ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

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 Director(s): Daniel Dimase, Bronn Pav, Brenden Smerbeck, Jamie Gagnon

Project Motivation

This project motivation comes from the scarcity of the product. Some companies do organize threats and provide solutions already or something similar. Feedly and other sources have options such as these for their customers, but those options are expensive. Aerocyonics wants to find a way to provide affordable options to companies that might not fully understand the need or value of tools like this.

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. We will be creating our own taxonomy for indexing these threats. The Cyber-Physical Security wheel will be our starting point to validate the accuracy of the Natural Language Processing (NLP) and the machine learning (ML) algorithms.

Anticipated Best Outcome

The ABO of this 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 ML to create the taxonomy, and also be able to scrape several databases for actionable intelligence for these threats. The final functional deliverable will be the SAInt Dashboard software that correctly lists the weekly security threats, correctly correlates each article to the relative threat, and offers solutions for each threat in a user friendly GUI.

Key Accomplishments

Create Content Manager: Scrape the existing weekly Articles of Interest for all threats and organize them in a GUI. The team has worked on this content manager using Python. The following files work in conjunction with each other to successfully scrape, organize and display the threats directly pulled from the Articles of Interest. See UML (Unified Modeling Language) Diagram.

fileReader.py: Imports the weekly security items and saves them a text file in the content manager.

findLinks.py: This program finds the specific starting point of the Articles of Interest in the string to allow for easier pulling of the articles.

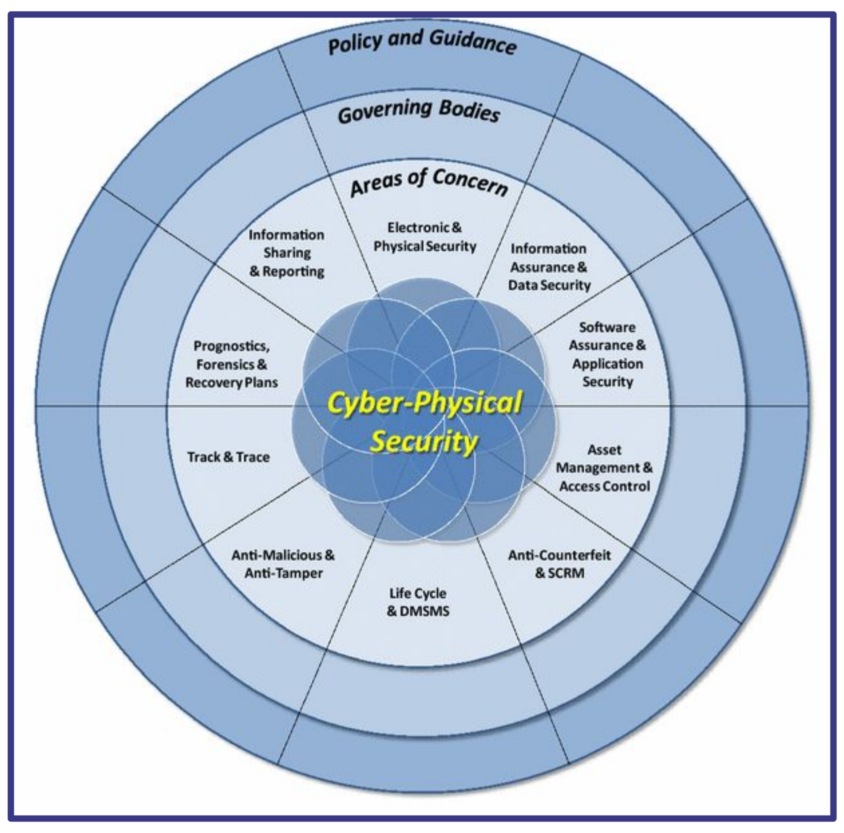
threatMatrix.py: Creates a two dimensional matrix of URLs indexed by weekly security items.

linkToTxt.py: Uses web scraping library BeautifulSoup to output a string of the content of a given URL. This file also includes a method that pulls the title of an article directly from the website.

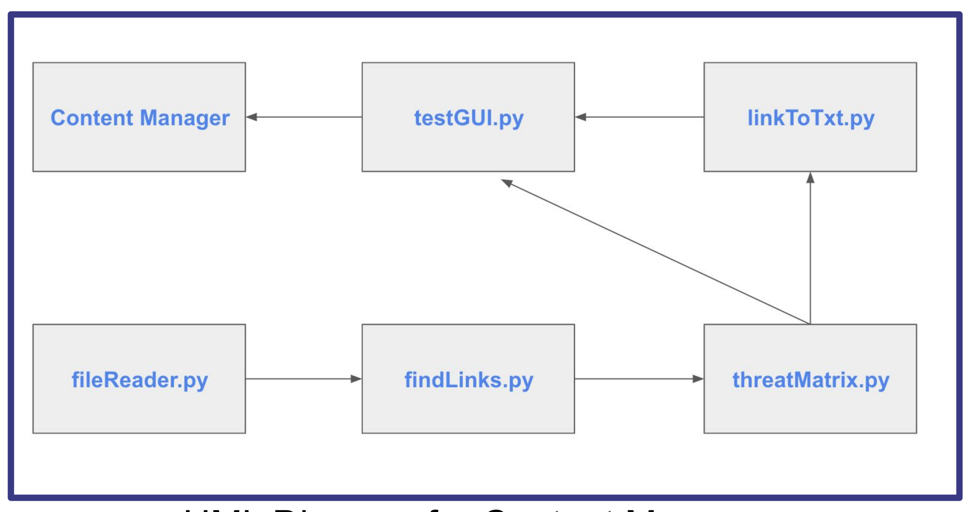
testGUI.py: Uses PySimpleGUI library and BeautifulSoup library to create a GUI with multiple windows.

Organization by Industry/Threats: Use ML to perform frequency analysis on all articles from the Articles of Interest to organize articles by industry and threats. The team received keywords from our TDs relative to each category that will be used to perform frequency analysis. See UML Diagram.

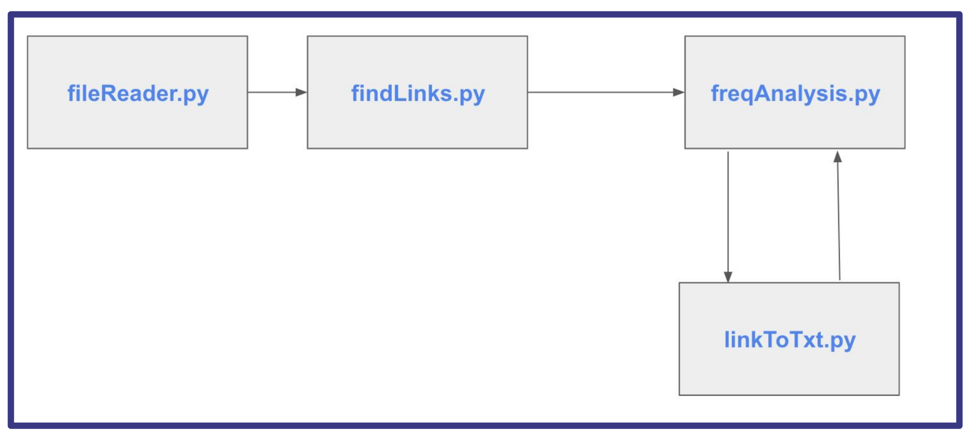
freqAnalysis.py: We needed to produce a sample for our NLP/ML to be trained from. This sample needs to be accurate, and we started compiling it manually. We soon discovered how long this takes. We were only doing this for the Cyber-Physical Security wheel. Our final taxonomy will be a lot more precise with a more expansive indexing. We decided to automate this process to make it easier. The idea was to manually come up with keywords that are specific to their category. This script will then do a frequency analysis on the keywords and categorize the articles appropriately.



Cyber-Physical Security Pinwheel



UML Diagram for Content Manager



UML Diagram for Frequency Analysis

URLs	Electronic & Physical Security	Information Assurance & Data Security
https://heimdalsecurity.com/blog/hive	0	2
https://www.cysecurity.news/2022/09/be	0	0
https://www.itechpost.com/articles/1138	0	0
https://mobilesyrup.com/2022/09/15/bel	4	2
https://www.scmagazine.com/news/ranso	0	0
https://heimdalsecurity.com/blog/yanluov	0	2
https://www.cysecurity.news/2022/09/rar	0	0
https://www.itworldcanada.com/article/cis	2	3
https://cyberintelmag.com/malware	0	8
https://thehackernews.com/2022/09/web	0	0
https://www.cysecurity.news/2022/09/we	0	0
https://www.cysecurity.news/2022/09/ma	0	0
https://www.itsecurityguru.org/2022/09/	6	12
https://thehackernews.com/2022	1	1
https://securityaffairs.co/wordpress/1357	0	3
https://www.malwarebytes.com/blog/new	2	5
https://www.securityweek.com/wordpress	2	11
https://www.darkreading.com/attacks	3	0
https://www.securityweek.com/u	2	11
https://www.helpnetsecurity.com/2022/0	0	3

Frequency Matrix TSV File

Remaining Technical Challenges

Organization by Industry/Threats: To start, we came up with a method of doing frequency analysis on keywords to categorize articles. The method will have to be expanded on for the final taxonomy, but we have a good starting point. Once we have enough articles that are accurately categorized, then we can start with the NLP. The NLP will use cosine similarity to come up with a correlation coefficient. It will do this by checking the cosine similarity between one article's text with the text from all the other articles in each category . Each category will then be assigned a correlation coefficient corresponding to the article that needs categorized. The article will be placed in the categories with a correlation coefficient above a specific threshold. The more articles that are accurate classified, the more accurate the ML algorithm will become.

Link Threats to Solutions: A critical part of this project is for the SAInt Dashboard to provide actionable mitigations to the user for any threat. There are several different methods the team is considering for finding the solutions. One potential method is to use a text scraper for specific websites/databases and then use NLP to accurately match the solution to a certain threat. Another potential method is using a BOT to surf the world wide web for specific solutions for every threat in our taxonomy.

Finalize SAInt Dashboard: The final step of this project is to create a user-friendly GUI. Each category will be displayed as a clickable button and once clicked, will display every related article. Every article will include a correlation rating with the industry that it is organized in. Each article will also have a clickable button to a new window that will include solutions pertaining to that particular threat. The GUI will also have cosmetic work done to it to ensure that it is the easiest and most appealing to use.

Implications for Company & Economic Impact

The best outcome for Aerocyonics, Inc. is to have an enhanced tool that will enable more extensive reporting options and actionable intelligence to consumers. Similar tools have been created but at a high cost to the consumers . The tool from Aerocyonics, Inc. will be an affordable solution for users who require solutions for the threats displayed. There will also be a free version for users that may not require actionable intelligence, but still want to browse through the articles with proper classification. More companies will be able to check in on the security risks of their industry and disarm the threats accordingly at a lower price.

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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 Director(s): 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.

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.

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.

Key Accomplishments

Software:

Block Diagram: Created detailed block diagram that outlines the software on both the front and back end to ensure that the final deliverable product includes all necessary components, and is easily understood by an operator.

Sensor Functionality: Created a program in python to read in both the inputs of the thermocouple, and PSD (Position Sensitive Device) sensor as a form of data acquisition for our test bench.

Tulip: Configured instance of Tulip Software, and created(not completely finished) a User Interface for the Human Machine Interface, including an authentication system to ensure the correct user is operating the test bench.

SQL Database: Created an SQL server to store our data, in addition to using this as a middleware between the backend programs(data acquisition), and our front-facing UI in Tulip.

Communication between front and back end: Set up a connection between Python, SQL, and Tulip, enabling the sending and receiving of data between the front and back end software.

Hardware:

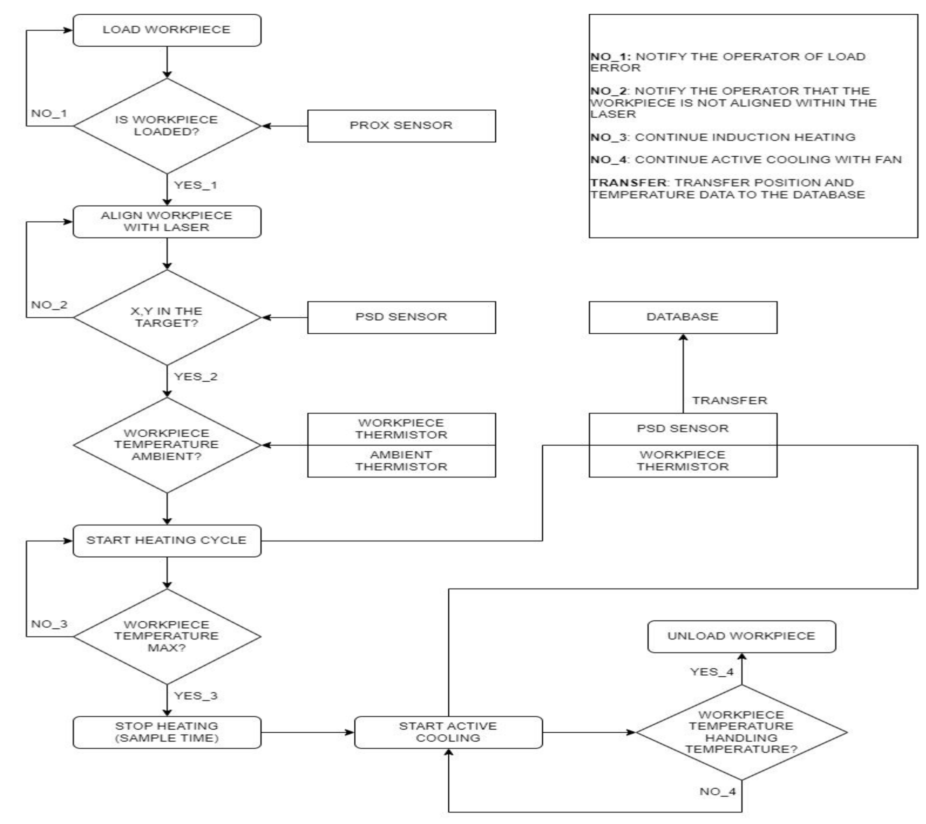
Testing the PSD sensor: Set up the straight-forward position between the sensor and the laser diode to test if the sensor detects the laser from the laser diode. This includes ensuring accuracy depending on distance and height.

Configuring the thermocouple: Set up the thermocouple and have it configured in order to convert values from voltage to temperature (in Celcius).

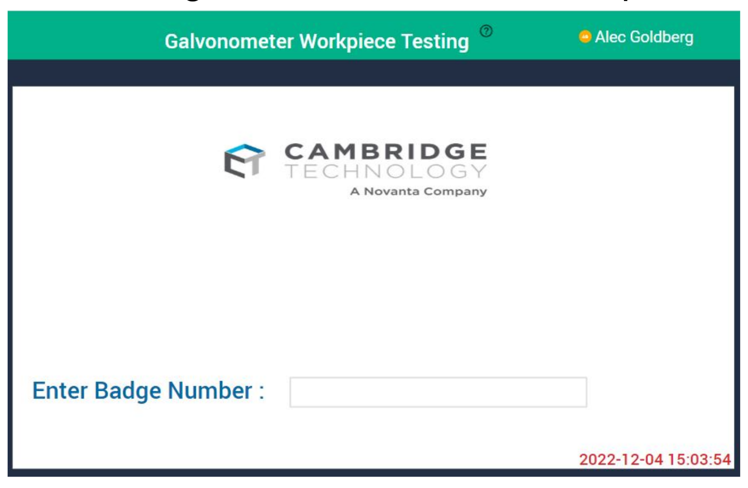
Safety Protocol: Research through possible causes that can interfere with any equipment during the heating process which includes RF exposure, Neodymium's magnetism, and EMI.

Relationship between laser and workpiece: Developed a trigonometric relationship between the laser and the workpiece using Snell's law of reflection (refraction neglected due to same refractive index in the mirror).

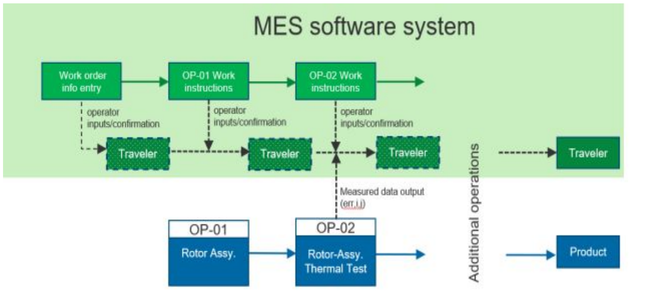
PID controllers: Researched on controllers that can control temperature based on the PID theory. This includes roles of how the PID theory is demonstrated.



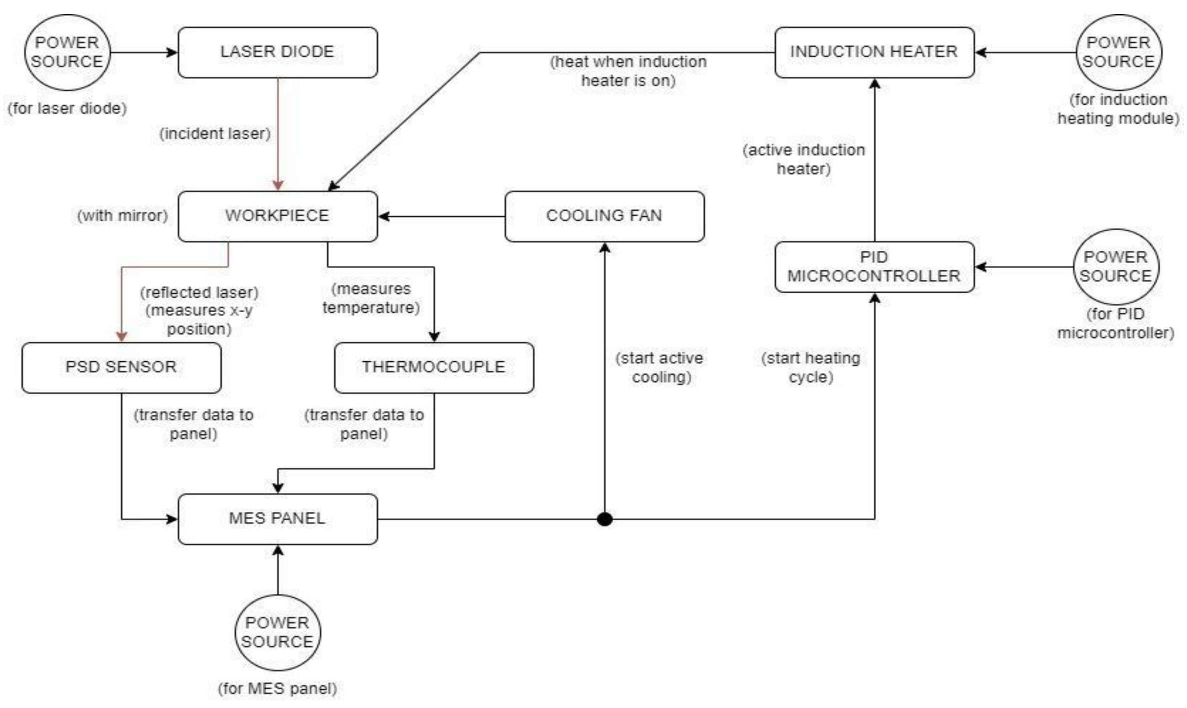
Block Diagram of the Test Fixture Operator



First page of User Interface



MES software block diagram



Block Diagram for Hardware of the Test Fixture Device

Remaining Technical Challenges

Software:

Communication between SQL and Tulip: A stable and secure connection must be made between the two, and intensive testing must be conducted to ensure that it can handle the large amount of data that will be going back and forth via the query.

Displaying Data on the UI: A form of displaying the data on the UI must be created, as this is integral to the operational ability of the Human Machine Interface.

Backend Calculations: Once the data is fully processed and functional, a program must be made in order to calculate the values that we need to ensure that our workpiece has passed its test.

PID Controller: A PID controller must be programmed and configured to allow us to accurately monitor the temperatures of both the induction heater and workpiece that will be used. This is crucial to ensuring that accurate values are calculated.

Finding passing value: Using data analysis, a value must be found that is used to determine if the workpiece can move onto the next step in the manufacturing process, or if it has to be held back due to a defect.

Hardware:

Positioning laser diode and sensor: Based on Snell's law of reflection, the laser is required to be reflected from the workpiece mirror and travel to the sensor at a certain angle.

PID Parameters: A PID controller needs to be tested to adjust the parameters with accurate temperature measurement to prevent overshooting the temperature and reducing the steady-state error.

Integrating all other components: The components are required to be integrated depending on the setup of how the heating process will work with accuracy. This includes careful positioning to prevent interference on all electronic equipment.

Finding accurate optical equipment: There are optional optical equipment that can help to satisfy the laser along its intensity and other physical characteristics.

Implications for Company & Economic Impact

The developed solution will have multiple implications for the company. Firstly, this will serve as a proof-of-concept for a state-of-the-art machine execution system, which will be able to be easily applied to other new manufacturing lines that are being developed. This will mark a complete transfer from a paper record system, to an intelligent and innovative digital MES system. Value stream improvements will be easily demonstrated in the new manufacturing line since a direct relationship between the newly acquired traceable data and the finished product quality will be shown. This will save the company a lot of time and resources.

