensing:** Current sensor connected in series with hot wire to Eaton receptacle to monitor variation in current at home outlet.
  - **Dummy Load Test with Relay:** A 100 watt resistor with thermal fuse and relay is used to test voltage and current before the appliance is connected to Socket Steward to ensure proper operating voltage and current.
  - **Manual Circuit Interrupter:** Connection of a resistor activated by relay connected to load neutral terminal to manually cause a ground fault to interrupt circuit in the event any feature detects the implication of a hazard.

- **Creating of prototype that fits within 4-gang box:** The Hardware team was able to design and create a prototype that included current and voltage sense, relay modules, dummy loads, alert systems such as voice and leds with our motherboard to all fit within a 4 - gang outlet box that is powered by the incoming 120VAC. A custom 3D designed faceplate was then printed to hold components together.**(Fig 2)**

- **Developed code to read and display current and voltage:** The software team wrote code that would read in the voltage and current coming from the circuit, then display it out onto a screen so that it can be viewed. It would also save this information to a file for further analysis. Additionally, code was written to detect different cases and also display those.

- **Developed and designed UI for Socket Steward:** The software team was able to design a user interface being powered from the Featherwing M4 express. On the OLED display we have the ability to start and stop data-logging and read real time temperature readings for our four different temperature sensors that will be placed on the outlet receptacle and one for ambient temperature.

- **Conducting tests to establish hottest points on our receptacle:** The quality assurance team replicated numerous tests found in the Consumer Product Safety Commission (CPSC) published research. After conducting many studies, we found that the sides of the receptacle above the screw terminal were the quickest to heat up on the exterior of the AFCI/GFCI outlet. The thermistors were placed on the outside of the receptacle to prevent our design from breaking UL standards.

- **Proof thermal runaway appears in damaged plugs:** While the quality assurance team was determining the hottest points on a receptacle, we used our data logger that was created by the software team to give us proof that thermal runaway is very capable of occuring in damaged plugs. Once an appliance cord is impaired either from damage or poor manufacturing, the resistance at the crimp will only begin to increase. Over a long continuous use of the given cord, it may become more hazardous as it will only increase in temperature. It was also determined that the chance for thermal runaway becomes higher as the impaired cord keeps being used. **(Fig 3)**

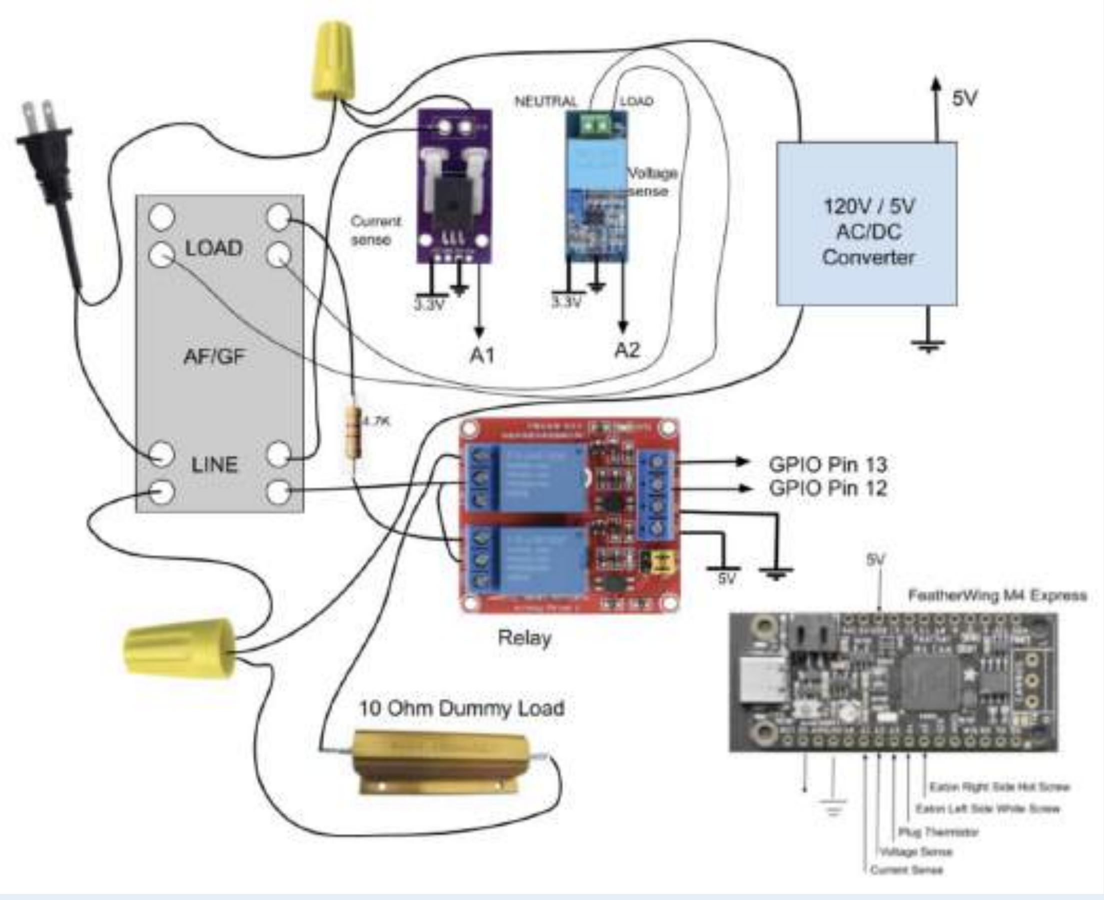


Fig 4: A visual representation of the connections for main components in the Socket Steward

Anticipated Best Outcome

The anticipated outcome for this project is to have a fully functional prototype, capable of powering an array of common appliances. The product will be able to detect each possible instance of hazards and cut off power to the attached appliance, and then communicate the hazard and the reason through a digital display and vocal audio to communicate with the user on how to proceed forward with usage. The desire for the final product is to safely terminate a hazard that has been detected, preventing any damage and ultimately informing the user what must be changed for safe continuous use.

Project Outcome

The anticipated best outcome was achieved. The team was able to design and build a prototype that does detect and terminate hazards and communicates to the user with issue detected and possible solutions.

Figures

Fig 1: Demonstration board to simulate various faults and outlet failures that may be common in a residential household.

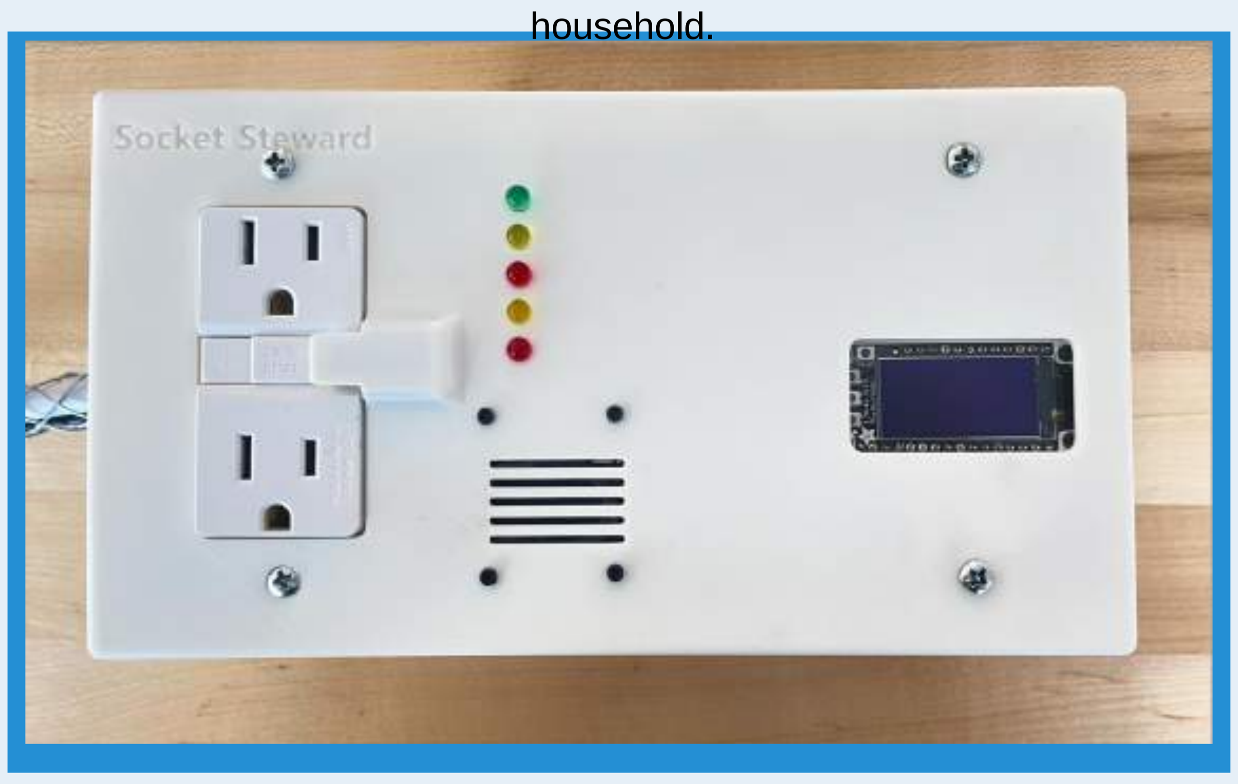


Fig 2: Top view of prototype Socket Steward system.