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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 Director(s): Frank Puglia, Christopher Charron

PROJECT MOTIVATION

Underwater, 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

Collecting Data and Finding Variation/Noise in the AMBATS Platform (Ongoing):

The main goal of the data collection is to find any source of variation/noise in the AM-BATS platform. The first set of data collection shows that the BMS current sensor has very limited resolution. In addition to that, there is an offset between voltage and current. Another data collection reveals that the BMS shows double the amount of the measured cell internal resistance. Furthermore, the positive terminal of the battery holder is a large and variable source of noise which is the cause of the high resistance of the battery cell. **(Fig.1)(Fig.2)**.

Converting Digital Twin to Python:

Starting off this project, we were given a digital twin using Microsoft Excel that generates battery data accurate to non-simulated data. The initial task was to convert this to Python in order to automatically generate the data to use to train the future machine learning models. It takes in a simulated profile, represented by amps at a specific time, and will calculate temperature, voltages, and damage done to the cells for the duration of the profile. Different versions will be made for each machine learning task.

Machine Learning (ML) Model Selection:

The project consists of two entirely unique machine learning issues. One being that of anomaly/fault detection and the other being optimization. On the anomaly detection side, we believe it is best to pursue a long short term memory neural network (LSTM). **(Fig. 4)**

ML Training Setup Formation (Ongoing):

In order to train our models, specifically the anomaly detection, we will be using the digital twin to artificially inject anomalous data. The hope being that our model will be able to correctly detect when the error occurred as well as what specifically what the error was.

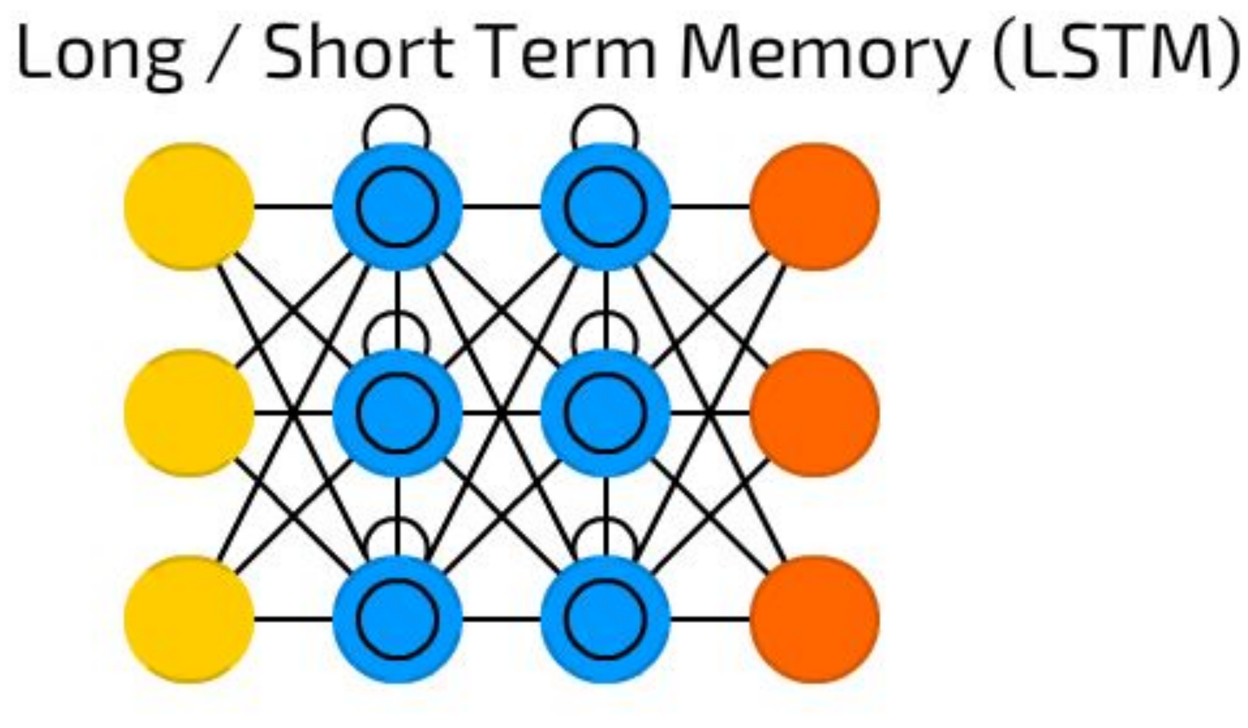

Fig 4. Visualization of an LSTM Neural Network

IMPLICATIONS FOR COMPANY & ECONOMIC IMPACT

If successful, this project will yield enhancements to battery performance for use in demanding maritime, aviation, space and military applications. Improved battery performance will further solidify EaglePicher Technologies as the leader in high performance Li-Ion batteries. In addition to this, if successful our Machine Learning algorithm would allow the creation of a BMS system that would be able to provide safer, longer lasting high performance Li-Ion batteries unlike anything else on the market. This project has the potential to advance the state of the art for battery reliability, safety and longevity across many applications and industries.

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.

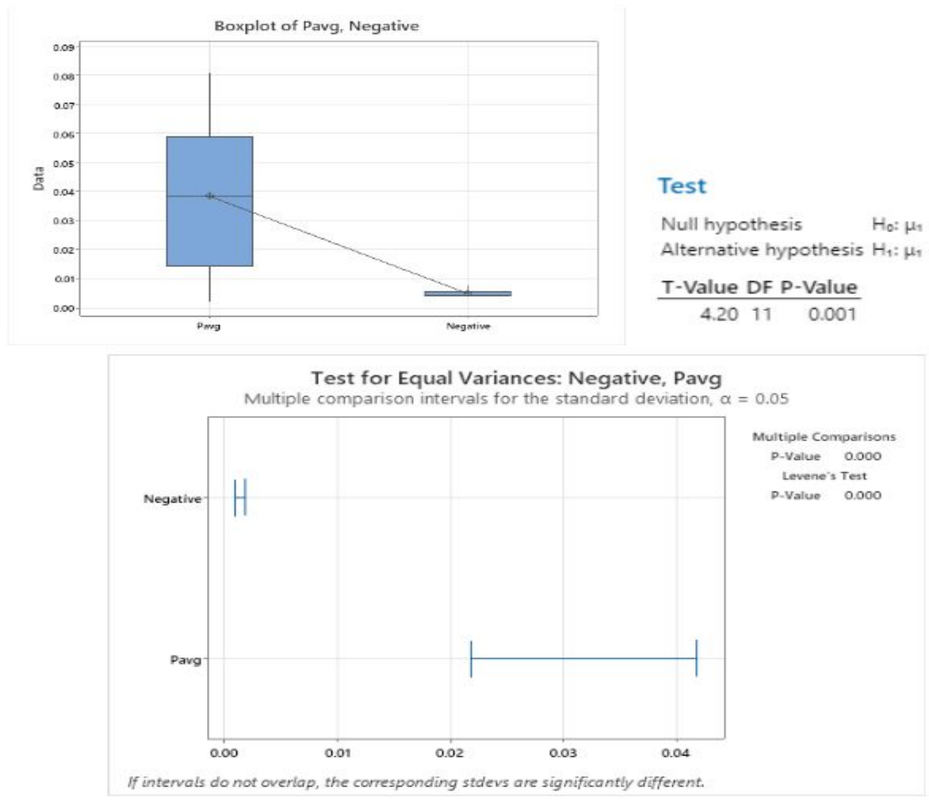

Fig. 1: Variation in the Positive Terminal Compared to

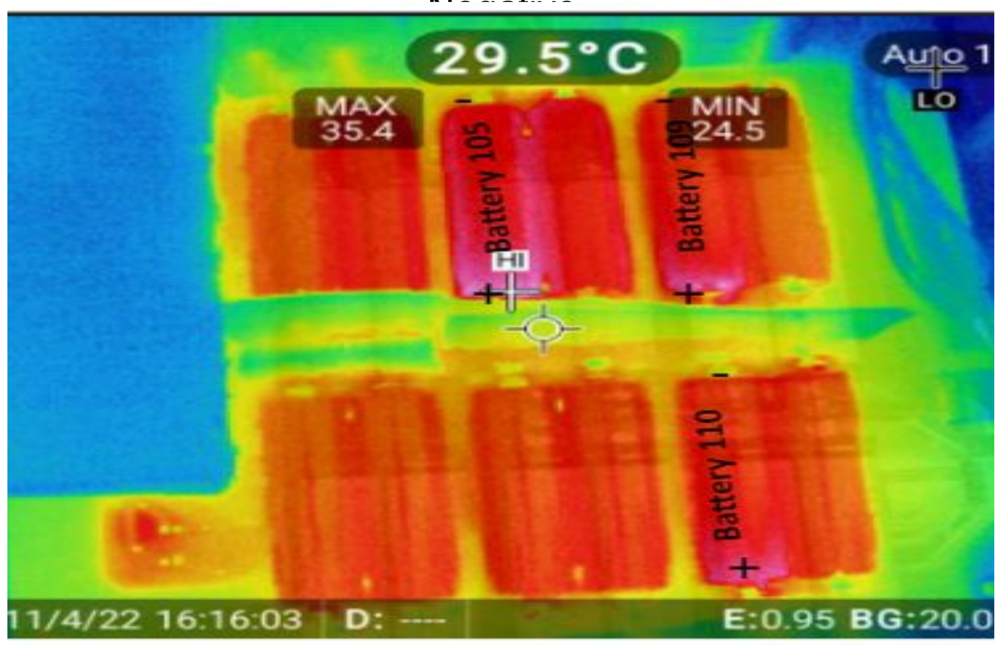

Fig. 2: Temperature Variation in Positive Terminal

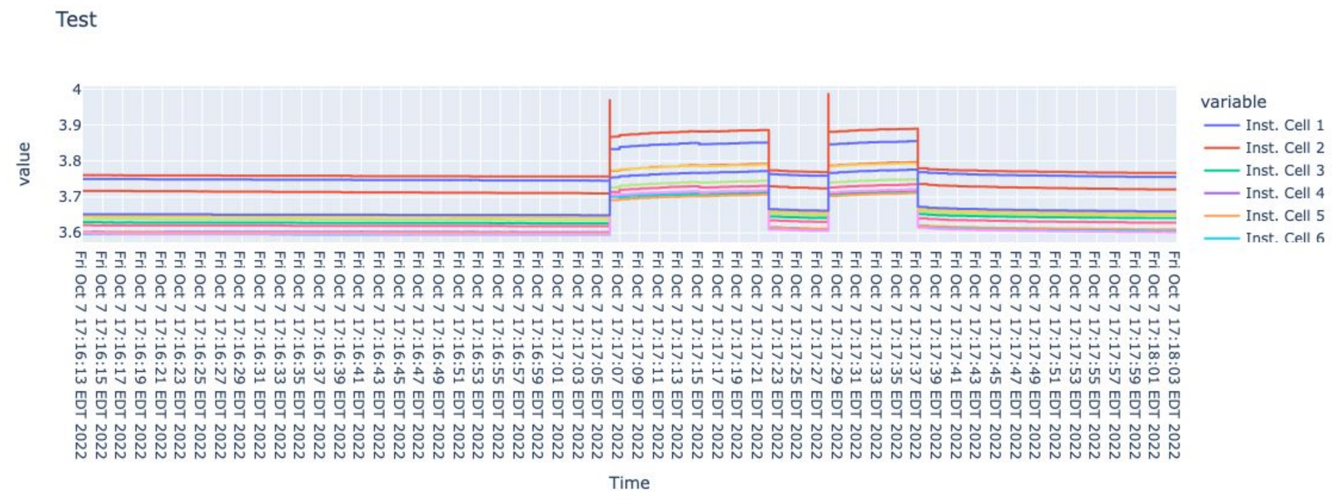

Fig. 3: Output of Data analysis tool interactive graph

REMAINING TECHNICAL CHALLENGES

Reducing the Source Variation/Noise:

This includes learning from the data collection and reducing the source of variation and noise to improve the AM-BATS platform. One of the things that need to be improved is to add a low-resistance battery holder. Also working along with the Eagle-Li team on the additional improvements to the AM-BATS platform.

Understanding the Delay between battery chemistry and BMS:

Going forward it will be important to timestamp and understand when exactly changes made to the system such as loading/discharging the cells appear on the BMS. Knowing this information will help significantly in the data analysis as it will help narrow down the window in which we should focus our attention.

Collect Data on the Updated Eagle-Li platform:

After the improvements made by the Eagle-Li team and the Battery Oracle team collect synchronized BMS and DAQ battery cell performance data for specific use cases. Both of our ML efforts will require massive amounts of data to build and deploy an accurate model. Once noise is reduced we hope that data acquisition can take place more efficiently.

Continue machine learning efforts:

Given the nature of machine learning as well as the platform being something worked on for the first time, the learning curve is extremely steep. Major progress has been made but there is still much to learn. However now that the fundamentals are more or less in place, we plan on branching out to our assigned roles of optimization and anomaly detection. From there developing a model to work on the digital twin and eventually the BMS/TI Daq.

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EaglePicher: Eagle-Li
Battery Management Research System (BMRS)

EAGLEPICHER TECHNOLOGIES

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

Technical Director(s): Daniel Wertz, Frank Puglia, Timothy Kelleher, Brandon Moore

Project Motivation

In a world shaped by the ever-growing need for enhanced technology, batteries are the backbone of what fuels such technology. In recent years engineers have developed the lithium-ion battery which is more efficient and sustainable than a regular battery. The problem with these types of batteries is that they are unpredictable. Having the ability to predict when a cell is deteriorating is almost impossible. 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. Team Eagle-Li believes safety should be the number one priority especially when working with such a dangerous battery cell.

Anticipated Best Outcome

The anticipated best outcome for our project is that we develop an improved Eagle-Li BMS laboratory platform. We will be using this improved Eagle-Li to perform live battery experiments to generate empirical data on voltage, current and temperature. It will help to identify the most sensitive indicators of battery degradation and performance changes that impact product safety and longevity using BMS data. Reaching our anticipated best outcome will also help the Oracle team. As their whole project relies on taking meaningful data that is accurate and can be looked at using machine learning.

Key Accomplishments

Did a real life investigation of the AMBATS Platform in Professor Jeong's lab with a demonstration of using it and how it works: After reading the manual of the platform, we were able to get a live demonstration of how the platform actually works and its operation.

Created Schematic for New Cell Holder: Used Fusion 360 to design a new cell holder to create a better connection with the battery cell as seen in Fig. 4.

Identified needed improvements to previous platform: After running some tests and analyses, improvements to the platform to obtain more accurate data were identified. The primary improvement was to build a new programmable load that didn't possibly interfere with the rest of the platform due to PWM operation.

Reviewed the design of the programmable discrete load with power calculations: A design for a discrete programmable load was given and we had to be familiarized with how it works, and the different values of voltage, current, and power we would have to account for. We also ordered the necessary components for building these eight channels. As seen in Fig. 2.

Began development of UI to interface with the 8 logic channels: In order to interact with the discrete load, it is important that there is a way to interact with the channels through software of an external computer. A UI needed to be developed so we could easily determine which kind of load profile we wanted. As seen in Fig. 1.

Building a dummy discrete load: In order to build this dummy load we will need to order a solder PCB board and similar components to the real discrete load we are building to be able to build a low scale channel of the discrete load to test the theory and get familiarized with it before working with the full scale 8 channel discrete load we plan on building. As seen in Fig. 3.

Interfacing with the usb 1208FS-plus: The universal library which is required to interface with the mc computing device has been installed in our visual studio IDE. The user manual for the interface has been reviewed as well allowing us to gain an understanding of how the device will communicate with programmable load. The ports of connection between the two have been identified as well.

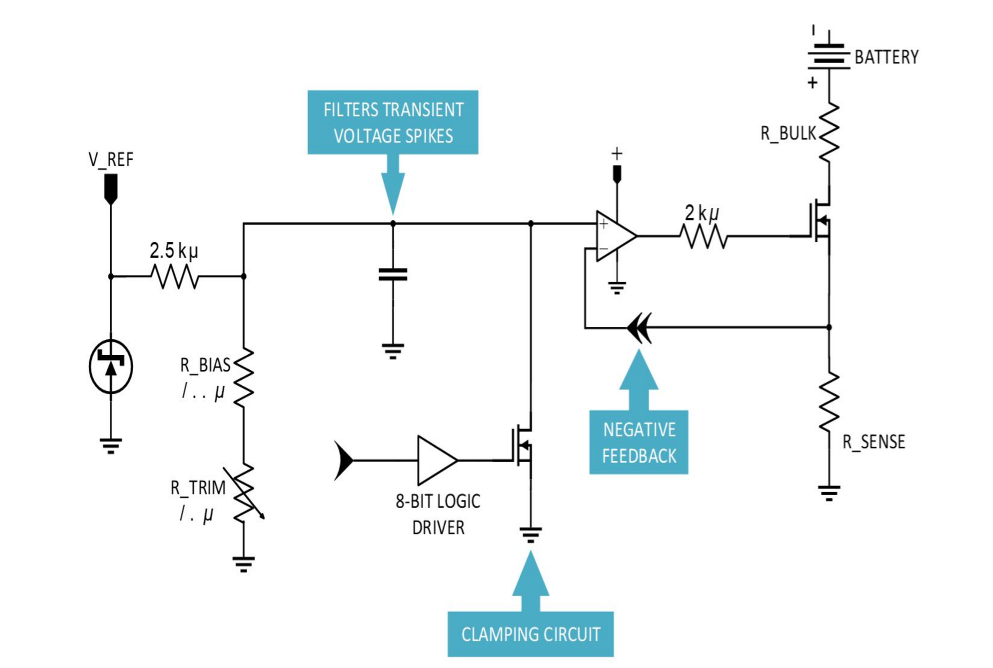

Fig. 2: Design for a single channel of the discrete programmable load

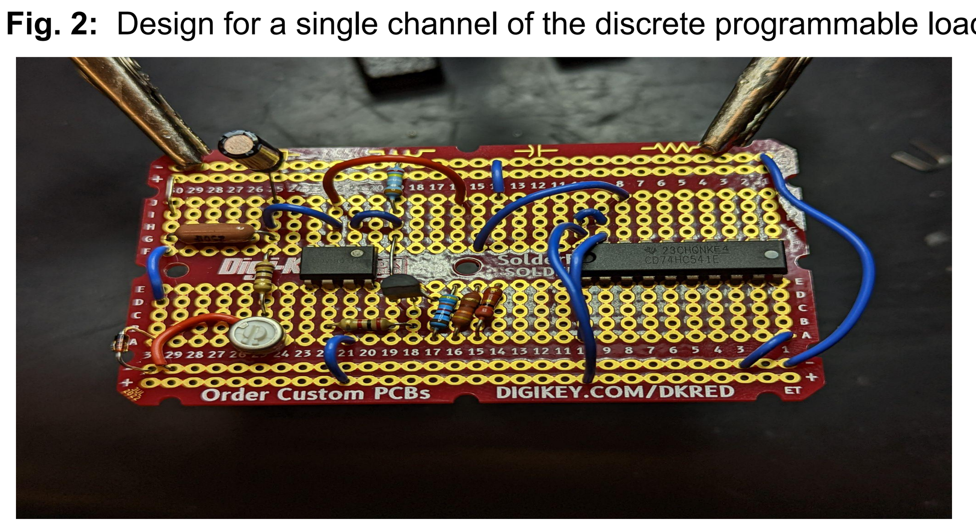

Fig.3: Soldered Board of Dummy Discrete Load

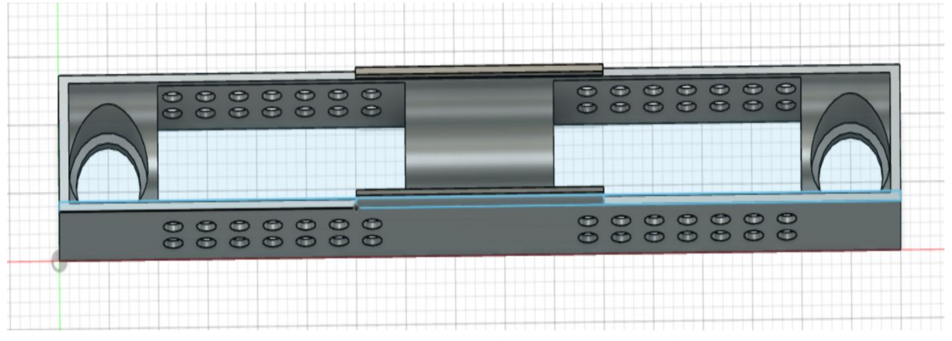

Fig. 4: 3D schematic of Improved Cell Holder

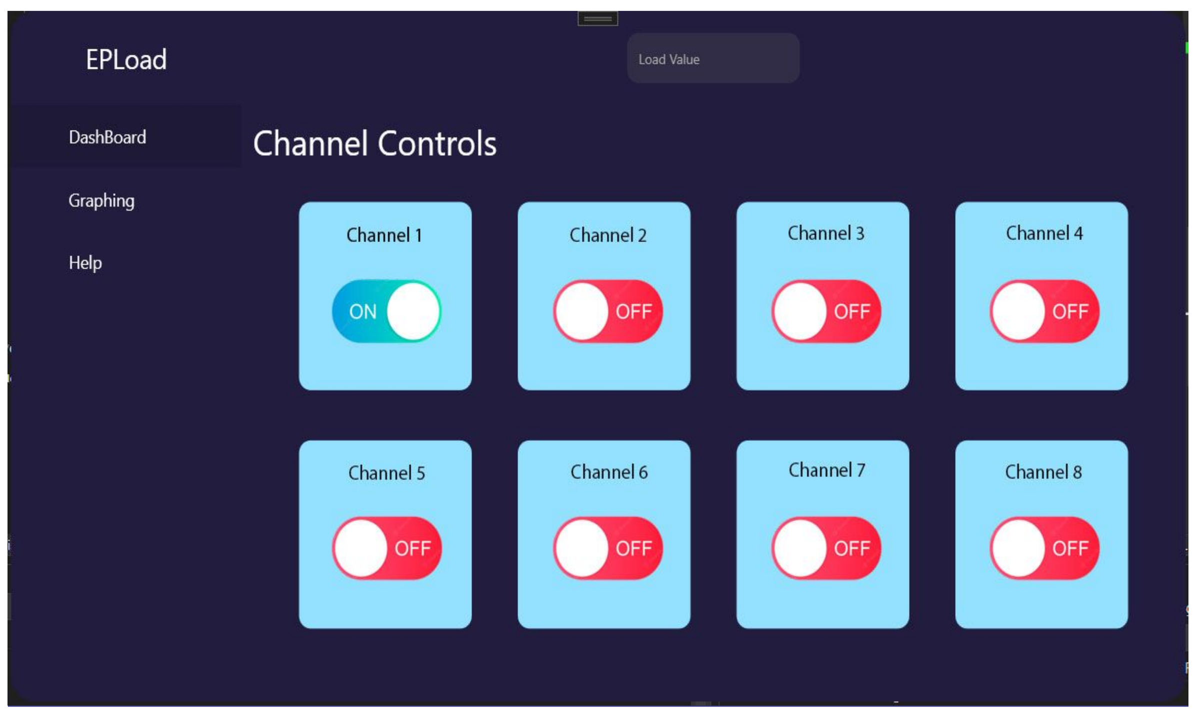

Fig. 1: GUI Layout for Discrete Load

Remaining Technical Challenges

FInalizing the discrete load: Finishing the PCB overlay of the discrete load as well as implementing the GUI. Then creating a housing system for the PCB.

Collecting data and running tests using the new programmable discrete load and power supply: Once the new programmable load is created, we will work with the Oracle team to run various tests in order to obtain data that can be used for machine learning. The discrete load will allow for better collection of data due to its ability to instantaneously switch loads.

Finalize a better cell holder for the AMBATS Platform: Once Radsok components come in we will be able to take measurements to correct hole size on Cell Holder. Once measurements are finalized 3D print these holders and implement Radsok components into the finalized holder.

Apply heat mitigation improvements to the AMBATS Platform: We will need to investigate how to improve heat transfer to the battery cells from external factors. This is necessary to ensure that our data isn't being skewed by external sources.

Create software for the programmable load: We are using the Universal Library in conjunction with C# in order to program for the discrete load. A beta version of the software was created in order to program the single channel small scale discrete load prototype. This ensured us that communication with the USB1208FS is possible. Since the proof of concept has be realized, we will continue to work on the fully scale GUI software. This software will contain radio buttons for controlling each individual channel as well as a user input for the load as a value. In the future we will include an interactive graph for creating time based load profiles.

Implications for Company & Economic Impact

The best outcome for this project would be to provide Eagle Picher with an improved functioning BMRS that can run live tests on Lithium-Ion batteries. The economic impact of this project would be a massive success for battery safety. Lithium-Ion batteries are some of the best batteries on the market now. Although when put under too much stress they can become very dangerous, sometimes even fatal. Our BMRS will aim to help monitor cell life and try to figure out patterns that help show that cells are degrading. Economically, the goal of the BMRS is to help prevent disasters involving Lithium-Ion batteries.

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A Multimodal Brain Monitor

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

Echo WEAR

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

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

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)).

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.

Key Accomplishments

Initial Component Selection: Materials list for both fNIRS and EEG components. For the EEG data collection, an off-the-shelf board, OpenBCI, was chosen. This offered a simple way to start collecting, analyzing and learning about the collection of EEG signals. The fNIRS components were loosely based off of an existing project 'DIY-fNIRS headband,' however required heavy reworking due to both chip shortages, and messy outlines of existing PCB schematics.

Integrated Circuit (IC) Replacement: The light intensity controller, MSP430F64IZCAT, was one component where there were no valid replacements for. By researching how this part of the circuit should function, a rudimentary LED driver circuit could replace the IC.

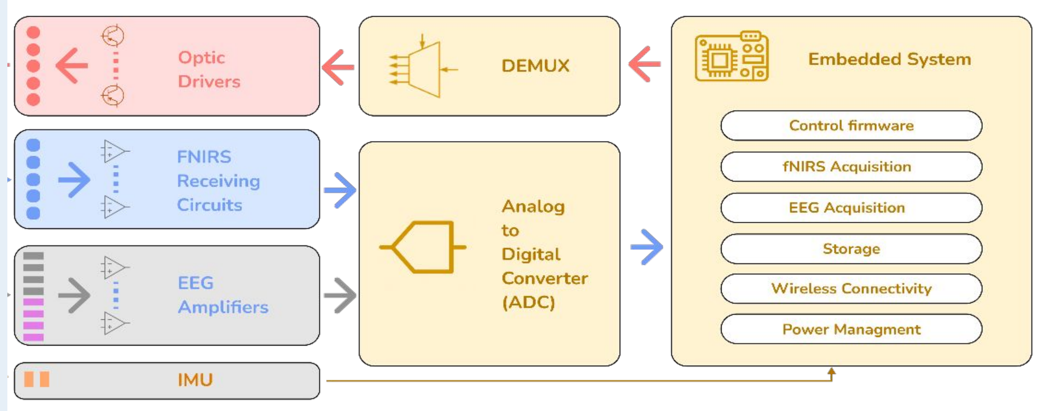
Nordic nRF Bluetooth Boards: Understand bluetooth and use SEGGER Embedded Studio to program two nRF boards to communicate through bluetooth, since the data acquisition system will send data wirelessly to a computer for reading and processing.

SparkFun OpenLog Artemis: This board is a data logger, which has a built-in IMU for logging triple-axis accelerometer, gyroscope, and magnetometer values. Able to save these values to a microSD card in a .csv file to easily read and interpret data.

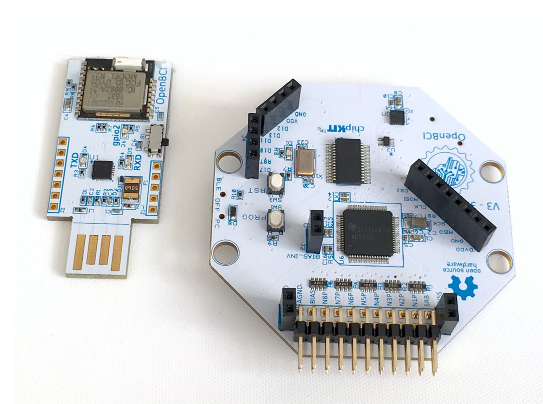
Hardware Schematic and Printed Circuit Board (PCB) Design: The fNIRS project is based off of an existing 'DIY-fNIRS headband' by HardwareX design. To accommodate component replacements and a 4 channel design, a new schematic and PCB design was drafted that simplified the original design.

Data collection with OpenBCI: Initial data collection was made with a headband that was constructed with a visor and textile electrodes. Using a GUI that was developed by OpenBCI, time series data may be recorded and stored into .csv files for later use.

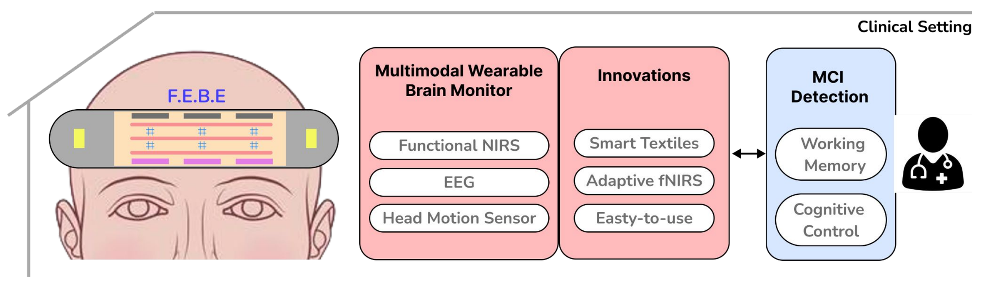
Signal Processing: To visualize the data collected, importation of the data into MATLAB allows for the graphing of the time series data, along with the Fast Fourier Transform (FFT), which allows for analysis of the electrical signals.



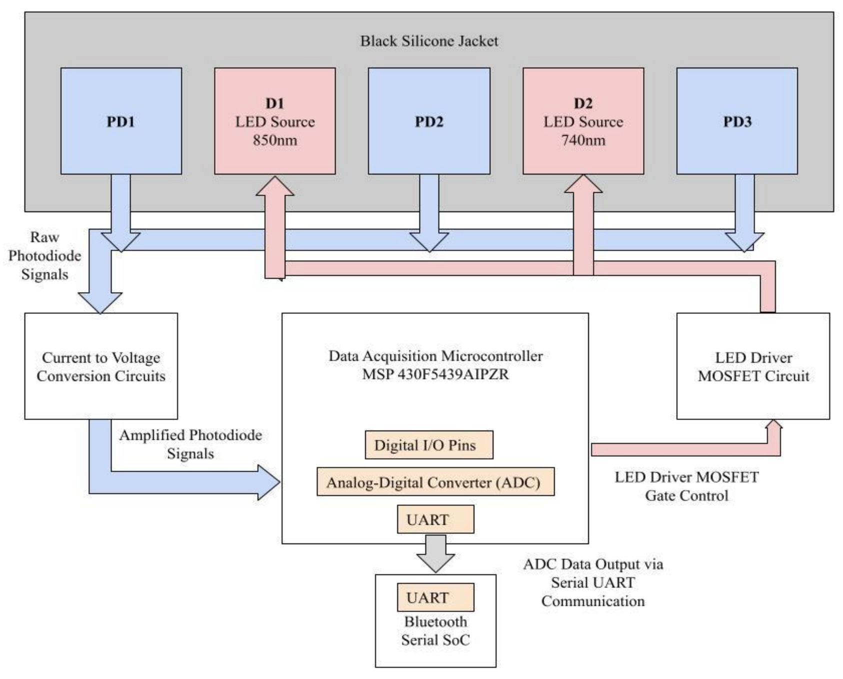
ABO Project Overview Block Diagram



OpenBCI Biosending Board (EEG)



Project Impact



fNIRS Detection and Acquisition Block Diagram

Remaining Technical Challenges

fNIRS PCB Construction: Due to the lack of a pre-existing library for the components in the fNIRS bill of materials, parts that do not exist will have handmade footprints following datasheet specifications. Although the datasheet is easily accessible, maintaining all minimum trace widths and solder and paste expansions for each component will be complex to implement.

Data Collection of fNIRS: The main microcontroller will be programmed to control the voltage follower LED source op amps as well as the LED driver circuit. It will also take in data from three outputs of the photodiode current to voltage conversion op amps. The signal integrity and data collection system needs to be debugged and tested.

Skin tone estimations (fNIRS): A known issue in fNIRS signal detection is poor signal quality in darker skin tones. Incorporating a skin tone detection system that would allow for the adjustment of the intensity of the light source would provide the user with higher-fidelity fNIRS data acquisition.

Combined (EEG/fNIRS) Headband: Implementation of both the fNIRS circuit and EEG circuit into the same headband. This will require the design, with placement, of the LEDs, photodiodes and electrodes in the headband, along with the design of the noise reduction processes that will be in place.

Firmware Implementation: Accurately implement firmware for the embedded system to avoid complications. The detected fNIRS and EEG signals will pass through two corresponding receiving circuits to condition, amplify, and filter the analog signals that will be fed to an analog-to-digital converter (ADC). The digital signals from ADC will go to the embedded system for storage and communication.

Noise Reduction: IMU data will carry head motion information. Using independent component analysis (ICA) and Kalman filters to remove artifacts and motion noise, digital filters will be applied to remove the electromagnetic noise.

Implications for Company & Economic Impact

This multimodal brain monitor is envisioned as a clinical product that can be used reliably by medical professionals, such as neuropsychologists and neurologists, to detect early onset mild cognitive impairments (MCI). The working prototype of an integrated fNIRS/EEG headband, along with a neurocognitive assessment system will allow for the collection of preliminary feasibility data from patients with MCI at RI Hospital. The impact of this project holds its importance in the significant number of people with MCI, which can develop into Alzheimer's disease and dementia. This project could allow for early detection of Alzheimer's, and similar diseases, and allow for families to access early interventions.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Advanced AC/DC Power Architectures for Modular Data Center Enclosures

GENERAL DYNAMICS
Electric Boat

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

Technical Director(s): Mike Brawner, Tyler Balczun

Project Motivation

This project will investigate next generation, high-voltage, direct-current power systems for mobile data centers. There will be technology assessments performed for any components or technology of interest. With the information researched the project will produce simulation models of capabilities for the power system developed for mobile data centers.

Mobile processing enclaves/data centers require stable and reliable high voltage DC power, typically greater than 400 volts. The power makes it to the individual servers and processors which convert the AC voltage to DC voltage on a component level, providing DC directly.

In this project, two main components we will be researching are Uninterruptible Power Supplies (UPSs) and Power Distribution Units (PDUs). A UPS is responsible for providing and storing power for the system while the PDU distributes that power among the loads. Battery, cooling system, circuit breaker, transfer switch, and power monitoring technology are among other components researched.

Anticipated Best Outcome

Our best outcome is :

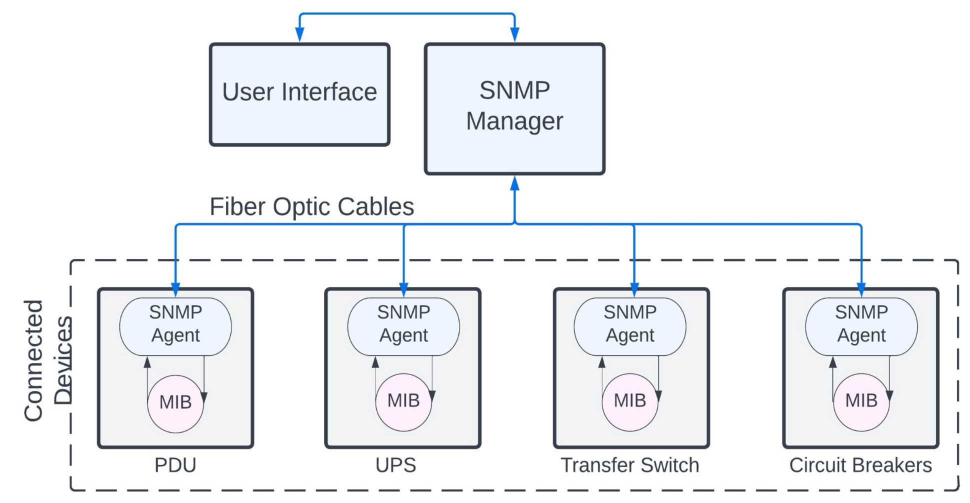
- Identification and assessment of power distribution Technology to include in our System
- Development of a full concept model including TRLs
- Prototype assembly and testing for key emerging technologies
- Simulation outcomes that show component capabilities and power characteristics of System

Key Accomplishments

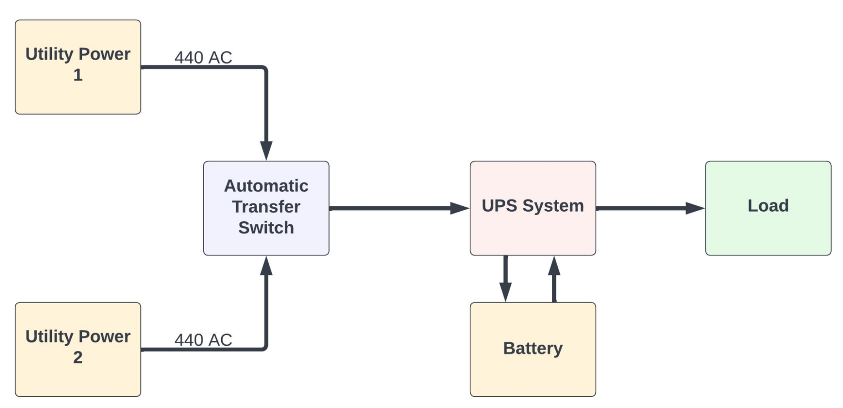
Initial Research of Power Distribution Systems: When first being assigned this project, we had a lot of background research to conduct to become familiar with the concept of a power distribution system. We discovered concepts such as power architectures (centralized vs point to point), and the fundamental ideas of redundancy, efficiency, availability and modernization. Along with these important concepts comes the type of voltage (DC vs AC) as well as favorable voltage levels to have in our system. From this point we concluded that having a centralized DC system best satisfied all of the important criteria.

Research of Specific Power Distribution Components: The next step for us 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. As we conducted research we kept track of important characteristics for these components to have, as well as important articles for us to go back and reference when we began the next step of our project, the downselections.

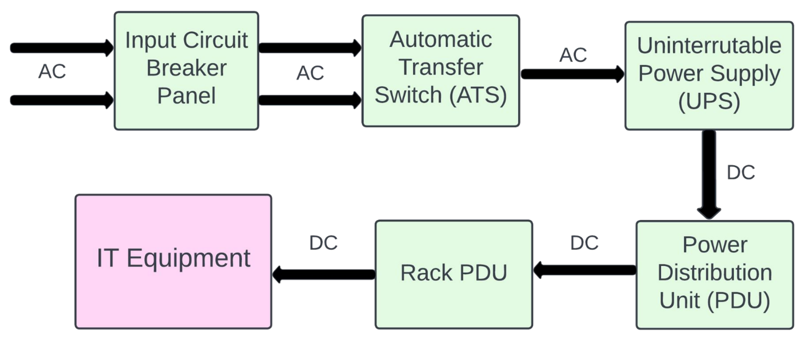
Technology Downselections: As we move closer to the actual design and development of our system, it was time for us to start applying all of the information we had come across so far. We chose to use a modified version of Pugh Matrices to keep track of our downselections. The first item for us was to narrow down the specific characteristics of our own design, as we had come across many different sources of information. We created matrixes for factors such as the location of the UPS, the location of the PDU and the layout of the server racks. The next section of Matrices is what we are currently working on, which is the Specific Components that will make up our system. So far we have finished Battery Technology and Cooling System matrices, but have the more important matrices on our horizon.



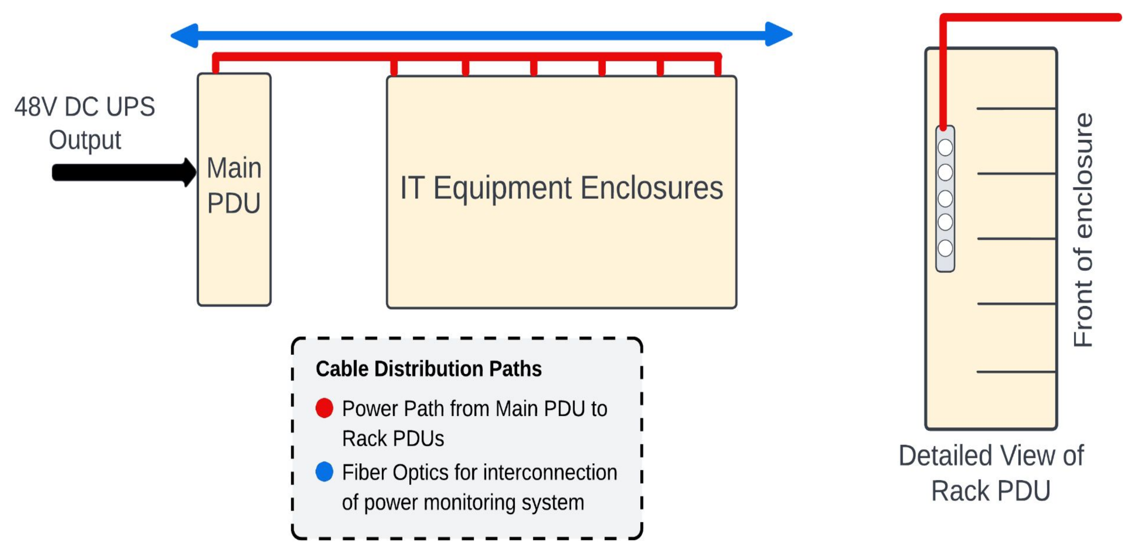
Communication of Monitoring System



Transfer Switch + UPS Power Path



Block Diagram of our Overall System



Power Path from output of UPS to IT Racks

Remaining Technical Challenges

Our remaining technical challenges consist of development of a complete concept model, finalizing our design and key components, as well as conducting simulations and physical testing of our power system.

We will need to set specific goals to reach and testing to complete by certain dates. We will also create a plan for this process by the beginning of our second semester in order to have a clear and concise idea of what we have left to do. This will help us solve and avoid any issues that we may have to face.

When finalizing our design and key components, we will have to review each technology and ensure that they will interact with each other as planned. We also will keep researching for new components or other technologies that could better our system. This is necessary to deliver a system that is efficient and provides a solution to our sponsor company's current situation.

Our prototype and testing need to show that our system is an upgrade from their current system and can be used for a long time to come. To do this we will have to develop a physical model and set parameters to test. This is needed in order to show our systems efficiency and prove that the technology we chose works well together.

Our simulations need to display how our systems works and how it responds in several scenarios. To accomplish this we will have to set parameters to measure and simulate real world occurrences that our system may have to come in contact with.

Implications for Company & Economic Impact

As a growing number of processing systems are being added to platforms, the capability to provide self-contained and appropriate power to each is increasingly desired. Next generation servers will be even more reliant on stable and reliable DC power. Flexible DC power technology and systems are critical and will be required to provide the capabilities to enable improved reliability. It will also be required in order to have hardware arrangement flexibility and potentially reduce costs. This project should provide a solution to this growing problem and allow for an improved and cost-effective DC power system for mobile data centers.