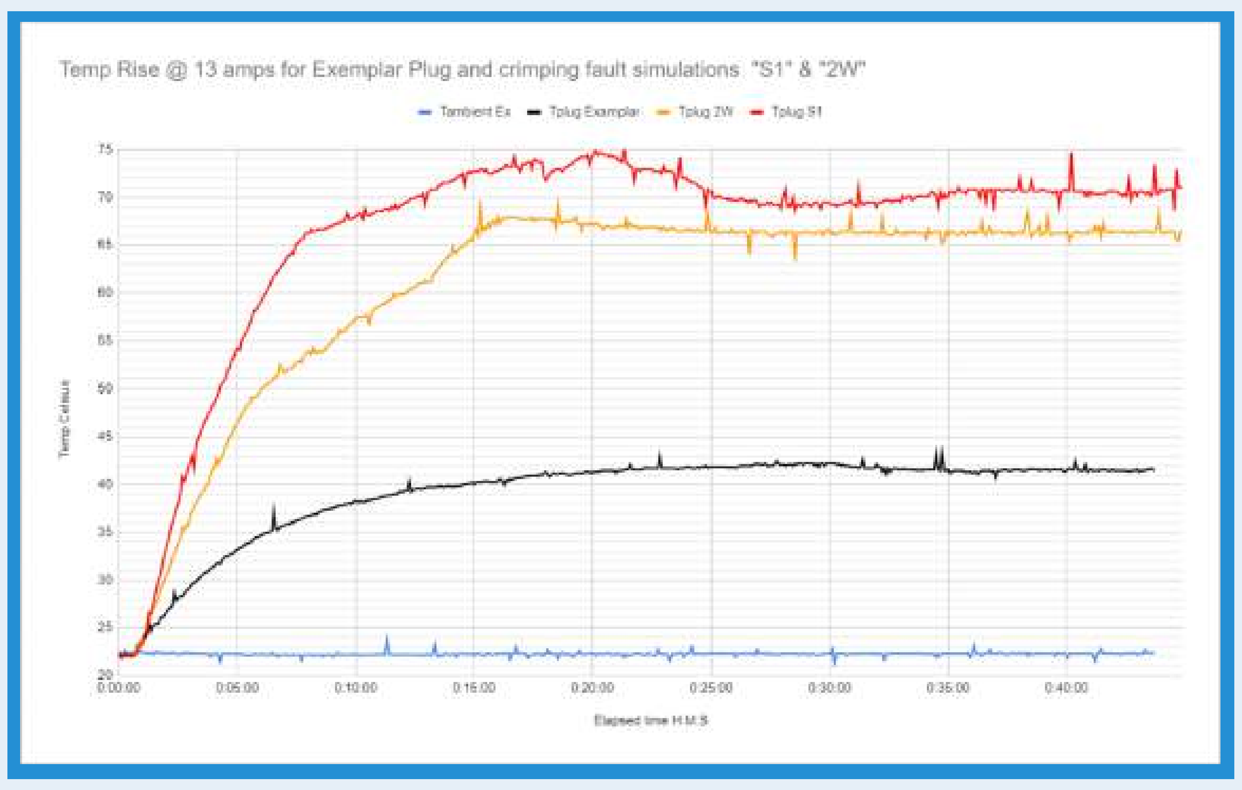


Fig 3: A 45 minute visual representation of two impaired plugs demonstrating thermal runaway.

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THINK BIG WE DO™

Standalone Cable Checker

Hardware Checker – Phase 3

VICOR
The Power Behind Performance

Team Members: Ricky Lao (CPE), Griffin Melican (ELE), Allen Ly (ELE)

Technical Directors: Nathan Shake, Daniel Hartnett, Al Binder

Project Motivation

Vicor Corporation sells a large variety of custom ICs to various consumers every year, which are tested before their sale to check their veracity. Should a product fail, Test Engineers at Vicor Corporation must determine the issue and fix it using one of the custom in-house testing systems they have developed in the past couple of years. However, they have not been able to keep up with testing the cables that the ICs integrate with as they do not have a custom system for that. The burden of testing these cables falls back on the Test Engineers, which greatly reduces the lead times. This is compounded with the fact that cable faults are usually disregarded as they merit a lower priority than a given system, like a PCB, which means testing them gets pushed further down the line. As these cables accumulate in quantity, the need for a platform to test and diagnose cable errors has become increasingly more relevant.

Key Accomplishments

Proof of Concept: We have demonstrated a proof-of-concept to the technical directors at Vicor Corporation, which they approved of. This demonstration consisted of AND gates, which represented the logic that would be used to test the cables provided. We concluded that other types of ICs would best suit our needs; we decided to go with mux's and demux's to reduce the amount of bubble logic that would be required to test the SCC, making it more compact and precise as there is much less room for error while designing.

Custom Footprints: While designing the PCB, we realized that many of the cables' headers did not have a footprint available in the libraries being used. Vicor Corporation has provided us with the datasheets we needed to create custom footprints, and we designed them so that they now exist in the Circuit Maker libraries.

Microcontroller Selection: Our initial selection was the Arduino UNO. However, we have recently discovered that in order to fulfill one of the specifications of the final SCC, our microcontroller would need more resources to test with. We concluded that the Arduino MEGA 2560 would best suit our needs and have integrated our previous version of the SCC built on the UNO with the MEGA.

LCD Integration: Our current version of the SCC includes an LCD to display various data points to the user. This way, it offers the user a way to examine which lines might be faulty, making testing much easier. While this was not an initial specification, it was proposed to the technical directors at Vicor Corporation, who approved the implementation.

Incrementation Modes: The SCC offers both a manual and automatic increment system for the cables being tested. This means the system can loop through all the pins to test them, or the user can do so themselves, allowing them to pinpoint faulty lines with more accuracy.

Additional Shorts Test: A new test was developed such that the operator can test any number of shorted pins over a cable. This required separating the mux and demux sides to individual columns, but this allowed for selecting any pin with any other pin. In addition, the operator will be able to switch between this and the continuity test using a single switch. Example outputs of shorted and faulty pins are shown in.

PCB Design: The Vicor Corporation team spent a great deal of this semester enveloped in the design process of the PCB. This involved, laying out all the components so that they allow for optimal routing, creation of traces for all components, and ensuring that all the design rules and constraints are being met. Throughout this process, there were also additional specifications added to the final product. These specifications were integrated in a swift fashion, which was due to the modular design methods that was applied to our PCB. After ample review, the technical directors overseeing the Vicor Corporation Team's project gave a few recommendations, which were taken into consideration.

PCB Fabrication: The fabrication process of the board involved two stages: one in which the team printed a test board, and a second stage for manufacturing the final boards, which would contain any edits necessary based on what was discovered during the debugging phase. There were some small changes made, after which the boards were sent in again for the manufacturing for the final time. In both stages, we assembled the boards using the components we had ordered, and tested to see if the functioned as intended, which they did.

Separated Testing Units: In order to more efficiently divide the workload for creating the SCC, we decided to create a separate unit for the larger 156-pin cable, and one for the smaller cables. This also allows for Test Engineers at Vicor to test their cables with greater efficiency as they can test both their smaller and larger cables at the same time.

Functionality: We were able to verify the functionality of the boards and prove that they work so that when they are handed off to Vicor corporation, they will be able to utilize the SCC's immediately. This test of functionality involved two main stages: creating a test PCB, then the finalized version. Our initial PCB would include the smaller sized cables for testing, as it would be much easier to adjust if there were any outstanding issues. The second stage involved the more finalized boards, which we were able to prove functioned properly.

Anticipated Best Outcome

The anticipated best outcome of this project is the creation of an in-house standalone cable checker. The cable checker will utilize two custom-made PCBs that will allow for multiple different cable connections; this will permit the Test Engineers at Vicor Corporation to test out their various cables. The Standalone Cable Checker will use a micro-controller to accurately test the veracity of the cables and display a visual reference on an LCD to the operator that tells them if the cable is fit for service or if it requires for the Test Engineers to repair them.

Project Outcome

We, the Vicor Corporation team, were able to complete our Anticipated Best Outcome a couple weeks before the deadline, meeting each of the milestones we had set at the beginning of this semester. With this extra time, we contributed our efforts into designing housing units for our SCC's to give it a more polished look.

Figures

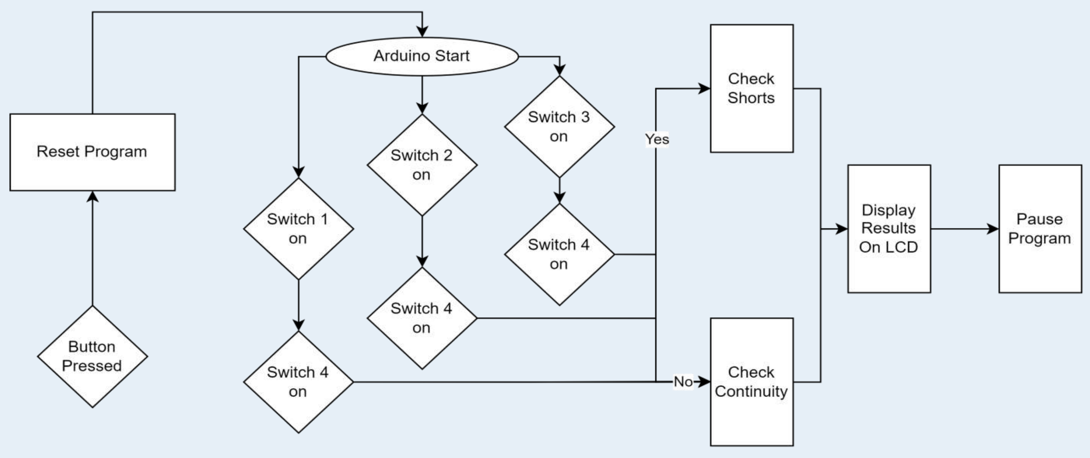

Fig. 1. Block diagram dictating the logic of the final SCC.

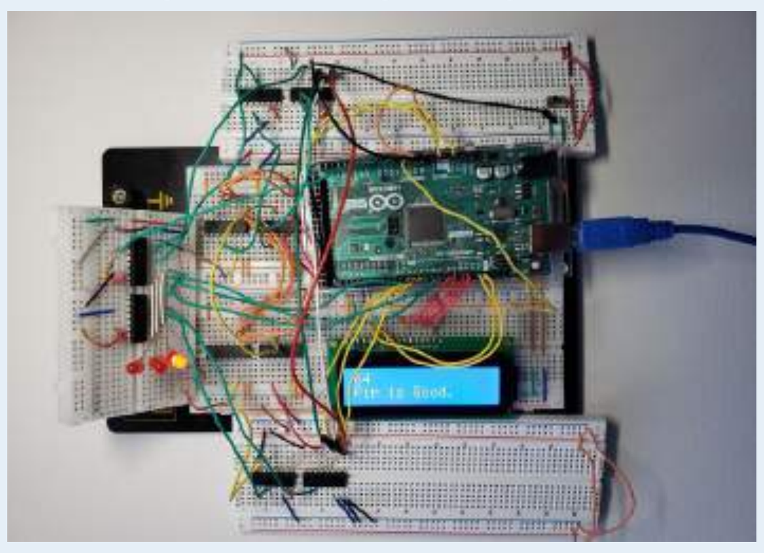

Fig. 2 Protoboard SCC, debugging and programing environment.

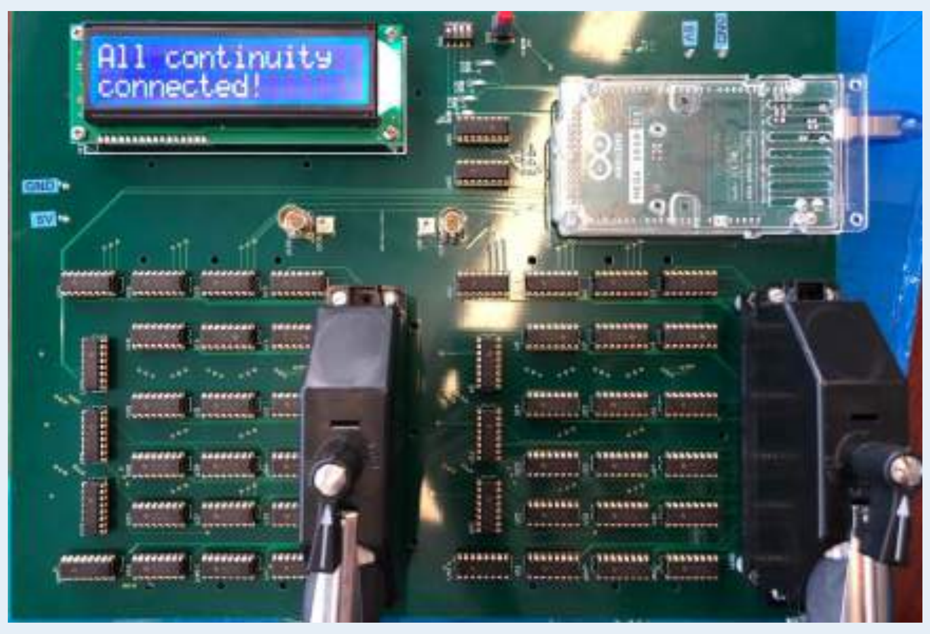

Fig. 3. 156-pinout cable SCC, powered on.

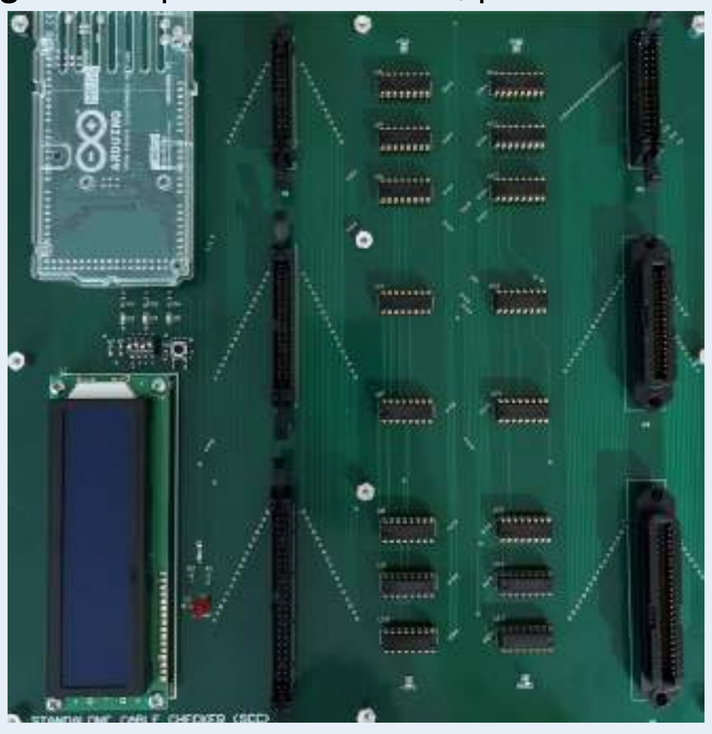

Fig. 4. Rainbow cables SCC, powered off.

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AGMESH

Active Greenhouse Monitor for Efficient Sunlight Handling

VOLTSERVER DIGITAL ELECTRICITY™

Team Members: Andre Costa (CPE), Edgar Ponce B. (ELE), Zachary Chofay (ELE), Rowan Woods (ELE)

Technical Directors: Camilo Giraldo, Stanley Mlyniec

Project Motivation

VoltServer has created a LED lighting platform utilizing their patented Digital Electricity™ which has become popular in the indoor agriculture field. One benefit of this technology is it allows for a dimming effect with LED lights. While this improves the power efficiency of the system, greenhouses typically contain multiple plant species in numerous stages of life. For this reason, each table requires a unique amount of light for a unique amount of time throughout the day for efficient plant growth. Some attempt to replace this technology by setting timers for the lights to turn on and off based on the sunrise and sunset times in their area. However, this does not factor in the variable sunlight a plant receives throughout the day. Our system would be able to sense the luminosity of the incident light on the plants and adjust the brightness of the LED to compensate for such events.

Key Accomplishments

Ambient Light Sensor Research: Performed research on light sensors that could be good candidates for the prototype. The light sensors being considered are LTR-329ALS-01 from Lite-On Technology Corporation, BH1730FVC, and BH1750FVI both from ROHM Semiconductor. After careful consideration and testing, we decided to move forward with the BH1750FVI light sensor for the prototype.

Design of Test PCBs: We used multiple sensors for redundancy, so we needed a way to communicate without collisions on the I2C bus. Sensors LTR-329ALS-01 and BH1730FVC only had one address programmed to them. Because of this, we decided to pass the data and clock lines through a multiplexer controlled by the Raspberry Pi. Sensor BH1750FVI has a pin that allows changing the I2C address. Both ROHM Semiconductor sensors have the same footprint which allows us to design less PCBs and ultimately saved us money. See Fig. 2 for sensor implementation.

Light Sensor Array Design: The team has come up with a design for an array of seventeen light sensors which will always keep one in an angle below 18° from vertical, which will allow it to have a response above 0.8 (Fig. 3), making the highest sensor value within an acceptable range of error. This eliminates the need for a compensation algorithm.

Software Block Diagram: A software block diagram was developed to better visualize the final prototype. The block diagram allows us to see how we interact with the user, DE transmitters, light sensors, and with the controller. Please see Fig.4 for the full diagram.

Sensor PCB Design: The final sensor PCB was developed using the BH1730FVI/BH1750FVI light sensor from ROHM Semiconductor. The individual boards will route to an interconnect board that allows us to have a seventeen-sensor array connected over I2C to the Raspberry Pi.

Connector PCB Design: The connector board allows us to communicate with the seventeen boards using I2C. The connector board serves as an intermediate board where the power and communication will be distributed to the sensor boards. The connector board can be mounted on to the raspberry pi as a hat.

Casing Logistics: With board development going well and sensor testing underway, the next consideration is housing. Our housing orients the sensors in a manner which reduces the change in observed brightness as result of incident light angle. Ideally, our housing would qualify for a high IP rating against moisture as well as a sufficient rating against dust. This would allow for proper implementation into a greenhouse environment. We would accomplish this by using a 3D printed housing sealed with RTV silicone and IP rated connectors. We would use Autodesk Inventor Professional as our CAD software for the 3D printing. Please see Fig.1 for the full diagram.

Power Supply Design and Assembly: The Raspberry Pi Zero W we are using requires 5V 2A DC power. Because of this we had to select an AC/DC converter which took 120V AC from an outlet down to the needed 5V while allowing the proper current flow. Once inside the housing the supply needed to be connected by micro usb-b to power the Pi. To assemble the supply we had to splice and solder onto both sides of the IP rated connectors.

Software Development: The software for this project consists of a python script which reads in light values from the sensors, determines what the maximum value is and then sends a command to the ETX8 to control the light accordingly.

GUI Development: The GUI is how the consumer interacts with the product to set brightness and read what the current brightness is. This is to be done through a web interface, running on a locally hosted APACHE server.

Anticipated Best Outcome

The Anticipated Best Outcome consists of the delivery of a prototype agricultural active greenhouse monitor for efficient sunlight handling utilizing dimming that meets all the requirements. This prototype will use light sensors and a Raspberry Pi Zero W to regulate the luminosity in the greenhouse with no human input other than the desired light threshold which can be accessed via a website. The solution will withstand the environment for which it is built and be able to interface directly with Digital Electricity™ transmitters. Proper documentation, delivery on schedule, test results and demonstrations of all the features will also be required.