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859 ELECOMP Website: https://uri.edu/elecomp-capstone

Low Frequency Radio Frequencies Over Fiber Optics

Implementing RF over Fiber technologies over low frequencies

GENERAL DYNAMICS Electric Boat

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

Technical Director(s): The name of your Technical Director/Directors

Project Motivation

This project will investigate and assess technology options and develop simulation models of capabilities for conversion and optical routing of Low Frequency Radio Frequency 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. As an increasingly number of processing systems are being added to platforms, the capability to mitigate Electromagnetic and RF Interference (EMI/RFI) is becoming more important. Increasing the use of optical cabling for signals of interest is a high priority area of investigation. System development to provide a capability that can support a range of frequencies and signal types over varying distances is required. Leverage and adaptation of the emerging technologies being investigated and developed in the commercial industrial base is highly desired. Technologies of interest include:

- Analog Conversion
- Digital Conversion
- Direct and External Modulation
- High Speed, Low Latency Buffering

Anticipated Best Outcome

Since this capability is not currently available for many low frequency signals, 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. The investigations will include identification and assessment of applicable technologies and components', systems Readiness Level (TRL) and potential risks for maturity of that technology.

Key Accomplishments

Research relevant to Radio Frequencies and Fiber Optics: Our Technical Directors have provided us with numerous online literatures to help familiarize ourselves with radio frequencies and fiber optics. Additionally, we have been reviewing other resources that we have found online regarding these topics. With this research, we look to come up with ideas for potential prototypes. This research will allow us to select the most optimal solution out of the generated ideas for potential prototypes.

Simulation software: As instructed by the TDs, we will be creating our simulation using MATLAB and Simulink. Both members of the capstone team have already downloaded the necessary toolboxes to perform our simulations. This simulation software is necessary for producing simulations of potential prototypes of low frequency radio frequency over fiber communications systems. Simulations that can model these prototypes are desired products of this project.

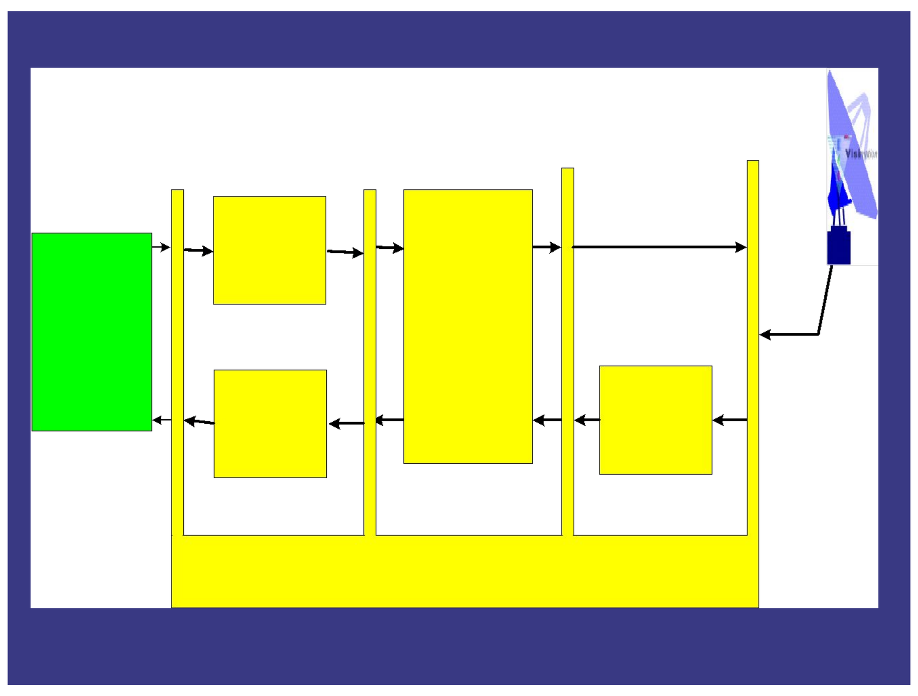


Fig. 1: Diagram of company's current implementation

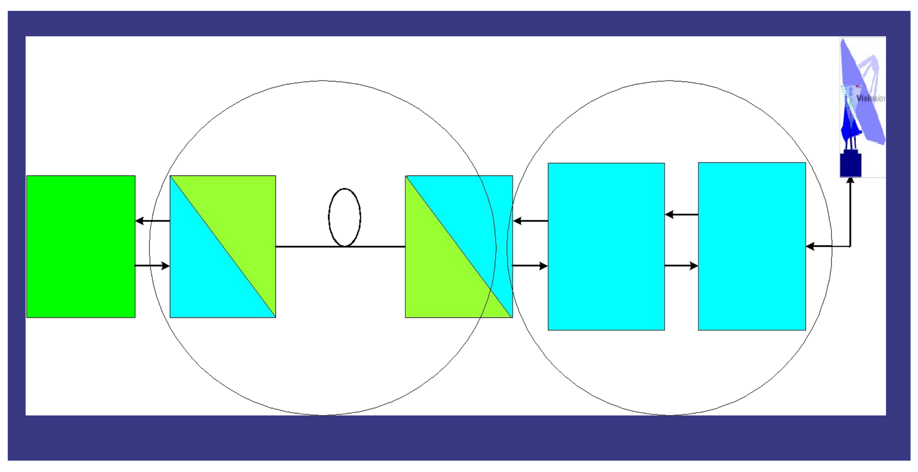


Fig. 2: Diagram of an RF over Fiber Optic system

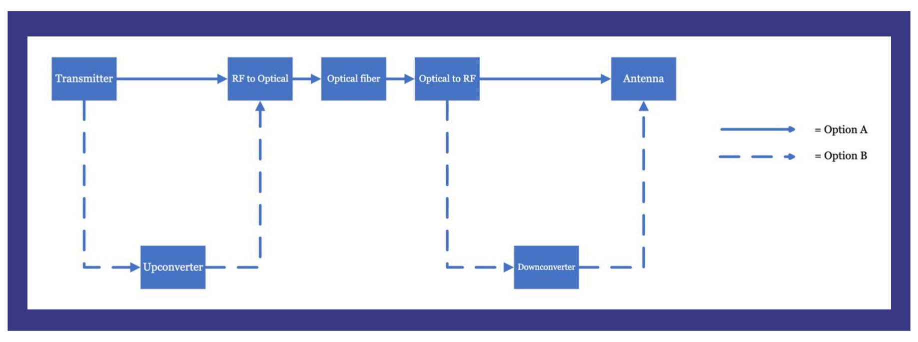


Fig. 3: Block diagram of potential implementations. Option A refers to directly transmitting low frequency signals to the E/O converter. Option B refers to using pre-existing high frequency E/O and O/E units by upconverting/down converting the RF signals to the necessary frequencies.

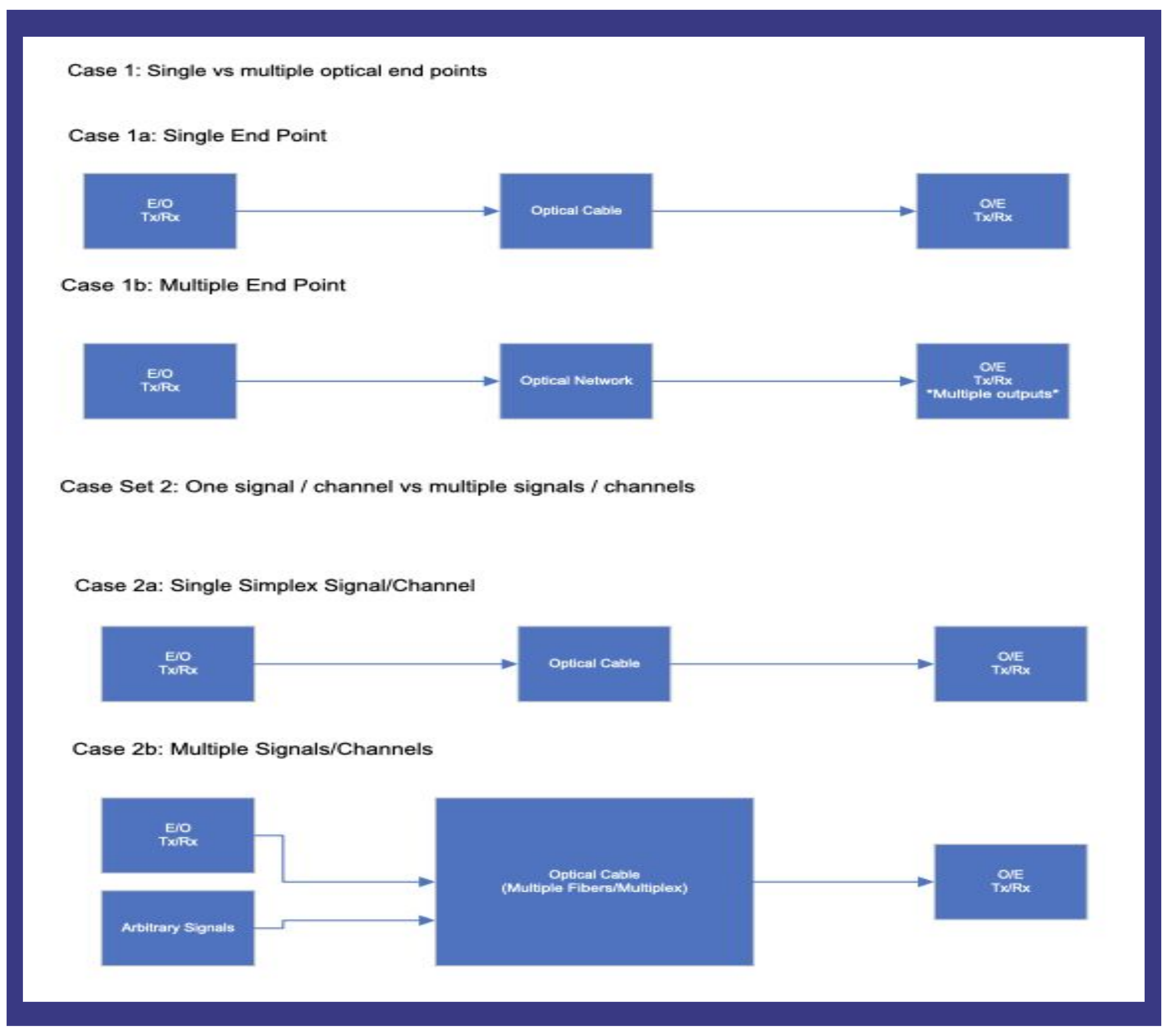


Fig. 4: Block diagram of optical communication system

Remaining Technical Challenges

Further Research: We plan to continue researching topics related to radio frequencies and fiber optics from our independent research as well as the literatures provided by our TDs. These include, but not limited to:

- Signal Modulation
- Up conversion/Down conversion
- Basics on Fiber Optics
- Analog Conversion
- Digital Conversion
- FSK, ASK, PSK
- RFoF designs
- Forward Error Correction

Familiarity with simulation software: Since neither capstone teammate has had to use Simulink, gaining familiarity with it is paramount. We have been following the hands-on tutorials provided by MATLAB and Simulink and have begun to experiment with the software. Currently, we have reviewed the following tutorial modules:

- MATLAB Onramp
- Simulink Onramp
- Simscape Onramp
- Circuit Simulation Onramp
- Wireless Communications Onramp

Identification of components for potential prototype: As part of our research, we continue to research and identify real-world components to test our simulation with real-world components.

Implications for Company & Economic Impact

Understanding the options and limitations of this capability and platform integration dependencies will enable Electric Boat to help guide its development and concept of operations. Compared to copper cables, Fiber Optic cables provide a greater bandwidth over longer distances at faster speeds. Additionally, Fiber Optic cables are less prone to damage and breakage, while also being lighter and thinner. This makes them more cost effective compared to copper cables. Electric Boat will benefit by increasing our system design and concept development capabilities and enabling next generation systems to be integrated into platforms with manageable impacts.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Show Controller Replacement

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

IGT®

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

Consulting Technical Director(s): Brenden Smerbeck - IGT Technical Director(s): Raymond Leland, Erik Hanley

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 was introduced to the marketplace in 2015 and is becoming obsolete. 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.

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.

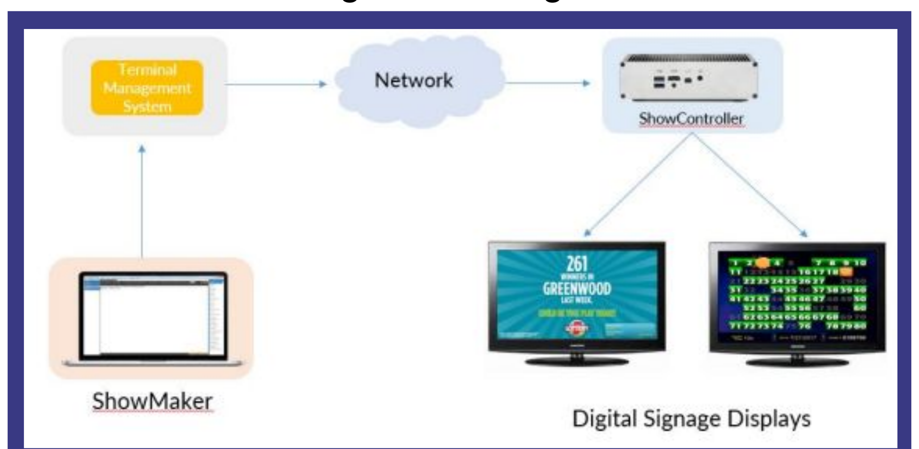
Key Accomplishments

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.

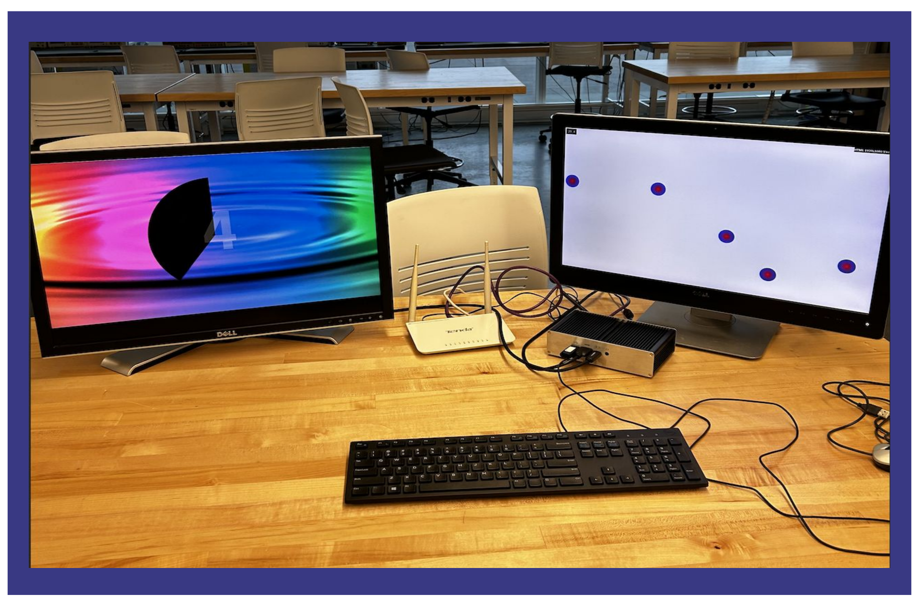
Component research and evaluation
The result from our buy vs build evaluation was that the team would be choosing a building option moving forward. This requires component research and evaluation. The most important component for this device is the CPU as it dictates almost the rest of the device; board,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

Benchmarking current VCU and Prototype board: Initial benchmarking was done on a prototype board with a Intel Atom x6413E CPU. 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. These test results are then recorded in an organized spreadsheet to be used to compare with other protoboards. The result from Phoronix Test Suite: GPUTest result can be found below. Benchmarking tests were also performed on the current, existing version of the ShowController.

Design of existing VCU



Block Diagram of Functionality



Example of ShowController Dual Output

Risk	Description of Risk	Impact to Project	Likelihood Of Risk Occurring	Seriousness of Risk Occurring	Grade	Mitigation Strategy
Component Availability	The components used for this project contains embedded systems/boards and computer hardware parts that could become unavailable due to supply chain issues.	The project will not be able to be completed without necessary hardware.	Medium	High	B	Our group will choose parts with more caution, making sure the component does not become obsolete and discontinued and confirm with IGT with what the company is currently working with to have a better scope of what's available/currently used.
Faulty Components	There is a chance that the hardware components we receive are faulty and do not operate as intended.	The project will not be able to be completed without fully functional hardware.	Low	High	C	We could order multiple of the same component, and test/prototype these parts as we move along with the hardware assembly portion of the project.

Biggest Risks to Reaching ABO

Implications for Company & Economic Impact

Having effective lottery advertisements and displays are essential to getting as many people to participate in the lottery as possible. Digital signage is a core requirement by IGT's lottery customers to support key lottery advertising and game draw results. The video controller device that we are developing for this project will be used as a part of IGT's standard product offerings to IGT's Lottery customers for displaying multimedia content to digital signage displays. There is also a possibility that the project results will be integrated with other IGT's products to provide more flexibility in designing new solutions for IGT's Lottery and Gaming customers.

Remaining Technical Challenges

Development Board Testing: With one of the possible CPUs for this product tested, we still have to test another to see which would be the better fit for our tasks. We still need to acquire, test, benchmark and record data for the Atom x6425E processor.

Prototype device testing: Once we determine the final hard specifications and what is reasonably possible to have on the board, we can begin building the prototype board with all the required hardware and I/O.

IGT Software and Firmware integration: Once the hardware is configured and setup we then have to take the existing IGT software and firmware and integrate it onto the new hardware so they work hand in hand such as the previous version of the VCU.

Formal Device Documentation: Once the final product is finished regarding hardware and software implementations we must help create formal documentation to explain each component and the schematics. This documentation will be modeled similarly to the current VCU documentation that we have been using as a reference.

Final Product Demonstration: After the hardware and software are integrated, the device will be transferred to IGT's Engineering team by the end of April 2023. The device can then be released to the market for IGT's customers. The last thing to do is to connect the device the same way it would be in a restaurant or bar, and configure it to digitally sign lottery games onto output display devices.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

BAMS

Biometric AI Measurement System

in-depth engineering

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

Technical Directors: Bill Matuszak and Dave Helms

Project Motivation

Wearable technology is currently a billion-dollar industry that is expected to continue expanding as consumers' interest in their personal biometric data grows. Data from these smart devices have already been used to successfully optimize athletic performance and have great potential to revolutionize the future workforce. In-Depth engineering has begun to explore whether information from biometric devices can also be used to optimize the performance of Computer Based Information System (CBIS) operators.

The objective of this project is to use Artificial Intelligence and machine learning to evaluate CBIS operator performance as a function of biometric data. The ability to understand and predict operator performance would benefit many organizations significantly by providing insight into not only how to best optimize their personnel but improve quality of life.

Anticipated Best Outcome

The anticipated best outcome of this project is the development of 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 a CBIS application and biometric sensors before being used to train a Machine Learning model that will classify operator performance based on operator interactions within the video game's environment. The resulting BAMS prototype could then be used to predict and improve the performance of operators of CBIS systems for air traffic control, power plant operation, sensor processing, and unmanned vehicle control.

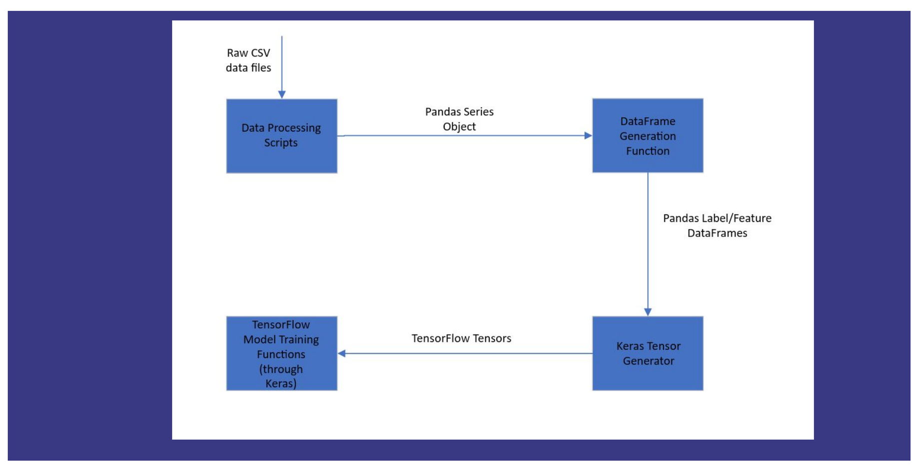
Key Accomplishments

Biometric Data Collection Apparatus: We have designed and implemented a networked set of biometric data collection devices to use to collect data for the ML model training section of the project. The goal was to make data collection as simple as possible so the group could efficiently collect data in our free time without having to fix or debug the system, wasting valuable data collection time. Another important consideration is consistent data output formatting, which we have also accomplished by having all the devices output to a consistent CSV format.

Data Processing Suite: The biometric devices we chose output vast amounts of data, typically every 10ms. Naturally, this must be processed and reformatted in a way our model training functions can use. The team designed a set of Python scripts which take the raw data in the form of a CSV from each device and calculate key metrics per session (for example, for the keylogger software we use to collect data, we calculate 'keys per second' for each data collection session). These scripts output the data in a Pandas data structure called a Series, which can easily be converted to a Pandas DataFrame which is itself converted to a TensorFlow Tensor object.