Project Outcome

Our final system is able to read the luminosity of its surroundings and adjust the brightness of the grow lights accordingly. Because of this, we did achieve our ABO

Figures

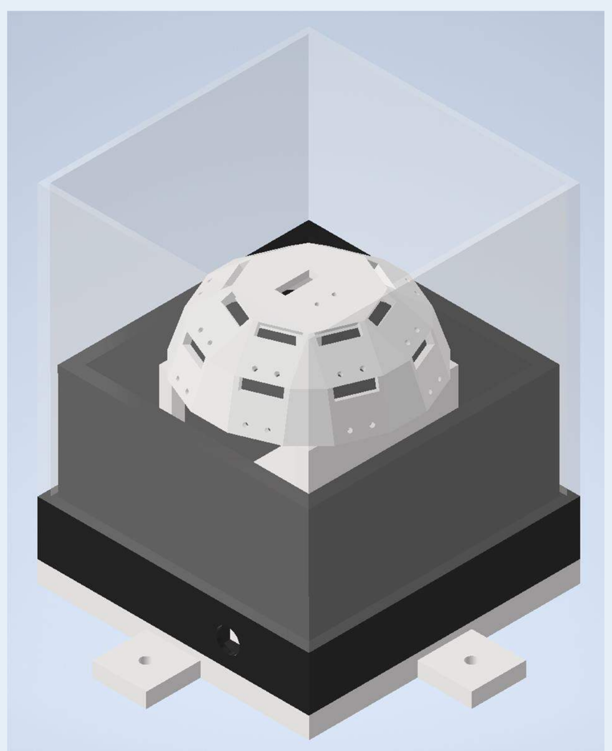

Fig. 1: Prototype Casing

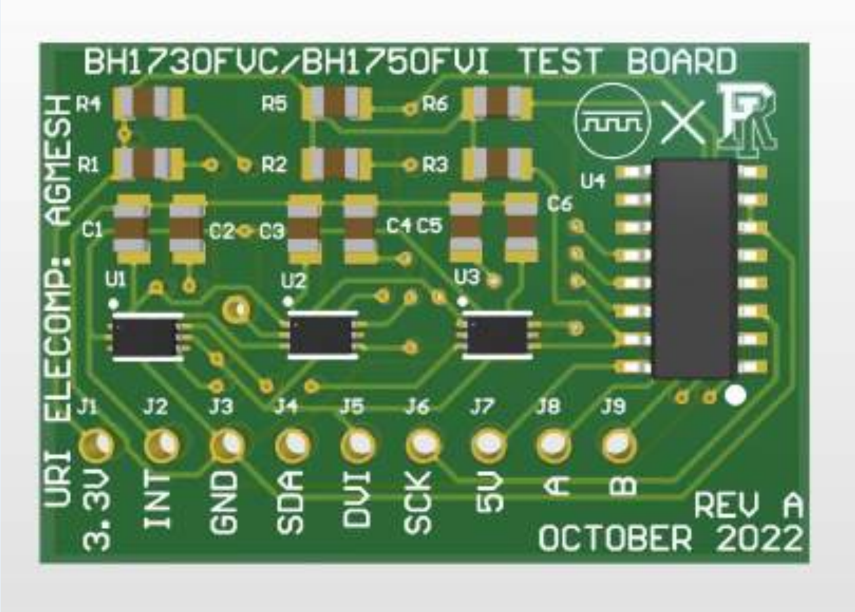

Fig. 2: BH1730FVC/BH1750FVI Test Board

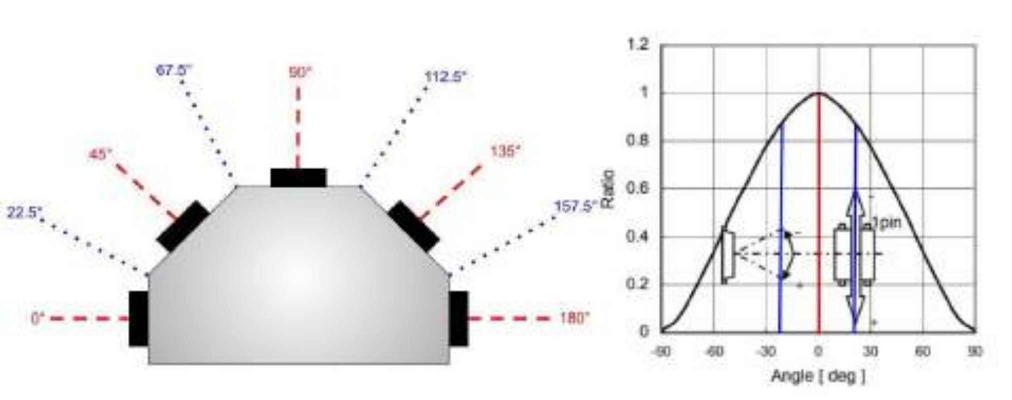

Fig. 3: Sensor layout and response curve

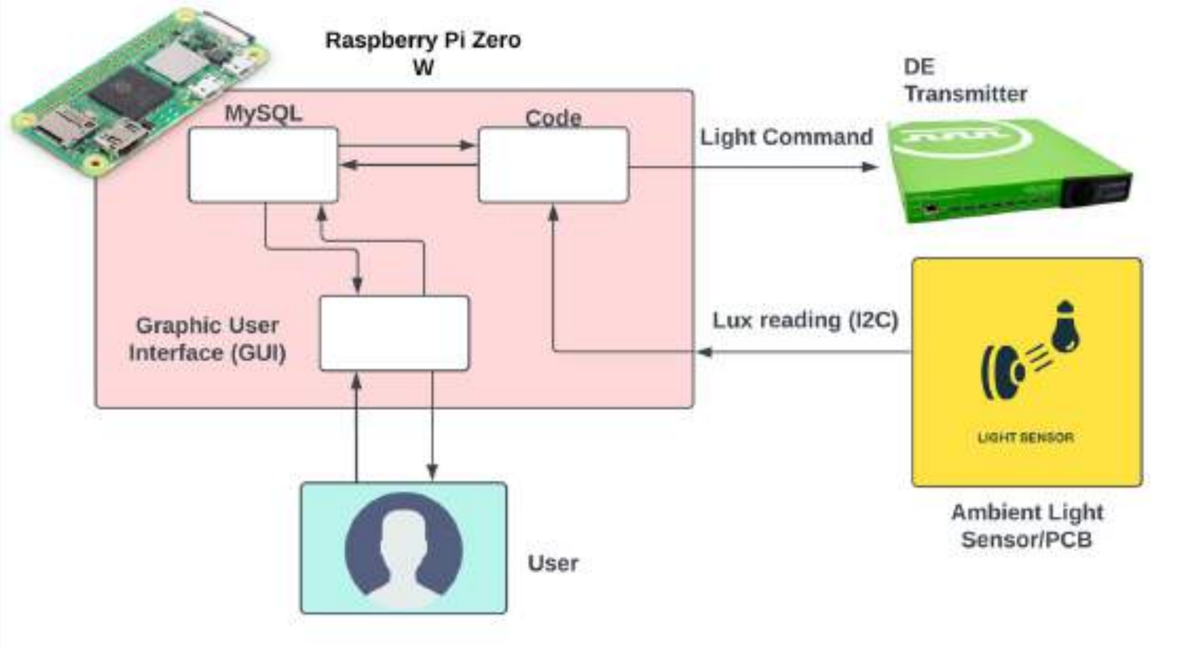

Fig. 4: Software Block Diagram

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ELECOMP CAPSTONE
SUMMIT
TUESDAY, MAY 9, 2023

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

CLEAR

Colored LED Event Automated Reader

VOLTSERVER DIGITAL ELECTRICITY™

Team Members: Aram Elmayan (CPE), James Kaye (ELE), Thomas Ricci (ELE)

Technical Directors: Stanley Mlyniec and Camilo Giraldo

Project Motivation

VoltServer's devices are built with integrated colored LEDs that can display status codes to the user by different sequences of LED blinks. There are generally three LEDs; one blue, one green, and one red. The status codes for each device are different, but the same type of light blinking sequences combining the three lights are used across the entire Digital Electricity™ platform.

There are times during the life cycle of a VoltServer device where it is useful to decipher what the LEDs are doing. One use case is for end of line testing in the manufacturing environment. Another use case is for in the field testing on units that have already been deployed to a facility. This test device would be used to make sure that the LEDs work properly and are positioned in the correct place. Sitting at a device and watching the blinks is a mundane task that should be automated.

Key Accomplishments

- **Sensing Algorithm Flowchart:** A flowchart **(Fig. 1)** was created that portrays how the LED Sensor Algorithm will operate. The sensing algorithm would search for light. Upon reading values for light it would then attempt to determine which color LED would be present based upon which RGB Voltage is higher at that time. Referring to the TX-550's blink behavior, cases were added for differing blink length/color sequences and this information would then be delivered to the GUI with a particular TX-550 Mode.
- **LED Sensor Testing Apparatus Design:** An apparatus was designed for photodiode testing. The design utilizes six ½" by 6" dowels segments that our team stacked, able to be tested at 0.5", 1" and 1.5" increments. The top of the apparatus was cut to allow for a LED light to be inserted either being Red, Blue or Green.
- **Photodiode Testing:** Utilizing the CLEAR 2021-2022 team's testboard, LED sensor testing was conducted **(Fig. 4)** utilizing the 3-channel APS5130PD7C Photodiode. Collected voltage and calculated current values using differing LED colors and at different distances.
- **LED Sensor Test Board PCB Design:** A test board was designed for LED sensor testing, includes 4x3 array of APS5130PD7C Photodiodes where each RGB signal was separately routed to 1 of 3 CD74HC4067 Multiplexers based upon sensor color. The output of the multiplexer was then routed to the AD8244ARMZ OP Amp, routed to three test points for data acquisition.
- **Development of Mounting System for TX550:** Our team was able to develop a housing for the CLEAR board, which has openings for the micro-usb input for the computer, along with a 9V battery input and a DC connector. Along with this, we were able to design a Mount for the TX-550 that is able to isolate most ambient light for photodiode testing.
- **Create GUI:** The GUI **(Fig. 2)** reads data coming from the microcontroller through UART to display a live feed of the LEDs. It accepts codes and translates them to human-readable status messages. It has the ability to send commands to the microcontroller such as running a single test or automatic test.
- **Redesign PCB:** The PCB **(Fig. 4)** was redesigned to include a 4*3 APS5130PD7C photodiode array, along with three CD74HC4067 Multiplexers and two LD29855BM50R Voltage regulators. The board was redesigned to a 1.5" by 1.5" board. To reduce space, our team also implemented a micro-usb computer input instead of a RS-232.
- **Firmware Development:** The firmware was designed using a dsPIC33CK256MP508 Family microprocessor and the MPLABxIDE software by Microchip Technology. An overview of the firmware's processes pertaining to our LED detection and recognition can be found in **(Fig. 1)**. The firmware is designed to detect when a red, blue, or green LED is being shown into the sensor array. It then starts a timer to determine how long that LED is on for. Using voltage values collected from the ADC and the photodiode sensors, it can determine the color being shown. Using a combination of the color and the timing of each LED blink, the firmware then determines the pattern that fits those conditions. Results are displayed through serial communication with the host computer on the GUI.