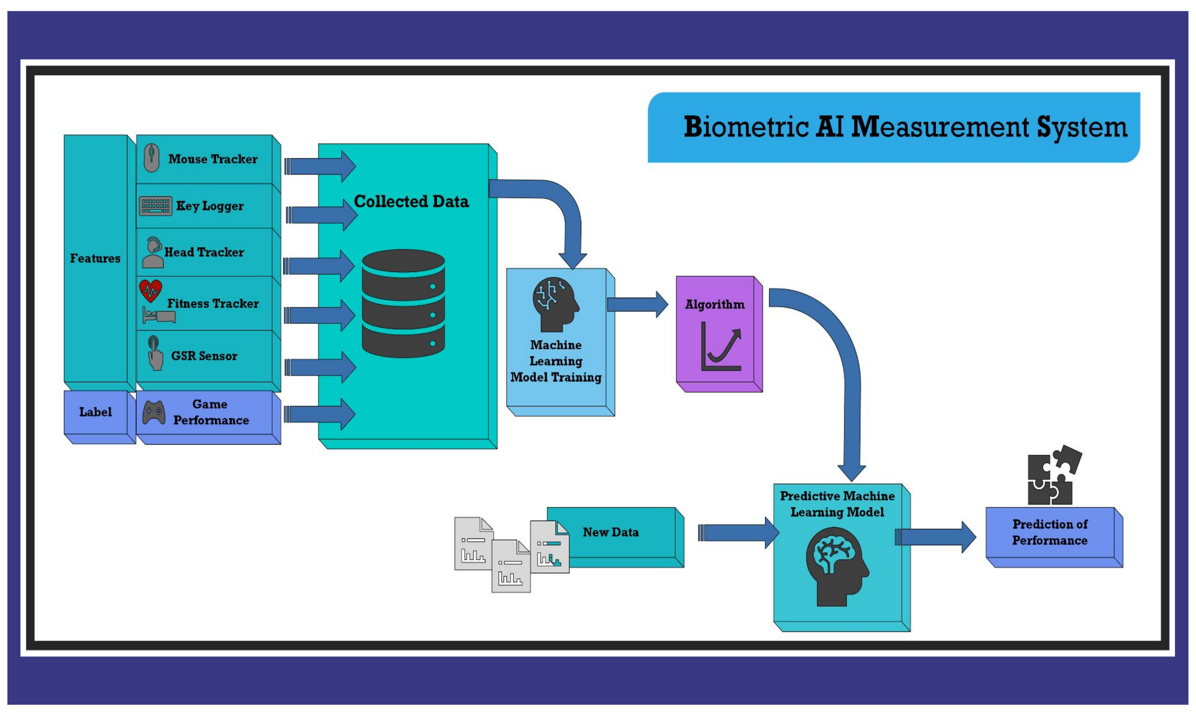
Preliminary Model Training (w/ Google CoLab Notebooks): Using the Google CoLab interface (CoLab hosts online Jupyter Notebooks and free-to-use ML compute resources) we were able to test training a preliminary model using some early data collected. Although we will not be using this environment in the future (we will instead be using one of the group's personal Nvidia 2070 Super GPUs for model training offline due to compute limitations on CoLab), this preliminary model shows our method of data collection and data formatting works, and we will be building on this preliminary model for future training, likely with modifications to the model parameters and model hyperparameters.

BAMS Data Collection System



ML Model Training Block Diagram

Screenshot of Data Parsing Script



Block Diagram of ABO System

Implications for Company & Economic Impact

Achieving the anticipated best outcomes for this project would provide In-Depth Engineering with a successful proof of concept that would serve as a foundation for future research into using biometric data to optimize personnel performance, specifically CBIS operators. Understanding when an operator needs a short or extended break will not only improve quality of life but will also increase an organization's overall productivity. Proving that there is a correlation between an individual's biometric data and performance could lead to a system that would allow In-Depth Engineering to better compete for Small Business Innovative Research (SBIR) contracts worth millions of dollars.

Remaining Technical Challenges

Data Collection: Now that our Data Collection Apparatus and the Data Processing Suite has been completed, the group plans on collecting mass amounts of data from the biometric devices and the game we have chosen as an analogue for real life performance (AimLab). To effectively train the model, we likely need hundreds of data points, each data point a session in AimLab, so this will take a long while. To assist with this, we will be dedicating multiple hours per week to data collection, as this is a crucial part of the project (an ML model's accuracy is heavily dependent on the data that is used to train it, following the engineering principle of 'garbage in, garbage out').

Model Training: Once we have enough data, work will begin on actually training the model. First, we will have to select a model archetype, although we are currently leaning towards using a Convolutional Neural Network model, due to its versatility and predominance within the industry. We were initially considering using a Temporal Convolutional Network, a type of Convolutional Neural Network, however since we lack real-time data to form a time series Tensor input this would be a poor choice of model. This will require some more education on model selection and training, for this we have some reference material from Google.

Model Tuning and Optimization: After conducting our first few iterations of a trained model, we will have to tune the hyperparameters and potentially add additional data or metrics collected to optimize the model. This is anticipated to be a long and iterative process, as we continuously run the model training functions and evaluate the results and reported model loss. Thankfully, Keras has very simple functions that allow us to visualize model loss and error and allows for us to swap the loss function within our model easy, allowing us to iterate quickly as we construct our model.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 21, 2021

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Contactless Underwater Battery

Contactless Charge/Discharge of UUV Battery

NAVAL UNDERSEA WARFARE CENTER NUWC DIVISION NEWPORT, RI

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.

Anticipated Best Outcome

Our group anticipates a working prototype by 04/14/23 that provides a manageable power monitoring system that allows wireless power transfer to and from the two coils provided. Allowing, for the recharge and discharge of the batteries, wirelessly, in an underwater ocean environment.

Key Accomplishments

Research- We began the project by researching key technologies related to this project:

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.

Lithium Ion and Nickel Metal-hydride Batteries-

Commonly used batteries in unmanned underwater vehicles.

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.

Circuit Design and Simulation-

We have started designing our wireless power transfer circuit and are currently simulting 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.

Fig 1: Block Diagram

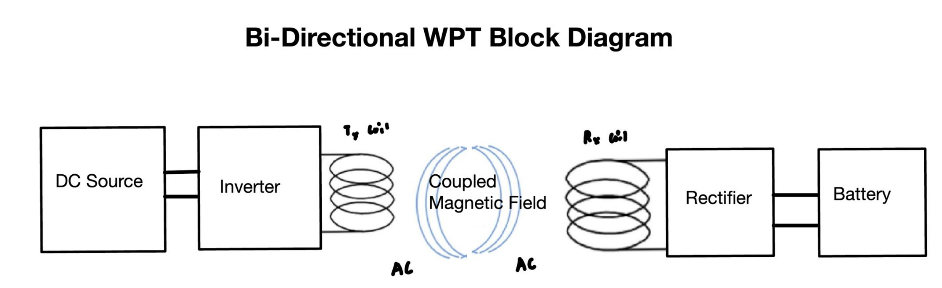


Fig 2: Future Coil Simulation

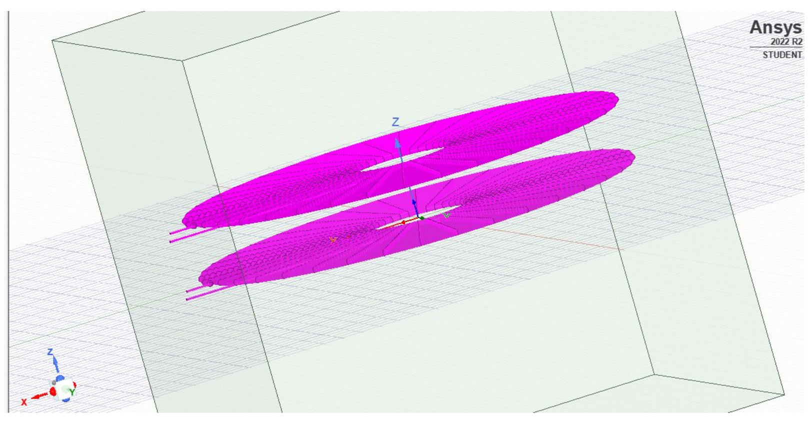
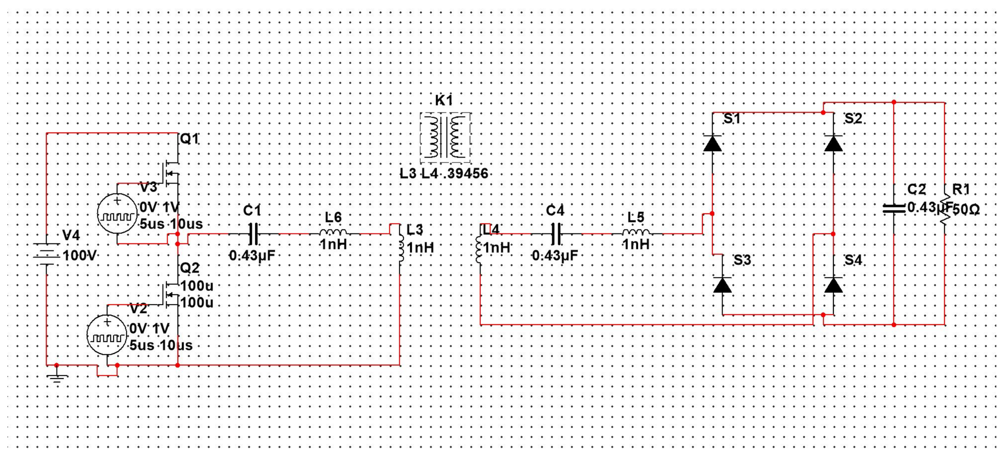


Fig 3: Circuit Design



Criteria	Category Weight	Microwave WPT	Inductive Coupling	Resonant Inductive Coupling	EM Induction
Distance:	3	4	3	4	1
Efficiency:	2.5	1	3	4	4
Alignment:	2	4	3	3	2
Environmental Capability:	2	1	3	3	3
Cost:	1	2	3	3	2
Operating Lifespan:	2	2	2	3	3
Feasibilty:	2	2	2	3	3
Total Score:		16	19	23	18
				Base Line/Best Option	

	Microwave Wireless Power Transfer
Distance:	10km
Efficiency:	50% close range (1m) 2-5% at ranges around 60m
Environmental Capability:	Cannot be used underwater due to attenuation underweater at high frequncies

	Inductive coupling
Distance:	Few cms
Efficiency:	Above 60%

	Resonant Inductive Coupling
Distance:	5cm-35cm
Efficiency:	Above 80%
Environmental Capability:	Works underwater

	EM Induction
Distance:	16cm-26cm
Efficiency:	Very Efficient 80%

Fig 4: Pugh Matrix

Remaining Technical Challenges

- **Circuit Design and Simulation:**

  In order to start developing and testing a prototype we must finish our circuit design. The design includes inverters, rectifiers and power factor corrections to control the type and amount of power in our transfer circuit. Then we must simulate our wireless power transfer circuit design until we get practical values to achieve our 100 watt bi-directional power transfer goal. We are using Multisim and Power Sim to simulate our circuits.

- **Coil Design and Simulation:**

  In order to start developing and testing a prototype we must finish our coil design. The coil design includes a specific amount of turns and coil diameter. Then we must simulate our design until we get practical values to achieve our 100 watt power transfer goal. We are using Ansys Maxwell Electronics to simulate our coil design in underwater conditions.

- **Prototype Development and Testing:**

  Once we finish simulation we can start to order parts to develop our prototype for our wireless power transfer system. Once we have received the required parts we can start to put together our physical system and test our prototype. We must make sure that our system can withstand the elements of underwater conditions. To combat these conditions we will plot our coils to keep them safe from the sea water and mimic an underwater charging station.

- **Comparing Results:**

  Using our results from simulation, we can compare our prototype results to our simulation results to help make an accurate working wireless power transfer system. Our circuit and coil simulation results will greatly help us during the process of making our prototype. Our simulation results will help us debug most of the problems within our prototype. Lots of testing will need to be done to the prototype to ensure the prototype performs in an underwater environment.

Implications for Company & Economic Impact

As the need for unmanned underwater vehicles grows, companies such as NUWC that find the utility of unmanned underwater vehicles will find great benefits from being able to wirelessly charge them. Unmanned Underwater Vehicles can act as surveillance and carry out missions too dangerous for humans. They are also used for intelligence, reconnaissance, mine countermeasure, and anti-submarine warfare. These vehicles can be made at a much cheaper cost than submarines. Also the ability to wirelessly control and charge these vehicles deflects the need for human interaction, saving money and resources.

ELECOMP CAPSTONE SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

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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

The motivation behind our project about applying self-sustaining energy to **Unmanned Underwater Vehicles** (**UUVs**).

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 with out the use of external power cables and other power generations sources.

Anticipated Best Outcome

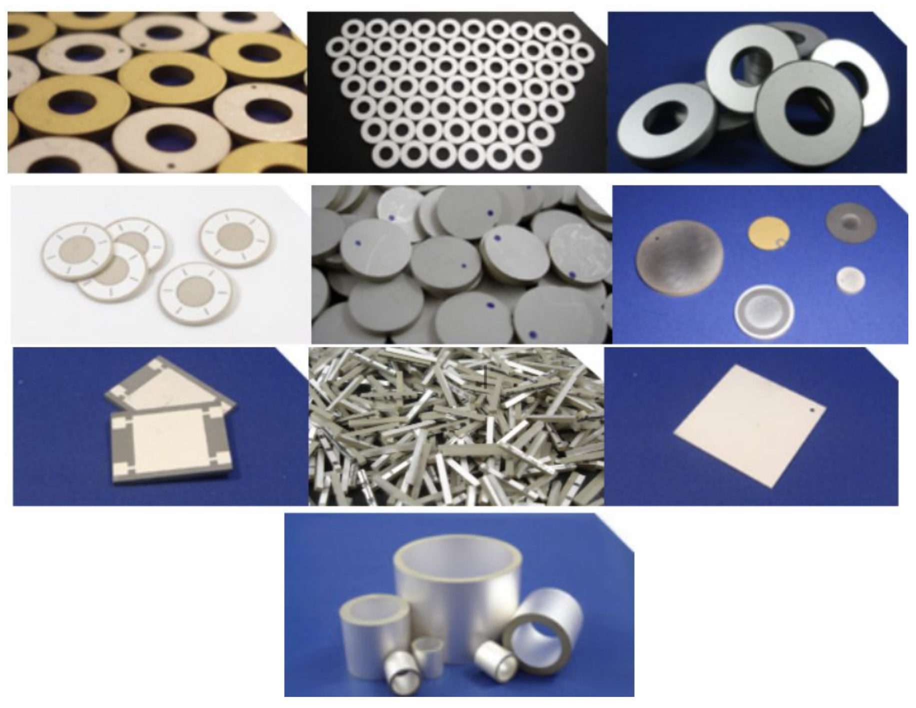
The anticipated best outcome of this project is to develop a piezoelectric underwater sound energy harvesting model that will feature a resonator, piezoelectric material, AC/DC rectifier, DC/DC converter, and a Micro-capacitor. This prototype will be intended to be tested and possibly support a proof-of-concept.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

Key Accomplishments

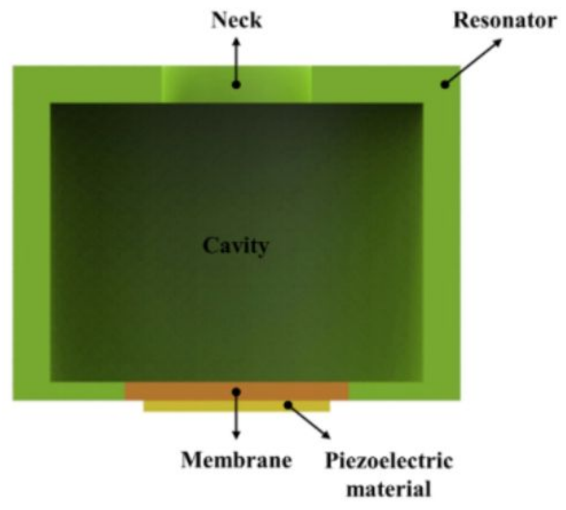
Sound Propagation and Sonar Research: We have gathered enough information to have a basic understanding of how sound propagates underwater and to what degree is it most prominent. Having background information on how the speed of sound underwater can vary at different temperatures and depths is going 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 (**Fig. 4**).

Sound Energy Harvesting Research: Most of our research on sound energy harvesting has been through published research papers that have extensive information on sound energy harvesting where teams of 2-5 people have conducted their own research describing their step-by-step process and have produced important findings as to what degree did their experiment did or didn't work and why. Some major takeaways include how to harness ambient noise and convert it into electrical power for electronic applications **(Fig. 3)**. The first step of this process is designing an **underwater resonator (Fig. 2)** that will help amplify the ambient noise enough so that the piezoelectric material will convert the sound energy into electric energy. For the most part, we have settled on a design for the resonator to take in sound from all directions without sacrificing the preferred Resonance.

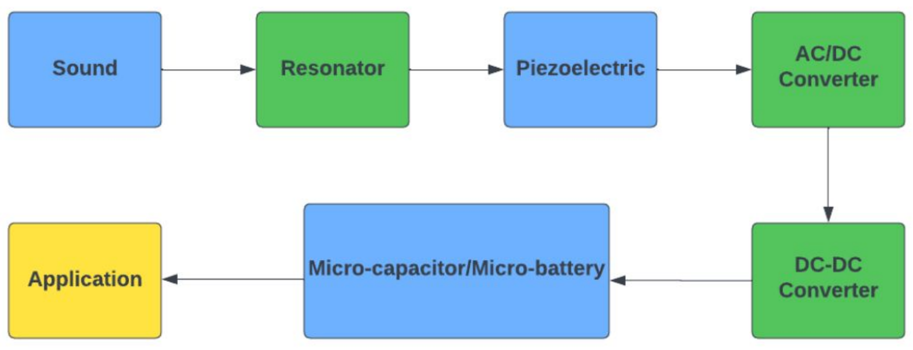
Piezoelectric Research: The Piezoelectric effect is when certain materials generate an electrical field in response to mechanical stress. In our case, the stress applied to the material will be amplified sound waves that can hopefully generate enough power to be stored in a capacitor. But because this 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.



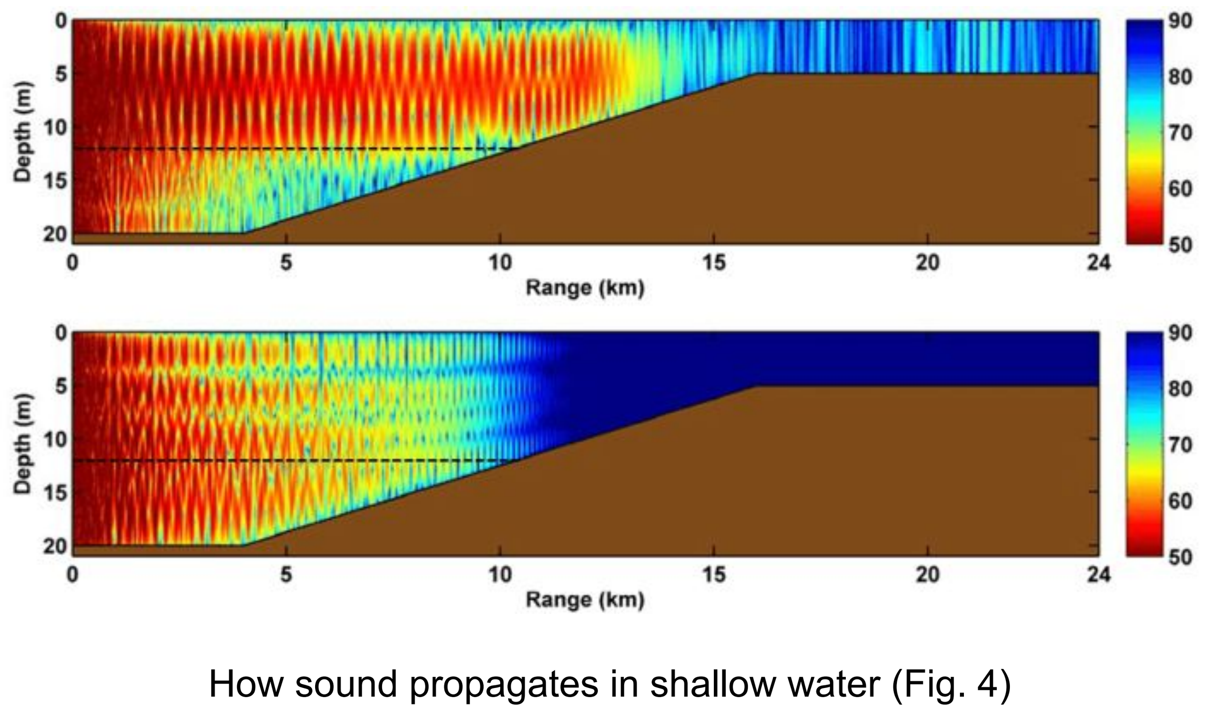
Common piezoelectric elements (rings, discs, plates, and cylinders) (Fig. 1)



Typical sound energy harvester (Fig. 2)



Block diagram of sound energy harvesting (Fig. 3)



How sound propagates in shallow water (Fig. 4)

Remaining Technical Challenges

Piezo Lab experiments (electrical response to vibration): Team experiments with the piezoelectric material will need to be conducted to determine the ratio of vibrational input to power output. Testing vibrational response in normal conditions will help determine if similar results can be obtained in underwater conditions. Troubleshooting ways to enhance minuscule vibrations using resonator and cantilever configurations.