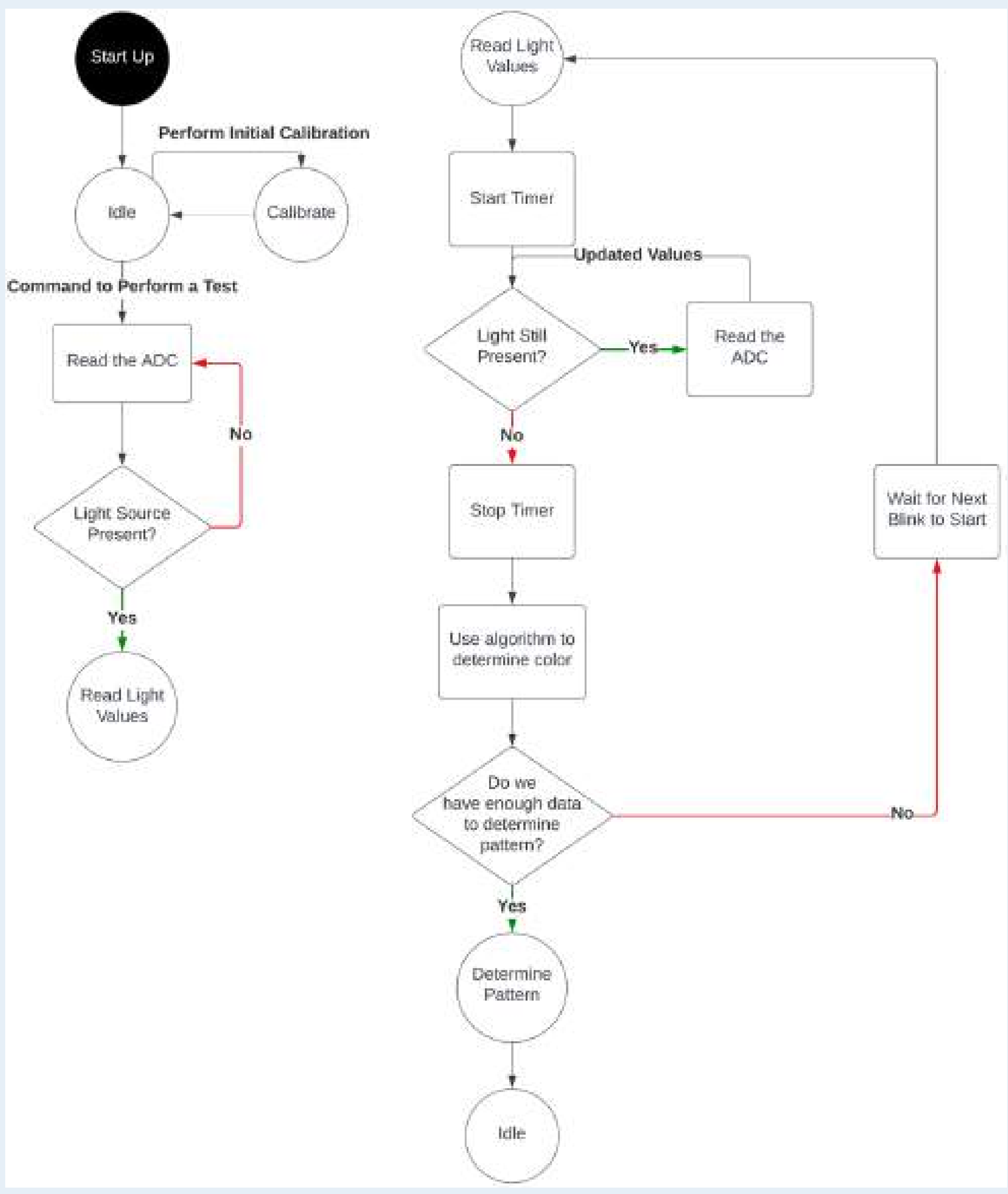

Fig. 1 Sensor Algorithm Flowchart

Anticipated Best Outcome

The anticipated best outcome of the CLEAR project is the delivery of a prototype that can accurately read flashes or solid color output from red, green, and blue LEDs. A device specific mounting solution will allow the LED reader to be easily mounted to any of VoltServer's devices. Aside from the prototype, other deliverables will include a bill of materials, a user manual for the hardware and software, firmware and software source code, schematics, layout, fabrication, and assembly files for two PCBs.

Project Outcome

Team CLEAR completed our ABO and delivered a functioning prototype of the LED reader to VoltServer. The deliverables included a functioning GUI, a user manual, a complete bill of materials, a redesigned PCB and a newly designed mounting solution.