The physical design of piezo electrical material (ring, plate, etc.): Determine which physical design of the ceramic piezo electrical material will need to be ordered **(Fig. 1)**. How will one design outperform the other based on the physical constraints of the prototype?

Resonator to piezo material configuration within the prototype: Determined a configuration that will produce the most amount of resonance for the piezo electrical material.

PCB Layout: A layout of electrical components that will need to consist of a rectifier and a DC/DC converter will need to be configured to a relevant size.

Encapsulation of electrical components to prevent water damage: Components will need to be able to be sustained underwater and remain completely dry while submerged. Determine the best design that will coexist with the resonator design.

CAD design of the prototype: Produce a 3D model of the design for possible 3D printing and fabrication purposes illustrating the exact dimensions of the prototype.

Positive buoyancy and Anchored to Sea Bottom: For better exposure to sound and to help the prevention of biofouling, the project design will need to be positively buoyant and anchored to the sea bottom by either an anchor or a heavy weight that is tethered to the device about 1-2ft from the bottom

Implications for Company & Economic Impact

The possible implications of our anticipated best outcome of this project on NUWC would our proof-of-concept that could potentially be applied to UUVs at NUWC which could then implement it at a much larger scale. This would bring further attention to alternative renewable energy sources such as sound energy harvesting and further develop the technology to be more efficient as energy requirements for newer devices become lower. This project, if commercially applicable, would be a crucial step toward the self-dependability of UUVs.

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ELECOMP CAPSTONE **SYMPOSIUM**
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

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Annunciator

PEC Phoenix Electric Corp.

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

Technical Director: 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.

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 and a new panel interface connection.

Key Accomplishments

Virtual Annunciator: Alongside a complete overhaul of the graphical user interface, a virtualization of the Arduino faceplate was implemented **(Fig.4)**. 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.

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 currently 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 CircuitMaker software to build a PCB **(Fig.2)**.

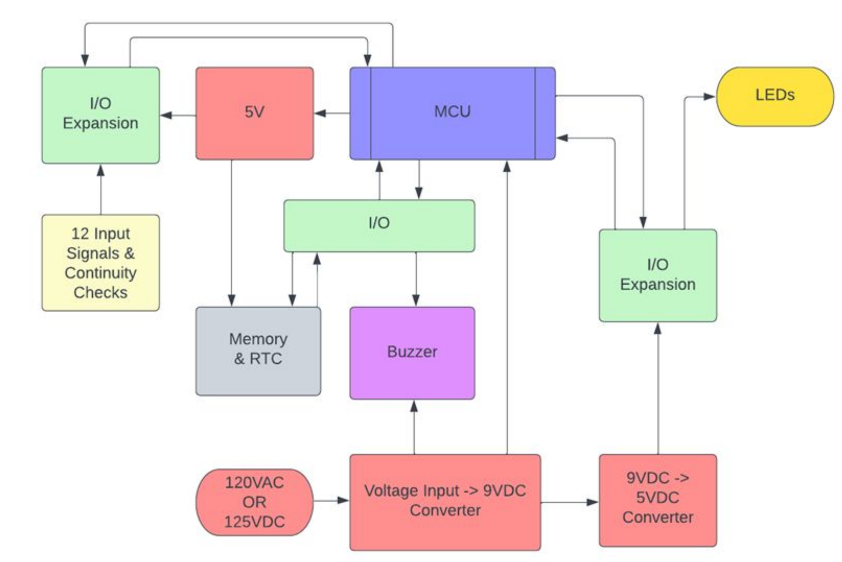

Fig.1: Functional block diagram of annunciator system.

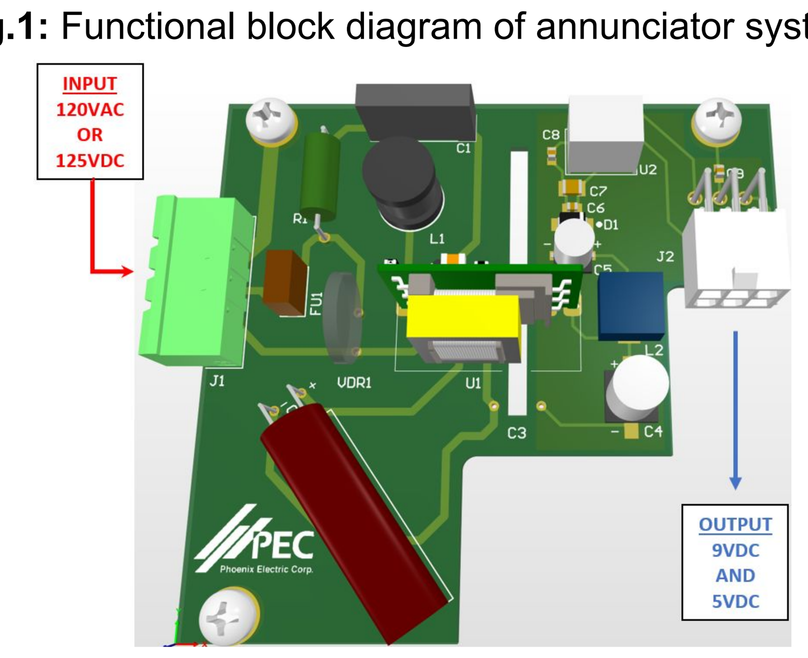

Fig. 2: Power converter PCB design.

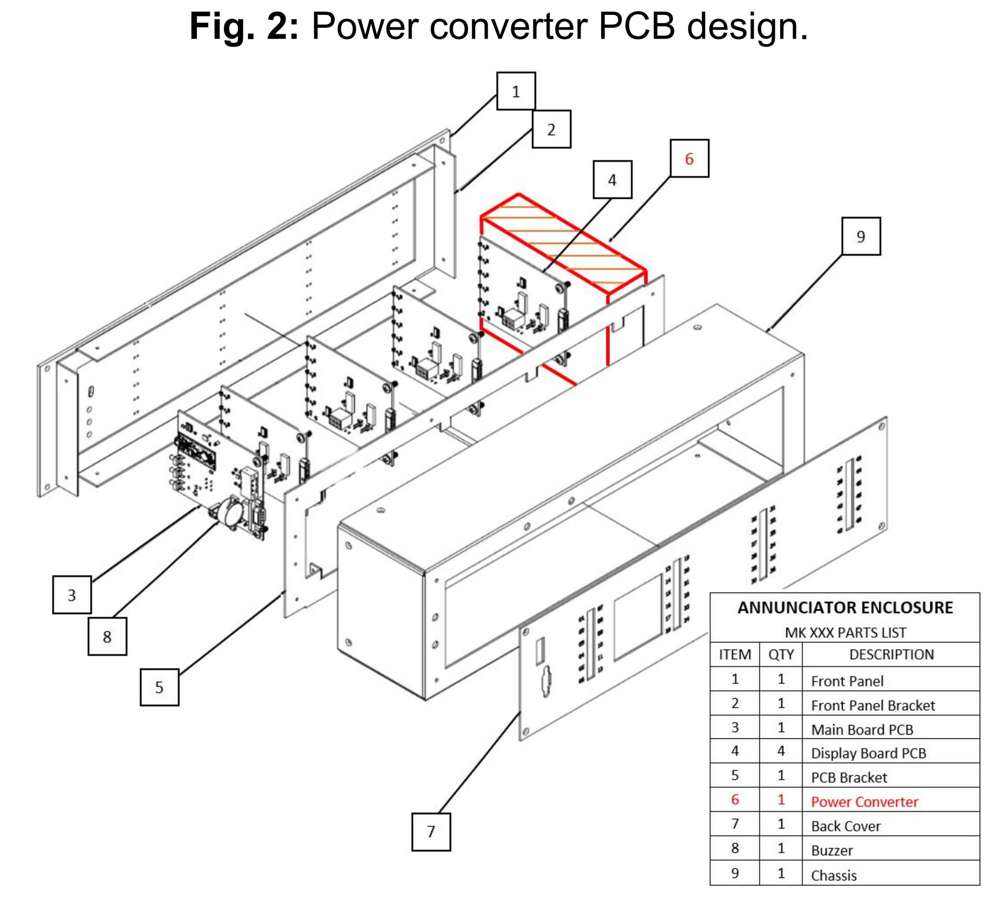

Fig.3: Annunciator parts breakdown with planned power converter location.

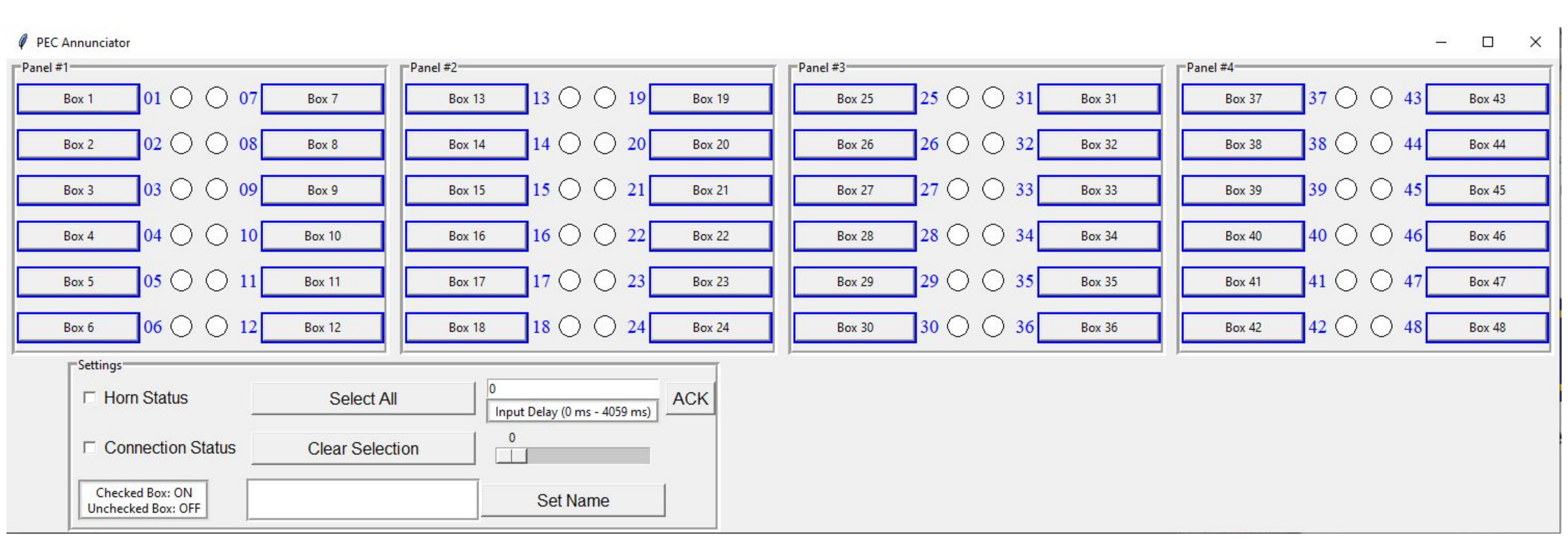

Fig.4: Virtual Annunciator (GUI)

Remaining Technical Challenges

Embedded code: The basis of the embedded software is already laid down; however, further developments must be made to meet the best anticipated outcome. In addition to a communication protocol, between the Arduino and the GUI, Modbus support has to be added alongside serial. A fully developed protocol will track packets of information with metadata to ensure lossless communication.

Graphical User Interface: To mesh with the embedded code, a receiving portion of code will have to be added to the graphical user interface. This will decode and encode packets of information communication with the Arduino. Improvements in information communication speed and reliability will motivate the development of the code. This will ensure that the Virtual Annunciator is always kept up to date and able to communicate with the physical Annunciator.

Power Distribution: As a result of designing our own power converter, we can completely customize the power distribution of the system **(Fig. 1)**. By fully taking advantage of this, we can minimize the number of required connectors and wires by integrating power into already existing transmission pipelines. Fortunately, existing connectors have empty pins that can be used for this purpose. However, implementing the best distribution method requires reworking existing systems to accommodate the change. Deep understanding of the system power network is essential.

Implementation of Power Converter into Chassis: The Annunciator is designed to be a rack mount device, and therefore has specific dimension requirements that cannot be modified. Everything must fit inside a limited amount of space. Due to the spacing required by internal parts, there is not much room left over **(Fig. 3)**. The shape, size, and placement of the board will need to be unique to fit, allowing for proper mounting and sufficient airflow.

Implications for Company & Economic Impact

By providing this end-to-end annunciator solution for Phoenix Electric Corporation, their needs on third party manufacturers decrease significantly. Not only this, but cost per unit also decreases. This is immediately observable when comparing power supply solutions: There is a large impact between custom and COTS hardware. By creating custom products, the overall footprint is reduced and the product can take any form or shape that is desirable for the application. By developing custom software, this effect is further increased and allows the company to take complete creative control. The end result is a solution that is incomparable to competing products.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

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Low Level Biosignal Acquisition

PISON

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

Technical Director(s): Jonathan Eagle, Tanya Wang

Project Motivation

This company's focus as well as this project's focus is on neural interfaces that fixate on gesture recognition and translating data from the body's natural physiological electricity into interpretable results.

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.

Anticipated Best Outcome

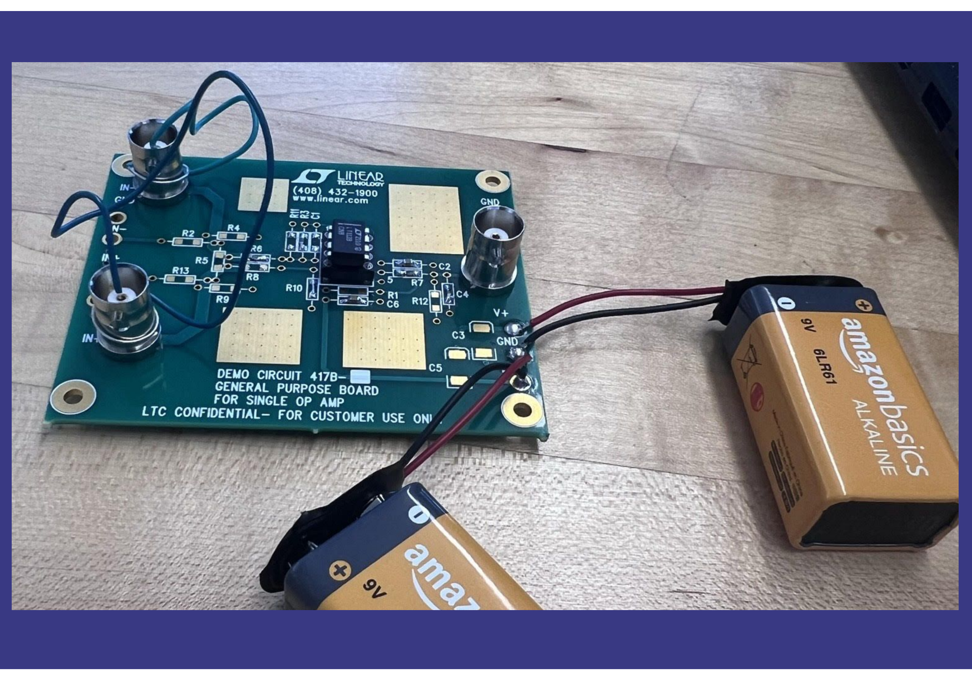
The best anticipated outcome for this project is a developed system that can filter out all ambient noise coming from wires, cell signals, etc. and pick up on our bodies biosignals which are a very low voltage. This will be achieved with the help of the LTSpice simulation as well as testing on the physical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

Key Accomplishments

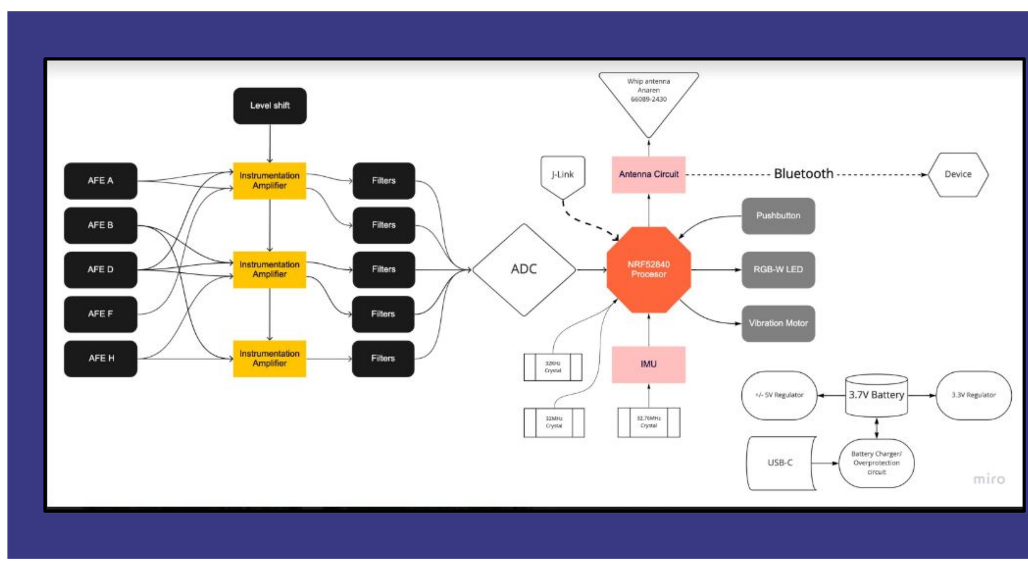
Construction of Analog Front End in LTspice:
To start, we were sent a diagram of the circuit that needed to be constructed in LT-Spice. Since the ADS1299 and some other operational amplifiers were not in the Spice Directory, we needed to create parts of the circuit manually. We built the circuit with op-amp models that we found online and implemented filters as well. Our initial task was to get "sin in, sin out," which we got and moved onto the next step.

Added Instrument Amplifier to Circuit:
Another component that was missing from the circuit that we needed to implement was the instrument amplifier. We were given the desired specs and characteristics on what it needed to do and worked off that. We ended up finding a suitable component that we downloaded from the internet and put it into the Spice library. We again obtained "sine in, sine out."

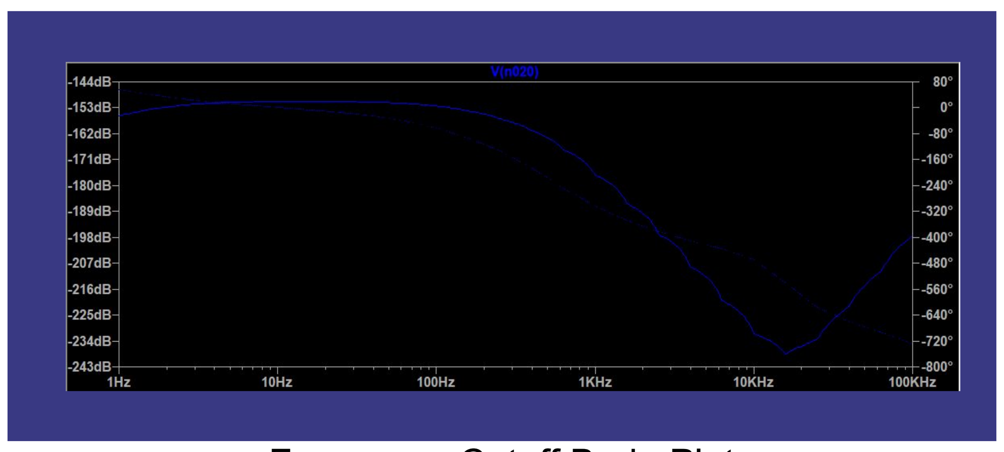
Tested Circuit and Found Frequency Cutoff/Bode Plot:
Once the circuit and instrument amplifier were built, we were tasked with characterizing the circuit and finding the cutoff frequency. In order to do this, we had to research on how to actually do it. We ended up using the AC transient analysis feature in LTspice to find the frequency cutoff which was around 100hz. I attached the graph below.



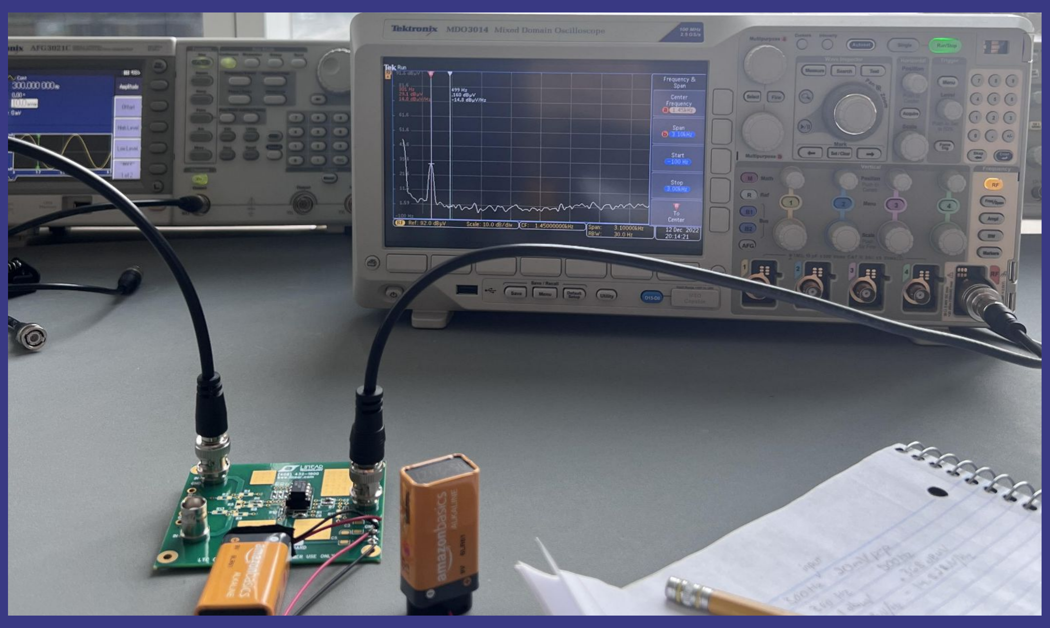
Demo Board



Block Diagram



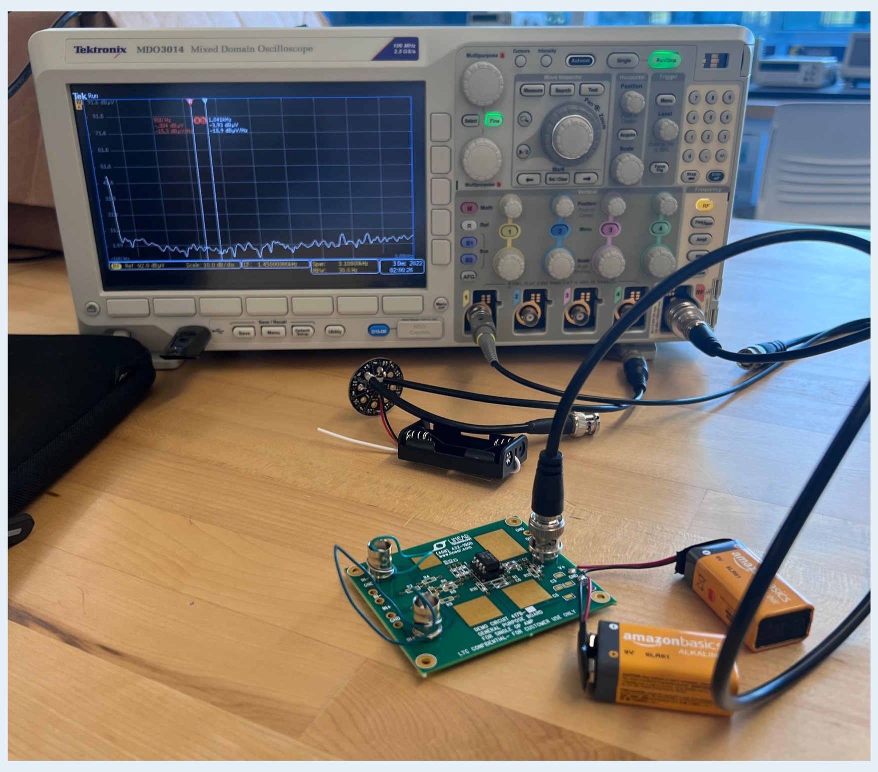
Frequency Cutoff Bode Plot



Testing the Demo Board

Remaining Technical Challenges

Testing and Characterizing the Pizza Board:
Our upcoming technical assignment is to start testing the Pison "Pizza" board that was provided to us. We will be going through the components to characterize each part, to verify that we are getting the right values that are expected, and to check that nothing is shorted, etc.



Implications for Company & Economic Impact

Pison's vision is to own the platform which translates human intention to machine-readable code. When the ABO is achieved, it will provide Pison with a baseline and framework in the acquisition of the low-level signals. Pison has customers within the Department of Defense and Fortune 100 to whom this kind of advancement in technology is extremely beneficial. These customers have a deep pipeline of pending projects fueling Pison's growth.

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ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

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Crisis Data Relay

RDSI

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

Technical Director(s): Josh Minasian, 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.

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.

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. Throughout the semester we used various configurations before deciding on configuring the database of the information in ObjectBox using our Dart/Flutter environment.

Database Implementation: Using ObjectBox, we were able to then start collecting a small sample of data from the ERG and create a demo database for our prototype application. In addition we created a simple translation between the database language and the ERG which allows our progress to be adaptable to any programmer for future maintenance **(Fig. 3)**.

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.

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.

Prototype Application: A Flutter project was developed that would give a rough prototype of how the application would run **(Fig. 2)**. It guides the user through either taking a picture of the placard or manually entering the ID. Once this is done the ID is read from the image or entered number and uses this as a key to display information from the database.

Fig. 2: Prototype Application

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

1104 **129** Amyl acetates

Fig. 3: Code Snippet from Database

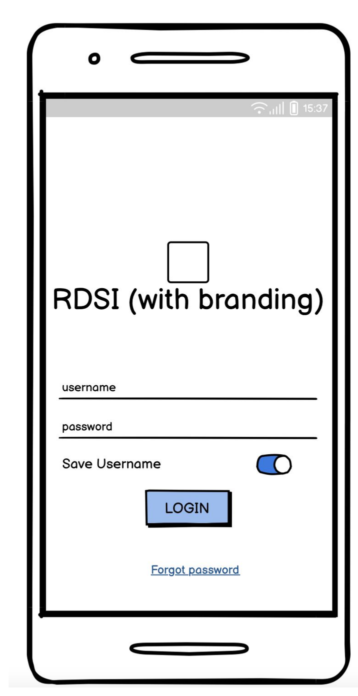

Fig. 4: Balsamiq Wireframe

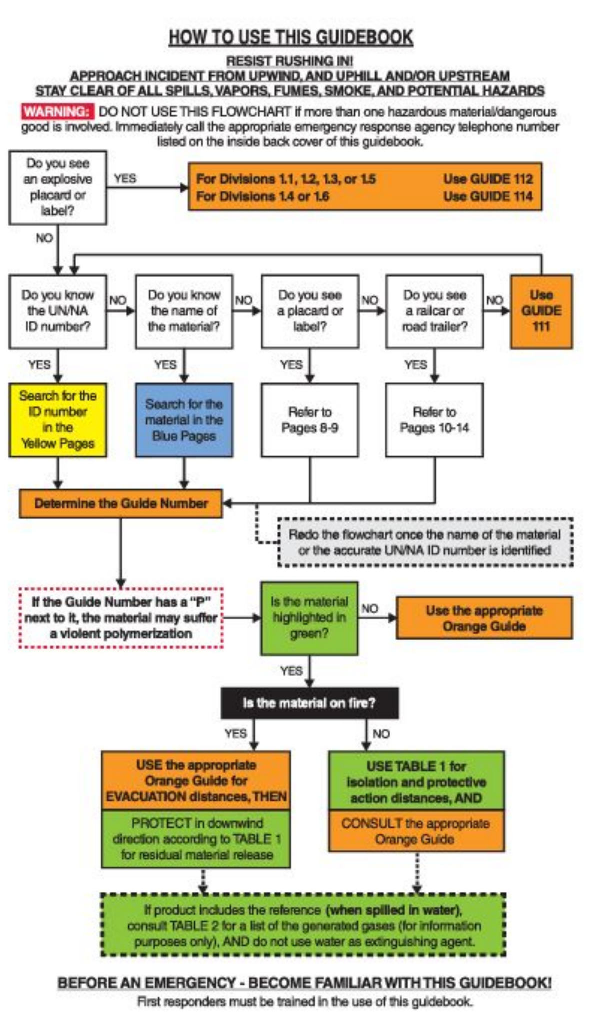

Fig. 1: ERG Book Flowchart

Remaining Technical Challenges

API: When the demo database is moved to the testing phase, we will need to set up an API in order to establish the connectivity between the top level and bottom level code. We will also have to ensure that all features work according to our development.

User Experience: Here we will be able to place our logic and how we would like the app to traverse through the information. In addition, we can start to place usable features in the demo applications and get an idea of how the end result will work.

User Interface: Improve the user experience to fit what the end user desires. Interview Firefighters to see what they like about the prototype application and what they think should be added or improved. Improve the flow of the application and layout so that it is optimal for the end user.

- **Mockups:** Translating ideas into something more practical for end vision that users will be able to see in the final product. We will be using the wireframes that were previously designed **(Fig. 4)** to finalize the outlook and plan button outputs and inputs.

Back-End Configuration: Once all necessary items have been declared, we will need to tie in all the pieces together with the database so that the information will be accessible to the various logic of the application. We will need to add helper functions to allow for accurate lookup and retrieval of the backend data to display to the front end.

Secure Network: After getting all the necessary functions working together, we will need to be able to secure the application to avoid any signal disturbance or interference. Securing the application will also allow the end user to use the application from any location without worrying about connectivity. This will be one of the final steps towards the ABO.

Implications for Company & Economic Impact

The best outcome of this project will provide RDSI a prototype application that supplies information from the ERG by scanning a placard. This will allow firefighters to be able to respond to an accident involving placards immediately. Since this has never been done before, RDSI would gain not only popularity within the Department of Defense community, but they will be able to monetize the application by selling devices with the application configuration. Successful implementation of this application could furthermore cement RDSI as a reliable figure in innovative technology for Fire Departments. Which could open opportunities for making other useful and potentially profitable applications that are not yet invented.

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TUESDAY, DECEMBER 20, 2022

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Submarine Network Fault Prevention

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

Technical Director(s): 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 ships and headquarters. With so many adversaries world wide, all trying to breach our communication protocol around the clock, it is paramount that the network remain secure to ensure constant communication incase of emergency. To achieve this, our project focuses on the issue of Network Fault Prevention and Analyzing the condition in which a network can fail by using modern day concepts and knowledge of Data Science, specifically Pattern Recognition to a network data set to identify and report evidence conclusions on the factor that led to point-to-point connection being compromised.

Anticipated Best Outcome

Our goal is to employ the Data Science concepts of Exploratory Data Analysis (EDA) to ultimately write a White Paper demonstrating our methods and findings. The Best Anticipated goal of this project is to research and analyze curated data from publicly available network datasets to identify system/component anomalies such as switch port Cyclic Redundancy Check (CRC) errors and port bandwidth/utilization faults by creating a model that can predict switch fault with a >80% accuracy rate. Ultimately, we want to establish a tool(s) that we can host on the Rite-Solutions network and a process that can be applied/used with tactical or production datasets.

Key Accomplishments

Data set finding and selection: The main goal of this project was to determine and predict switch fault within a network, so we decided to look for datasets that contain SNMP data logs. We finally narrowed down to 3 different datasets, which are UNSW Canberra, SNMP MIB 2016, and CrawDad dataset. We ended up choosing UNSW Canberra due to its sheer amount of raw data to work with.

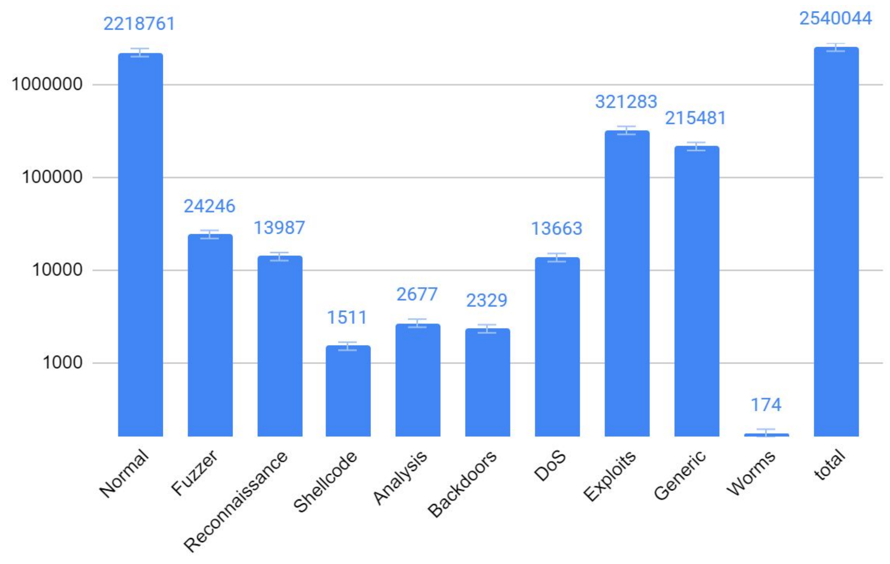
Networking architecture research: Research on how switches work within a network system, including the OSI's seven layer. Furthermore, we dive in depth about network malicious attacks such as Denial of Service, Worms, Shellcodes, Exploits, Fuzzer and Reconnaissance, and how those attacks can create the perfect environment for switch failures.

Exploratory analysis research: The idea behind Exploratory Data Analysis is to help look at data before making any assumptions. It can help identify obvious errors, as well as help with pattern recognition within the data, detect outliers, and find interesting relations among the variables, all which are very important when it comes to machine learning, and artificial intelligence.

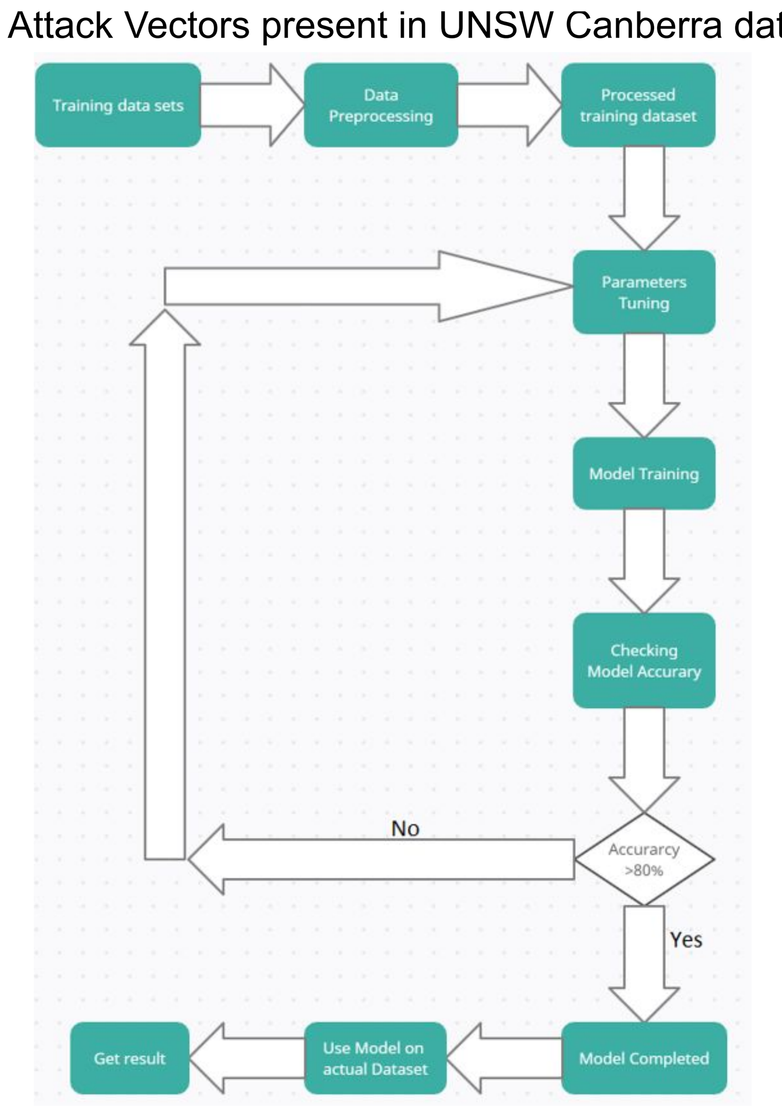
Dataset analysis: Finding an alternative data set that has potential of being useful to and exploring the origins of the said datasets and how it reflects to how it could be used in a relevant submarine attack.

Decision Resolution: Deciding on which tools would be the most useful to the project such as the programming language that we would use for data analysis, integrated development environment, datasets.

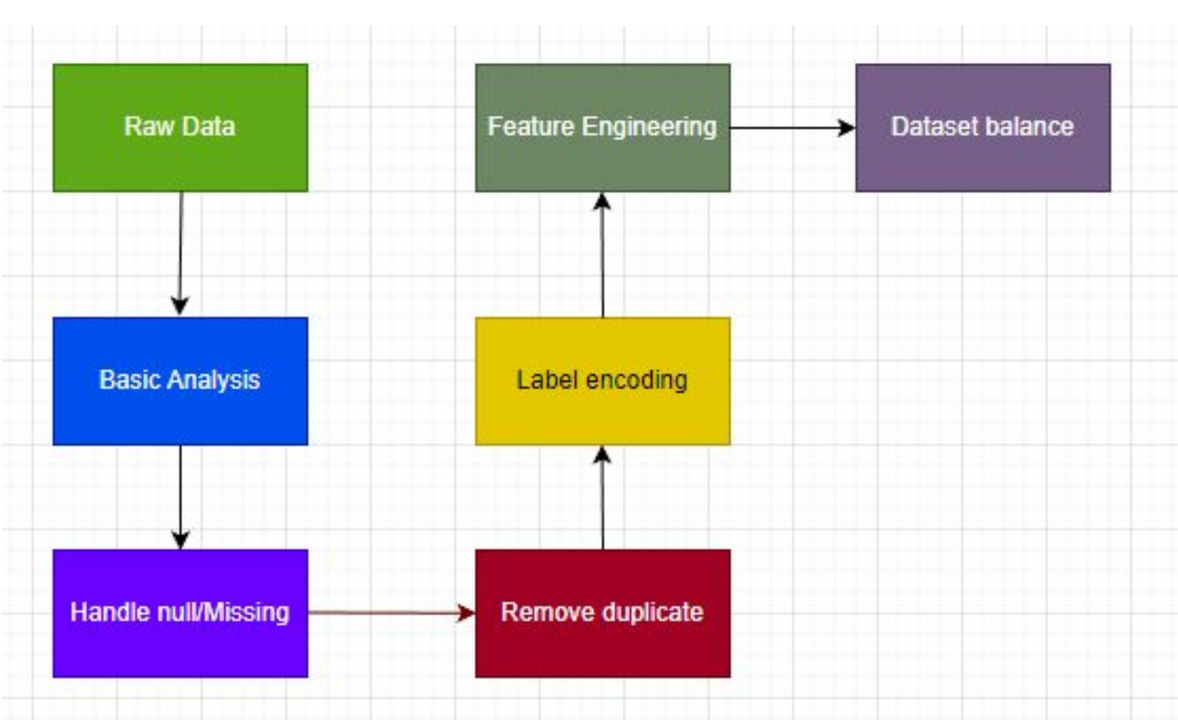
Deliverable 1: A preliminary findings report . The scope of this document is to describe the central features, their significance to the problem at hand, and their relationship with each other. This will show the TDs on the progress of the team on the project.



Attack Vectors present in UNSW Canberra dataset



Pattern Recognition Model Pipeline



Data Preprocessing Pipeline

Remaining Technical Challenges

Data selecting: The USNB Canberra dataset contains over 100GB of raw data, some of which is not relevant to the project. In order to save disk storage and simplify the analysis part, we will have to reduce the number of unnecessary data points.

Data preprocessing: To study under which conditions that could lead to a network switch failure, we will first need to preprocess the data to be more usable. This involved data cleaning(removing missing data and reducing noise), and data transformation (normalizing).

Data analysis: We will then attempt to perform data analysis to gain key insights about network conditions and switch failure. This includes statistical analysis and running regression on the datasets.

Model accuracy improvement: Once we have a model for detecting and predicting switch fault running, ideally we would like it to have an accuracy greater than 80%. There are many ways to achieve this ranging from more feature vectors and parameters tweaking.

Bandwidth Calculation: We need to be able to calculate input utilization and output utilization as it is not obviously present within the given data set. This will help us to predict switch failures

Data visualization: To pick out any obvious patterns and to effectively showcase our result, we would need to translate our result data to a graphical format in a clear and simple manner.

White Paper write up: At the end of our phase 2, we will then be starting the work on writing a formal and technical White Paper to articulate our methods and findings of the feature analysis. This paper will follow the IEEE format and will be presented with a demonstration of the project.

Implications for Company & Economic Impact

Rite-Solutions is continuing to expand our network monitoring and fault detection capabilities for the United States DoD/Navy customers. Rite-Solutions is currently the prime contractor for the AN/BYG-1 Inter- Subsystem Monitoring Tool (ISMT), a tool which monitors and facilitates the troubleshooting efforts for the hardware and software communications aboard submarines. This research can enhance Fleet's capabilities for network threat detection as well as train our potential future workforce on how to solve the problems of this program and beyond. However, the White Paper will be accessible by the public so anyone can use the findings to improve their networks against an attack.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

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Project Socket Steward

Smart Power Monitoring & Disconnect System

SOUTH COUNTY GADGETS

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

Technical Director: Jamie Murdock

Project Motivation

The goal is to design a consumer plug-in smart power 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**
- **Appliance Damage**

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 in order for safe continuous use.

Key Accomplishments

<u>Industry and Hazard Research</u>: Causes of fire and electrical hazards induced by issues along the outlet circuit, the circuit from breaker to appliance, was researched in order to find solutions that would detect the onset or beginning of these hazards.

<u>Feature and Component Selection</u>: Based on the conducted research, features that could detect the hazards were selected to add to the circuit of the Socket Steward. Causes that had similar hazards became grouped under the same solution, as many different causes lead to the same hazards and many could be detected under a similar solution.

<u>Determining Location of Thermal Runaway</u>: Two tests were conducted involving the increase of temperature, a common cause for ignition hazards. Two areas were tested and monitored, the attachment plug and the outlet contacts.

For the attachment plug, a thermistor was implanted into the attachment plug between each prong, while a thermistor was attached to one of the prongs, which was heated using a soldering iron.

For the outlet contacts, a modified soldering iron was made to fit within the outlet receptacle and heat the contacts. Thermal imaging was used to capture where the temperature was most detectable from the outside, which was determined to be just above the terminals that were connected to the contacts, which is where the thermal sensor will be placed in the final product.