Figures

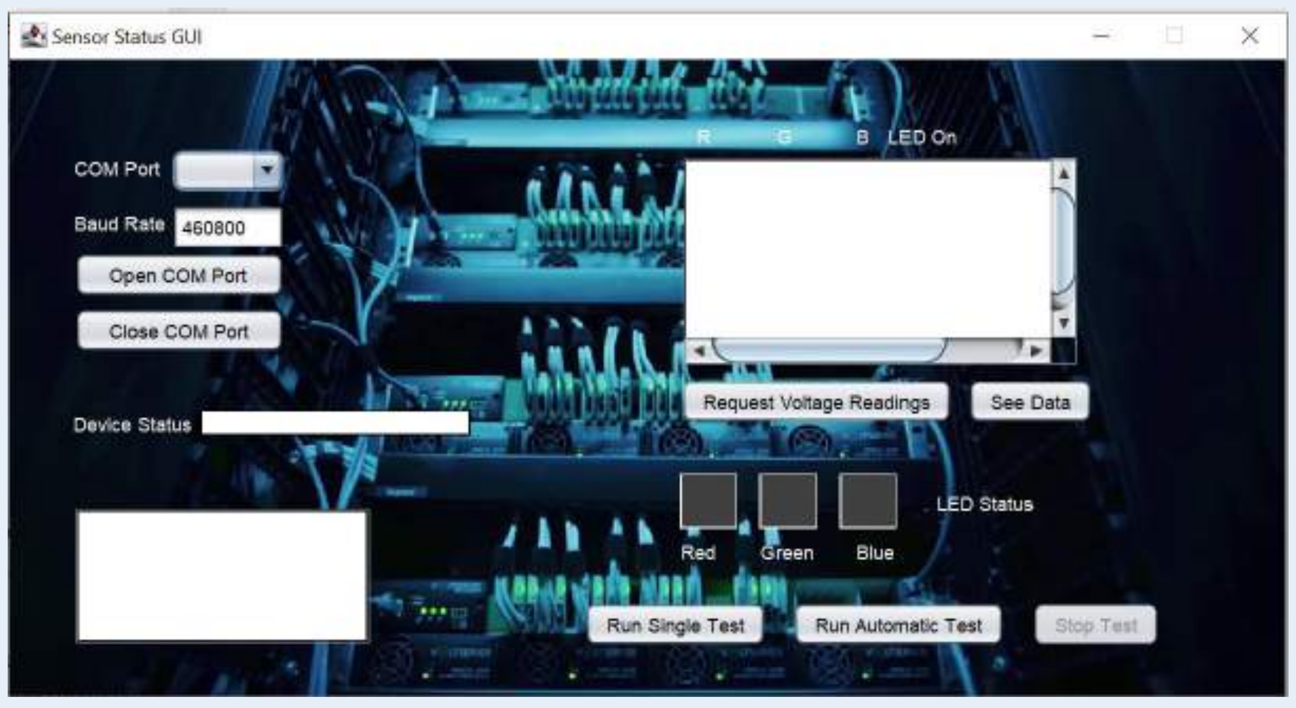

Fig. 2 Graphical User interface

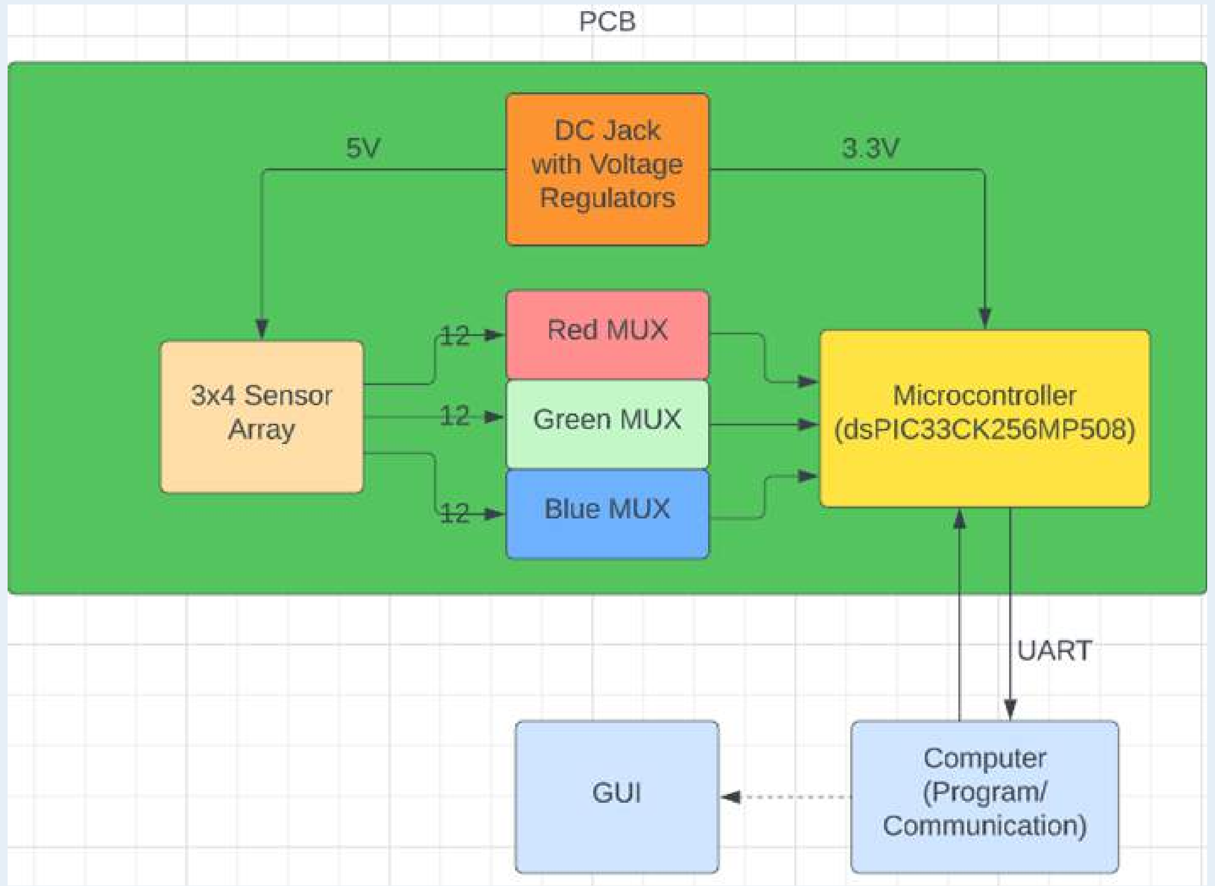

Fig. 3 Overall Block Diagram of Design

Fig. 4 CLEAR PCB

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THINK BIG WE DO™

Smart Baby Monitor

With Integrated White Noise

Team Members: Dao Thounsavath (ELE), Nathan Dwyer (ELE)

Technical Directors: Dr. Andrew Cavanaugh, Steven Anzivino | Consulting Technical Director: Kiran Thakur (ELECOMP '22)

Project Motivation

Using the XMOS xcore.ai chip as well as the XMOS voice frontend, the project plans to create a smart baby monitor equipped with AI sound detection, de-noising, white noise generation, and two-way communication between units. Most smart monitors function connected to cloud computing for their ai and are often paired with white noise machines or a music player. This project seeks to combine these functions with onboard AI that can perform more complex tasks like sound detection and send an appropriate alert to parents without the need for an internet connection. Due to the ability for the monitor to capture personal data on families, consumers are interested in offline monitors which often comes at the cost of AI processing as that process traditionally happens in a cloud hosted environment. With a dedicated onboard chipset, this project plans to allow consumers to protect their privacy without sacrificing features of modern devices.

Key Accomplishments

Tested and Verified XMOS Explorer Dev-Kit: Through XMOS' documentation and SDK, we were able to test and confirm that the Dev-Kit was working. Through this we ran several pre prepared examples in which we could test features of the chip such as Wi-Fi connectivity, microphone recording, AI processing, etc.

Machine Learning Model Selection: After careful deliberation and consultation, a Recurrent Neural Network (RNN) was selected to perform the audio analysis. RNNs are ideal for learning relationships within temporal data meaning the sound detection can refine itself over time when placed into a new environment with different sound characteristics.

Created New PSU Prototype: After spending time to review previous buck converter designs, we implemented a new chip with a few external components from the previous design. Before we decided to ask a company to create a PCB for us, we used a Voltera V-One machine to make our new design in-house for testing to avoid any extra costs and times.

Audio Codec Selection: Due to the previously designed codec being out of stock, we had to narrow down a selection of new codecs and we chose the CMX655D. We were able to design a new schematic with the same process used for the buck converter redesign; implement some external components from the previous design.

CMX655D Evaluation Kit: After the decision of the CMX655D audio codec, we wanted to get an evaluation board to test before we commit to any final designs or builds. We reached out to CML Microcircuits and they agreed to provide us with a kit.

Debugged and Improved XMOS Examples: Using example projects from the XMOS SDK, we were able to test features the board was capable of as well as try to add features together to build demos we could build upon.

Audio Codec Software Driver: Interfacing of the Osprey board and the chosen audio codec will have to rely on a custom software driver to get the audio back across the chip into a usable format for the AI to read, de-noise, check for events, and the monitor unit to send to the parent unit.

Power Supply Testing: After we redesigned the new power supply, we ordered the components as quickly as possible and tried to take advantage of the Voltera machine to create our PCB in-house. However, we were unable to get proper tests due to the need for a more precise machine for the IC chip pins. Once we complete the codec schematic, we will integrate the two redesigns onto a single board and have it professionally made to avoid the precision issue with the Voltera.

Audio Codec Schematic Redesign: For the most part, the new redesign for the audio codec is complete with feedback from our Technical Directors, we just need to apply the finishing touches and figure out how to terminate the pins that we do not need according to the CMX655D datasheet.

Full-Duplex Connection: By connecting the explorer board to a test network, we were able to create a half-duplex connection by send instructions through an MQTT broker to the board —accomplished by revising XMOS code that worked only when connected to the internet by faking an SSL handshake. By using the MQTT-SN (MQTT for Sensors) protocol, we can turn the connection full-duplex and send our microphone stream to the remote pc as binary audio data — a format picked early in this project for its simplicity and low-latency.

Final Daughterboard Redesign: After troubleshooting our first few batches of PCBs, we created a new board. This board solved our previous main issues and all that is left is to send in serial signals that verify that it works as intended. We verified that the paths for serial signals are connected, so the daughterboard is ready for I2C configuring.

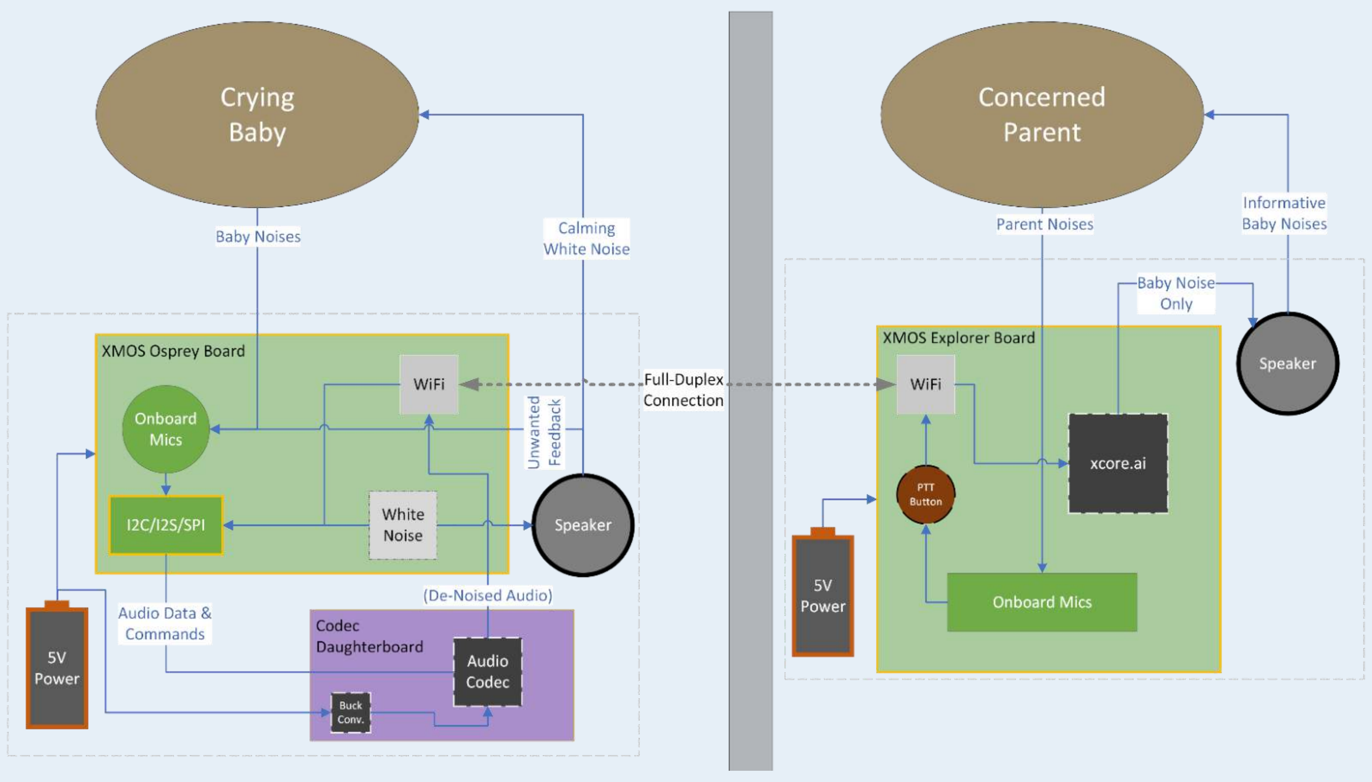

Figure 1. Project Block Diagram

Anticipated Best Outcome

The project plans to create a fully featured prototype of an example smart baby monitor by the end that could be housed within a footprint competitive with common baby monitors — although the footprint does not need to be perfectly optimized. The prototype should be capable of producing and recording audio, performing audio de-noising, and communicating with a remote parent unit using full-duplex communication. Features that go beyond the scope of the ABO include AI detection of audio events as well as the merging of the dedicated audio codec and Osprey boards to slim the footprint into a one board unit.

Project Outcome

The Anticipated Best Outcome of the project was not yet fully achieved.

Figures

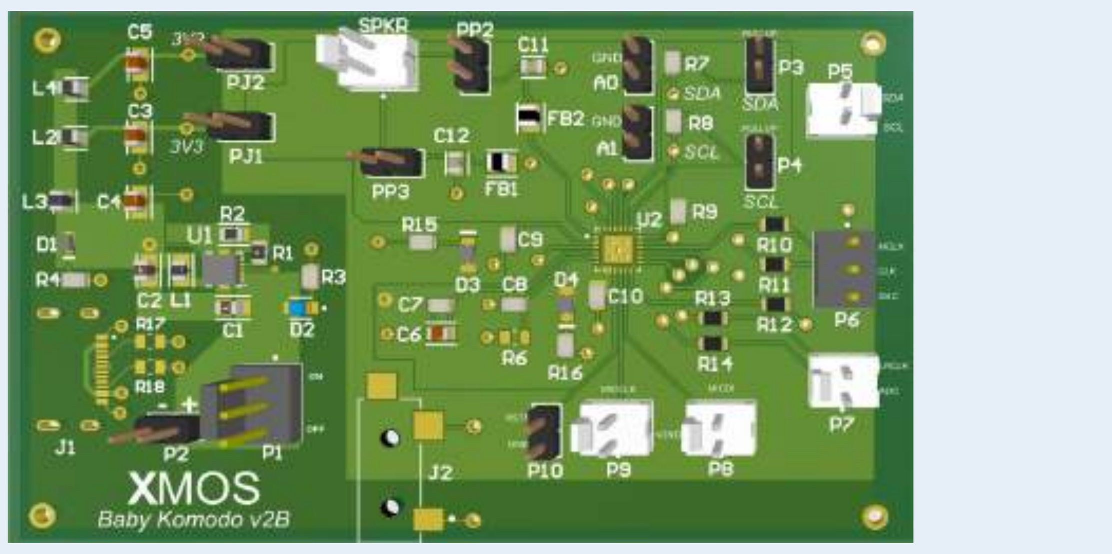

Figure 2. Final Daughterboard 3D Render

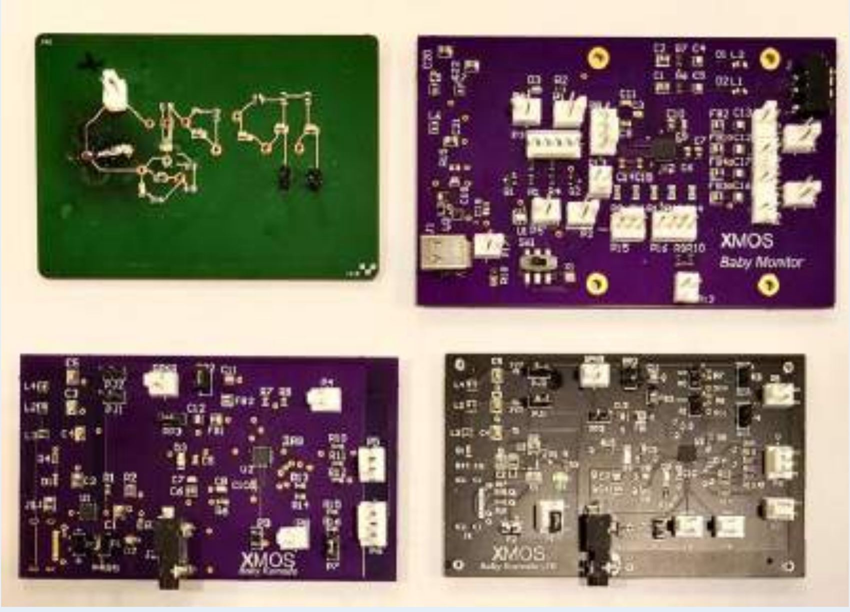

Figure 3. All Four Iterations of Daughterboards

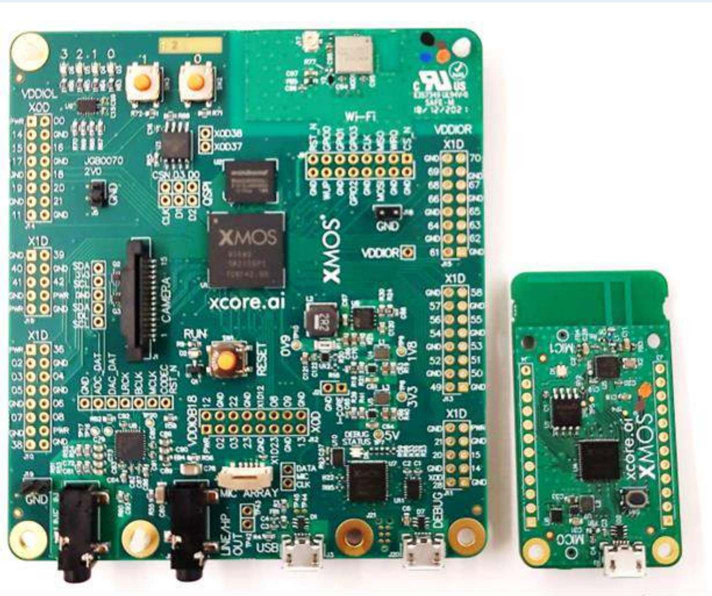

Figure 4. XMOS Development Boards (Explorer Left, Osprey Right)

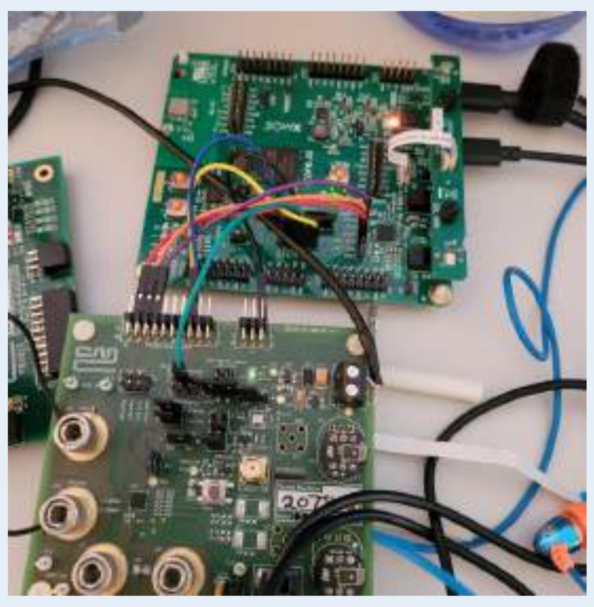

Figure 5. XMOS Explorer Board Linked to CML Codec Eval-Kit

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THINK BIG WE DO™

Torque Measurement

Printer Realtime Torque Measurement

ZEBRA

Team Members: Abe Gilbert (CPE), Jacob Ribeiro (ELE), Oskar Schnippering (ELE)

Technical Directors: Matthew Corvese ('08, '16), Patrick Hegarty

Project Motivation

The motivation for this project stems from the fact that the printers are meant to use different forms of media. The printer can print on regular paper, adhesive paper, envelopes, waterproof paper and many more. The media is also not necessarily manufactured by Zebra, resulting in varying levels of consistency in quality. Often, lower quality media gets stuck to the print head, resulting in a failed print. Since there is currently no way for the printer to measure torque while it is printing, Zebra would like us to develop a robust system for technicians to use to test various types of media using the stepper and transducer with the desire to fully integrate our system within the printer itself. If a printer can measure torque in real time as it is printing, a process could be developed where it uses the feedback and adjusts other print settings accordingly and avoid printing issues.

Key Accomplishments

Fixing and Updating Code: The STM32CubeIDE code was left in a non-operational state from the previous year. The Input Output Controller (IOC) was not able to be used to generate the configurations set in the IDE. Without a properly setup IOC, this would make it nearly impossible and time consuming to add features to the code that are needed to achieve the ABO. These problems were fixed and now allow for easier adjustment of code.

GUI Development: The GUI had significant progress made to it. It can output the label with the torque output as shown in Fig 4. The GUI can send the data to the STM32CubeIDE code in the microcontroller with a press of a button. The data will then be automatically received once the apparatus is done printing. A data plot can be seen and adjusted to see the torque data. All data received can be saved to the users file system and opened at any time for viewing. For easier viewing of the plot, it can be essentially zoomed in by specifying the percentage of the average torque value. The percentage of the average torque is then subtracted from and added to the average value to create the new min and max y value.

Dev-Bench Interfacing: The current Dev-Bench is wired as shown in Fig 1 and operates as shown in Fig 1. In addition, it came with code made from last year's team which and unnecessary functions and errors. This code has since been cleaned up, and due to this, the pinouts had to be rewired and updated. Wiring from one place to another has the cable stay together to have the Zebra Technician able to diagnose problems with the board if they were to arise. This will make the entire Dev-bench easier to understand and more efficient.

Transducer Interfacing: Torque data can be obtained from the torque transducer as voltage. A voltage divider was created to decrease max voltage from 10V to around 3.3V, since the STM board could only take that amount. The torque is obtained every step pulse from the printer and stored directly into the STM board's memory. It is then sent to the GUI directly after the apparatus is done printing. That voltage is then converted to torque in Newton meters (Nm) within the GUI code.

Low Pass Filter: The low pass filter was introduced into the data stream to filter high frequency noise spikes that are coming from the torque transducer as can be seen in Fig 2. In addition to causing inaccurate data collection, the spikes also have the potential to stall the print cycle. Following instructions from our TD, the original design was made to filter out all signals above 1100Hz, however later in the semester, we discovered that signals as low as 200Hz were causing issues, so we lowered the cutoff frequency by adjusting the value of one of the resistors in the low pass filter design.

Constant Current Power Supply: The purpose of the constant current power supply is to provide the particle brake with the desired amount of current to modulate the torque resistance it puts out. To control the two different particle brakes that we have, two different designs had to be made, one outputting 24V, 0-24.9mA, and one outputting 24V, 0-49.9mA. Using a 2N2222 transistor and a 24V single voltage op amp, the power supply design(s) are controlled using a resistance value as seen in Fig 3. During testing, a resistor decade box is used but in the next phase of the implementation, the goal is to use a digital potentiometer, controlled by the STM board, making it software controlled.

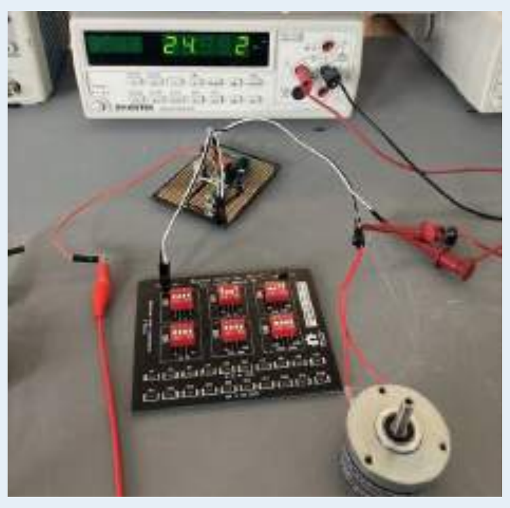

Fig. 3: Particle Break with supply. Will be placed on a future apparatus to simulate the printer's motor.

Anticipated Best Outcome

Interface the torque transducer, printer, and external stepper motor driver to one device. The device will sync the torque output with each step signal sent from the printer. A known label would then be sent to the printer to initiate the test, An Image of the label will be used as a background of the output for the torque graph, thus providing a visual aid for torque output vs label content. A GUI would be developed to control the test and provide graphical output of the data. Then make it so that the device can be used on any printer.

Project Outcome

The Anticipated Best Outcome was achieved. Aside from a point that was put off for the next year, all points were completed.

Figures

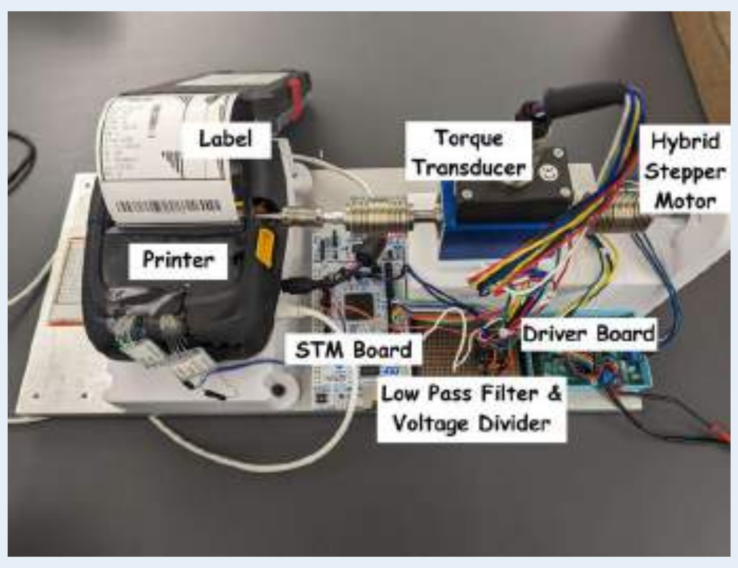

Fig. 1: The functional prototype assembly. From left to right we have: the printer, then the STM Board that runs the code, then after that is the LPF and the Voltage Divider. The transducer which gets the Nm and sends it to the LPF for spikes, then lastly the driver board to run the motor.

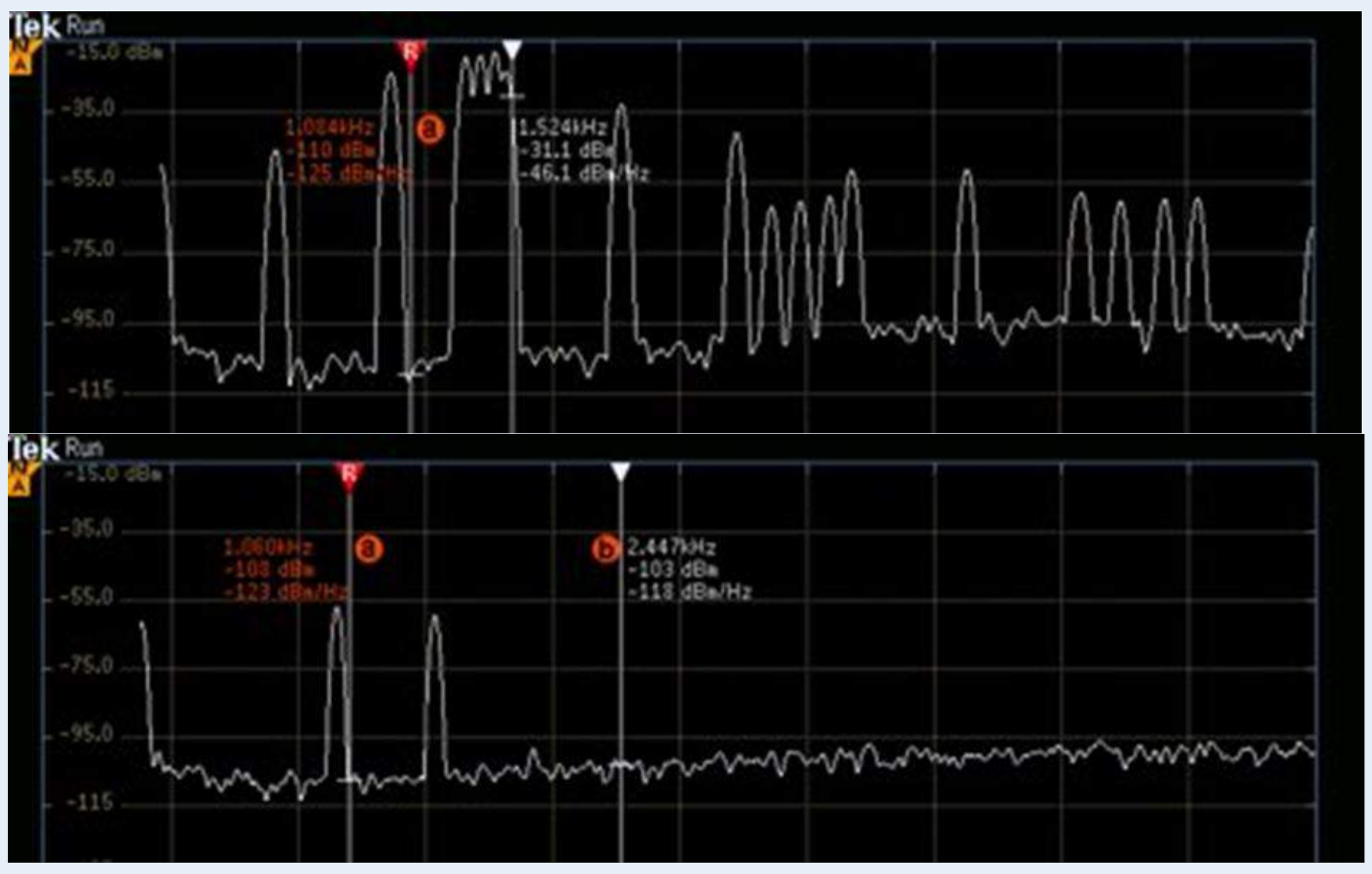

Fig. 2: Spectrum analysis showing LPF attenuating undesired frequencies. Noisy Input (Top) Clean Output (Bottom)

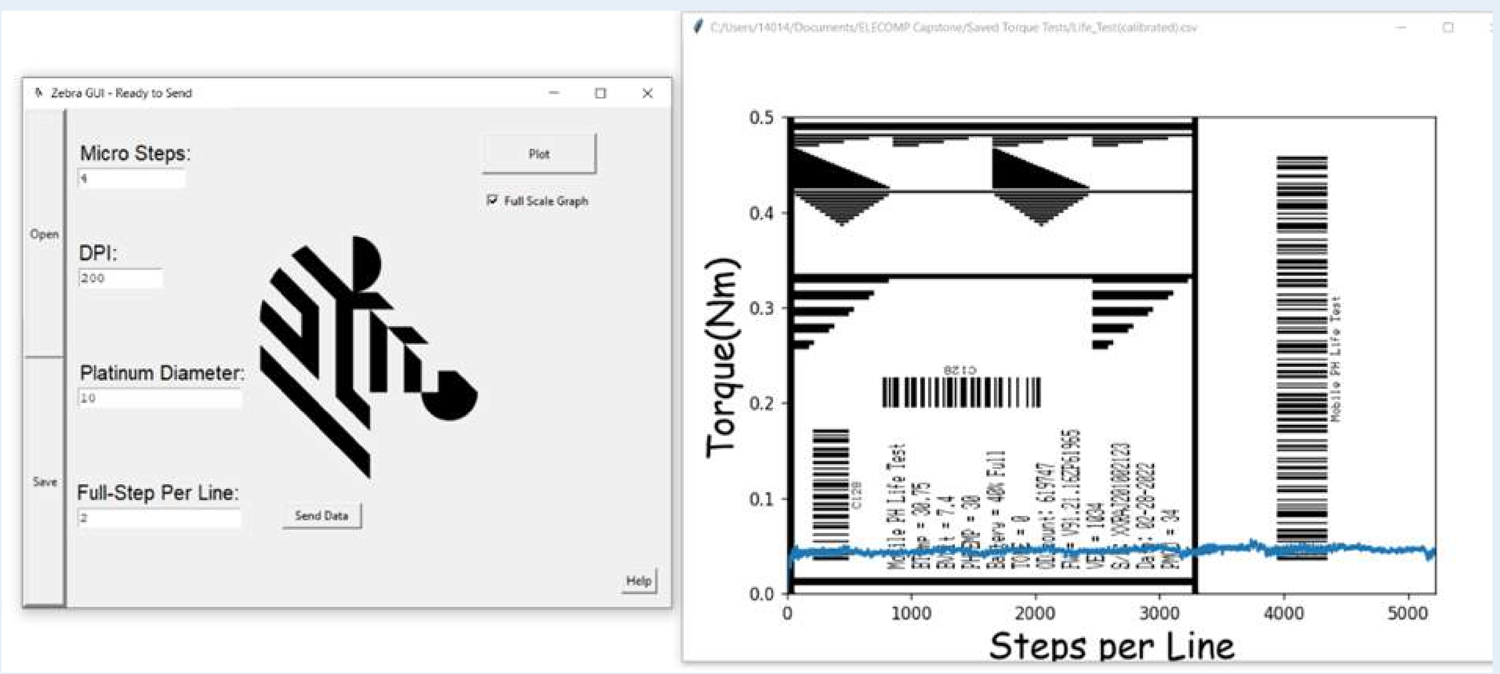

Fig. 4: GUI interface along with an example of torque data obtained from printing the shown label

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