<u>Drafted Block Diagram</u>: A baseline design of the product was drafted to include a basis for components, circuit design and function. This will be a foundation to which more is added and tuned.

<u>Consulting with Arthur Lee and Joe Gundel</u>: The team has consulted with two experts in the industry, Arthur Lee, a senior electrical engineer from the CPSC who directly works with products concerning safety and the voluntary standards that products follow, and Joe Gundel, a senior embedded software engineer at Hayward Industries who will be supporting the project with advice for the software development.

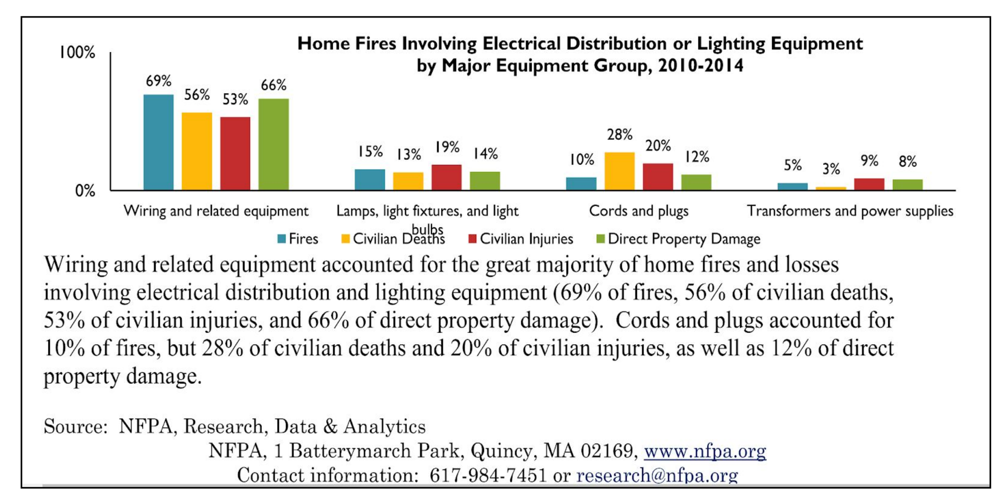

Fig 1: Home fires involving electrical distribution or lighting equipment

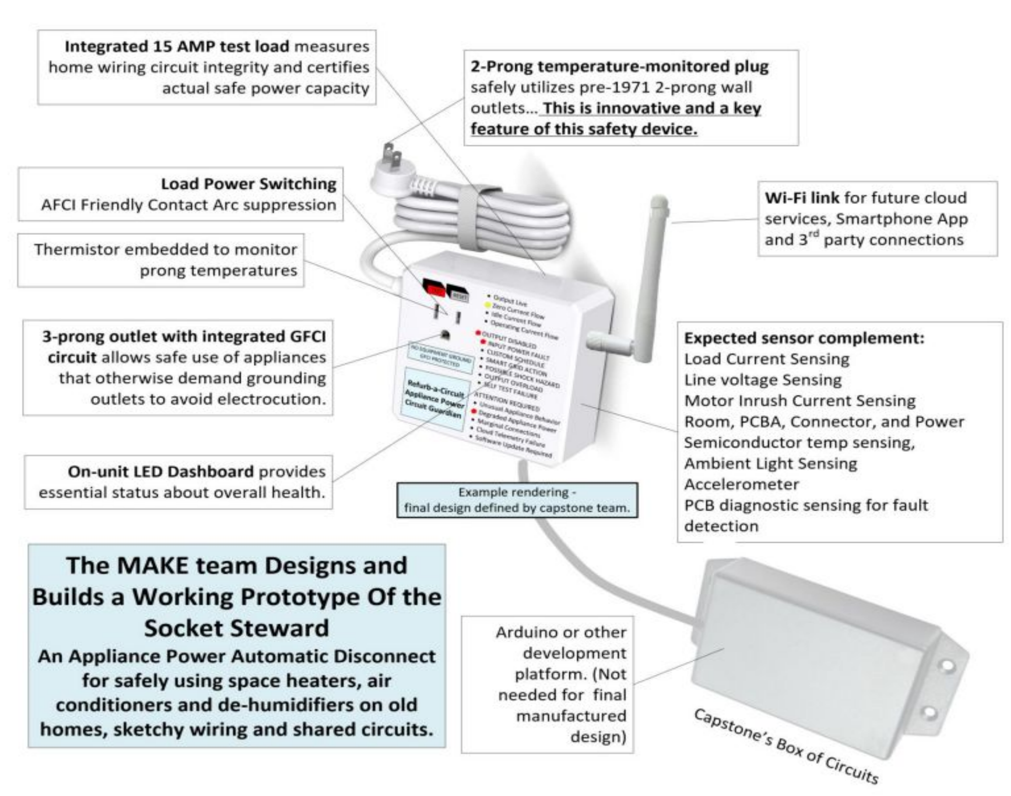

Fig 2: Base concept for the final look of the Socket Steward

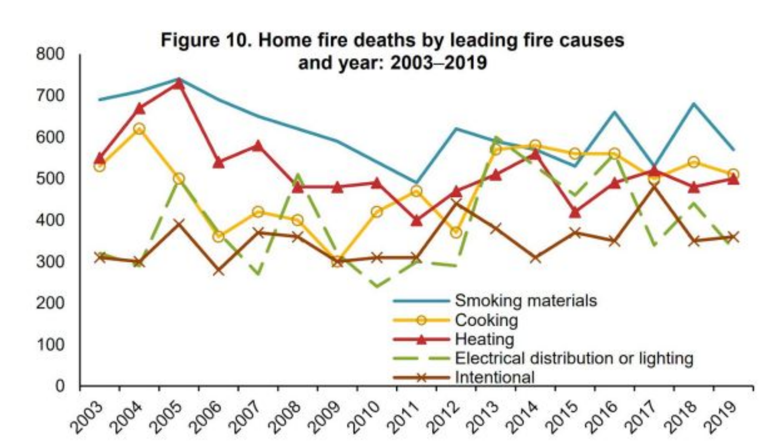

Fig 4: Deaths caused by house fires per year from 2003 to 2019, with electrical causes averaging between 300 and 600 deaths over 16 years, with no show of decline.

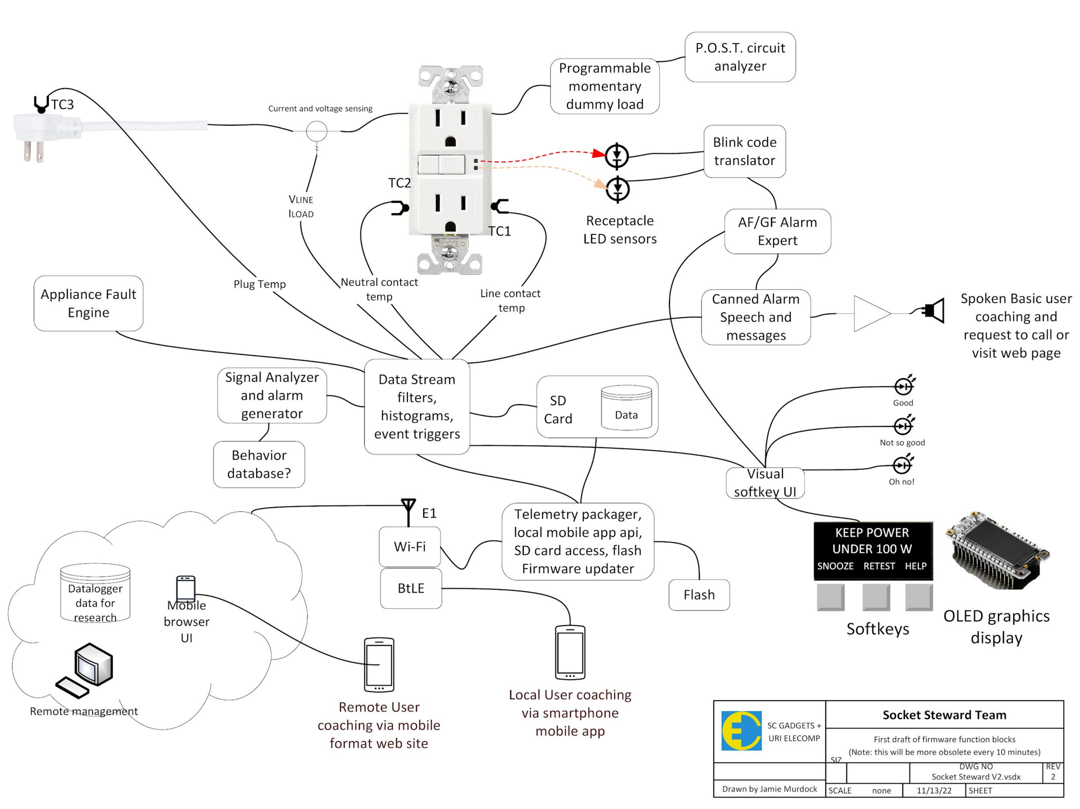

Fig 3: Drafted Prototype Design of Socket Steward

Remaining Technical Challenges

- **<u>Development Platform / Software</u>:** The team has decided to build the Socket Steward off of an AdaFruit Featherboard. Determining which Adafruit Featherboard with which wing attachments the team wants to use to begin building off of has not been decided yet. Once this is resolved, the team can begin coding and drafting a prototype layout.
- **<u>Prototype Layout</u>:** Once we complete a prototype layout of the Socket Steward, we then can begin to design a custom PCB design for one singular main board for implementation into a custom 3D printed housing space such as pictured in (**Fig 2**)
- **<u>Complete PCB Schematic</u>:** To achieve ABO we must finalize a schematic for PCB design so we can begin testing. Having a finalized PCB schematic as soon as possible is extremely important to ensure we don't have any delays with testing and designing. To achieve this we must select and approve components that will be used sooner rather than later.
- **<u>Determine mounting and routing options for buttons, LEDS, OLED screen</u>:** While we will custom design a faceplate and have that part be 3D printed, we will have to be mindful of height requirements from the carrier PCB to the faceplate. One idea was to use light pipes to transmit the LED signal. Another option would be to custom design a housing with mounting stands at a specific height for the LED, OLED and buttons to be accessed.
- **<u>What sensor are we using for attached receptacle temperature</u>:** The team has agreed upon using a thermistor for this feature. We just need to narrow down options to a component that is in stock, with a low price point and that has a small size constraint to fit within a plugs header.

Implications for Company & Economic Impact

The National Fire Protection Association along with 300 other safety standards, say that outlets, extension cords, branch circuit wiring, and other electrical wiring faults amount to 270 average annual deaths, 18,450 average annual fires, and $691M average annual property damage. Product safety standards have forced manufacturers to make safer products and building codes have forced new homes and their wiring to have more inherent safety features, which haven't been effective in completely mitigating fires. The Socket Steward will be marketed in a form that delivers on its promise and in a form factor and cost that people will want to buy.

Standalone Cable Checker

Hardware Checker – Phase 3

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.

Anticipated Best Outcome

The anticipated best outcome of this project is the creation of a housed, 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.

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.

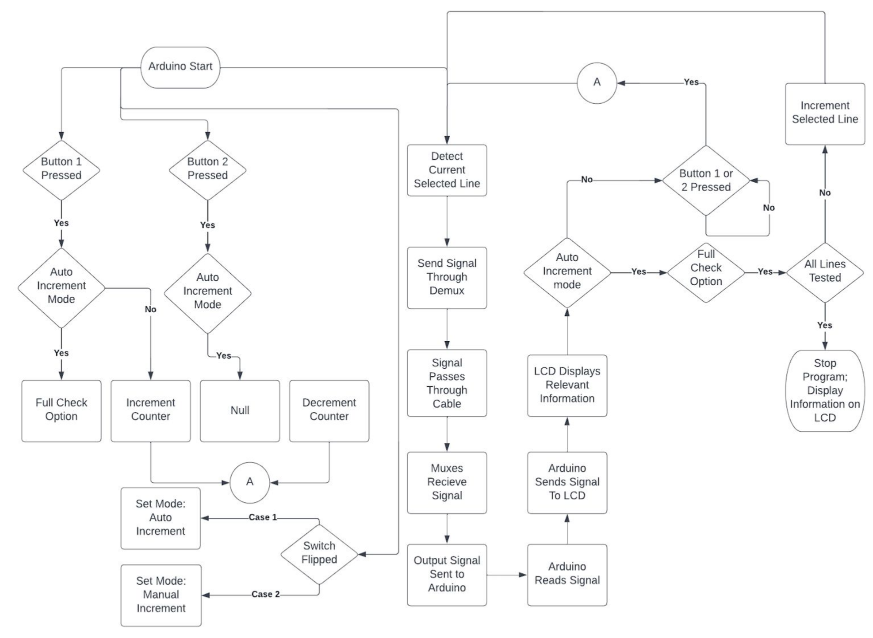

Fig. 1. Block diagram dictating the logic of the SCC.

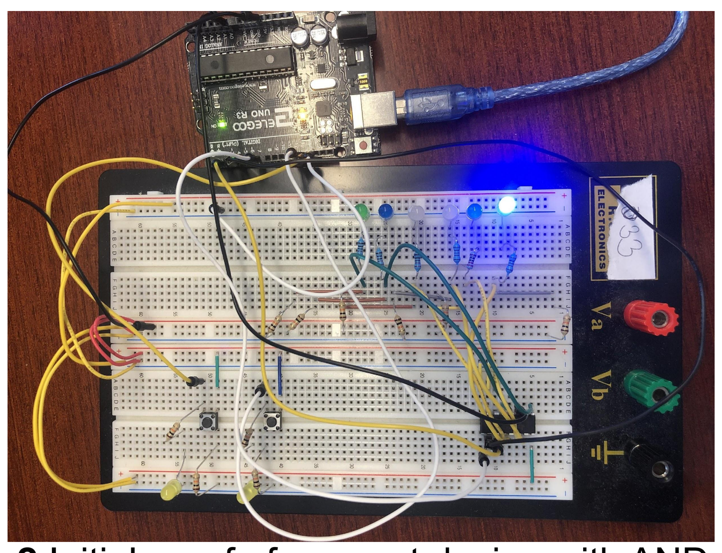

Fig. 2 Initial proof of concept design with AND gate

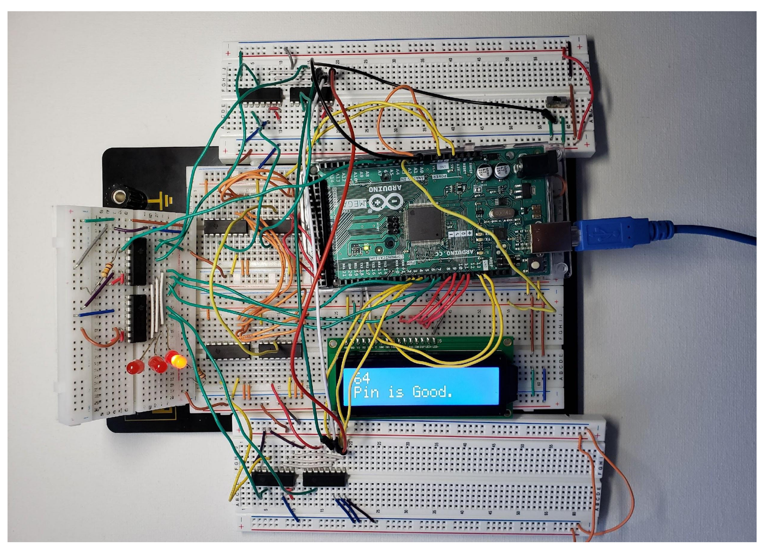

Fig. 3. Second Prototype with 3 layers of demuxes and muxes

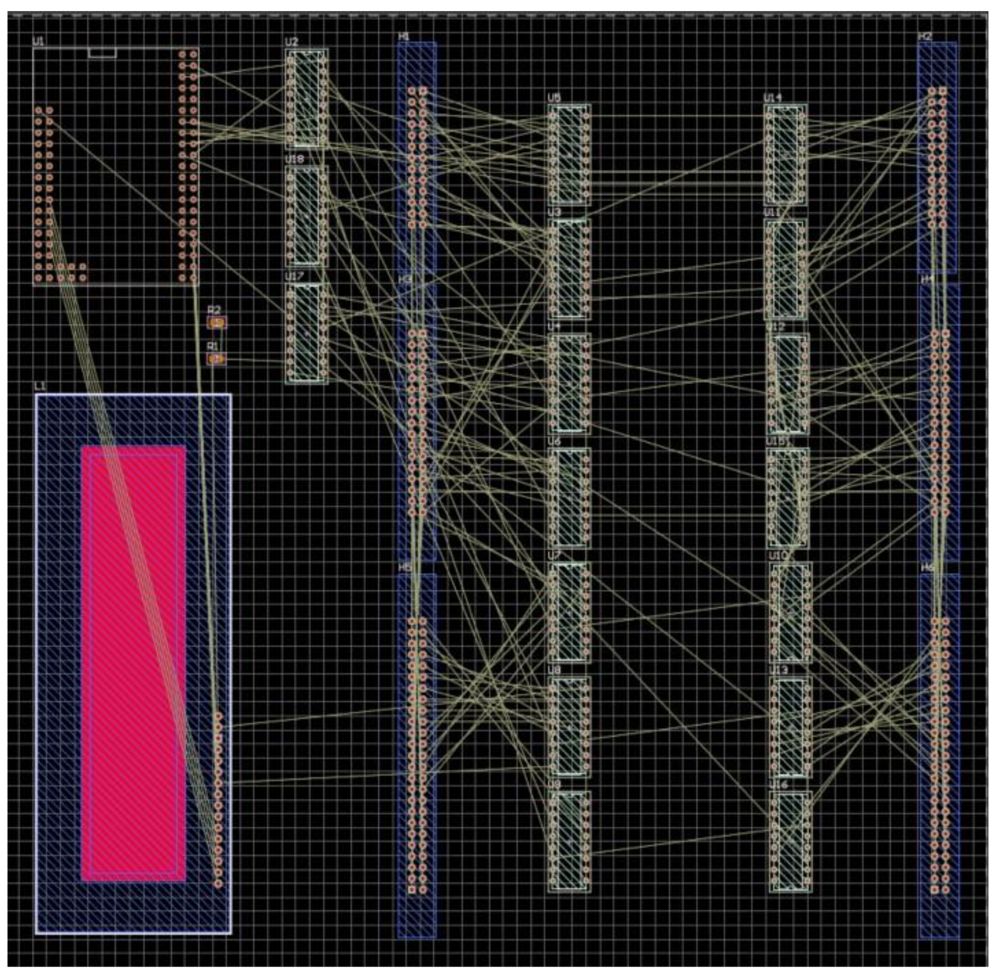

Fig. 4. Prototype PCB design capable of testing 26, 34, & 50 pin cables which is currently under evaluation for production.

Implications for Company & Economic Impact

The creation of the Standalone Cable Checker allows for a vastly reduced lead time for testing the cables Vicor Corporation uses on a daily basis. This will reduce the costs of operation by reducing the number of "wasted" cables, and the time spent to test the cables as well. Cable faults impose delays and displace efforts on the test engineers that must deal with them. By creating the SCC, the test engineers will then have a tool that allows them to simply interface the cables with a microcontroller to automatically test the individual lines, mitigating the loss of time and money for Vicor Corporation.

Remaining Technical Challenges

Power System Design: The main method of powering the testing circuit so far is using Arduino's own 5V supply and thus from the USB port. While we can achieve a similar result for the ABO using a power supply breakout board, this is cumbersome for a final system and not ideal when the device needs to be sent to a test house. A solution designed specifically for the system will be made.

Single-Platform Design: In a recent meeting, it was brought up how the 174-pin cable is bulky and may impose problems if its cable testing system is assimilated with the other cable testing systems on a single board. Whether the 174-pin cable should be isolated or the platform be expanded has not yet been determined. However, it does seem that the optimal route leans more towards developing two separate boards, one carrying the connectors for the 174-pin cable, and one containing all the other headers.

Housing Enclosure Design: The housing will require the encapsulation of the PCB, Arduino, and, if decided to be internal, the power system. It seems that there will be two separate boards, that will be rather large, so this issue will be addressed at a later stage once the actual PCB has been designed and manufactured.

Loss of Voltage: At the current stage, we have demonstrated a prototype with a couple pairs of mux's and demux's that includes all three layers. However, we have not been able to create a mockup of the finished product on the breadboard. We theorize that the amount of traces used combined with the fact that the Arduino Mega may not be able to fully power up the circuit might cause some issues with testing. We have opted to continue the development of the breadboard prototype along with the schematic to test this theory.

ELECOMP Capstone Program Director: Professor Harish R D Sunak

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ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 21, 2021

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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 Director(s): 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.

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.

Key Accomplishments

I2C Research:

A key area we needed to grow our understanding in was the I2C programming protocol. The circuit consists of two lines, the clock (SCL) and the data (SDA) with pull up resistors of 4.7K Ω connecting to Vdd (typically 3.3V). Each device has a connection to ground, so when the high and low signals need to be generated, the device connects the data or clock line to ground, thus pulling the signal low. In I2C the lines are high by standard because of the pull up resistors.

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. Although sharing many similarities, these sensors have differences that we need to consider when choosing the 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 (**Fig. 2**) and ultimately saves us money. See **Fig. 1** for sensor implementation.

Light Sensor Array Design:

The team has come up with a design for an array of nine light sensors which will always keep one in an angle below 22.5° from vertical, which will allow it to have a response above 0.8 **(Fig. 3),** making compensation algorithms easier to implement.

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.

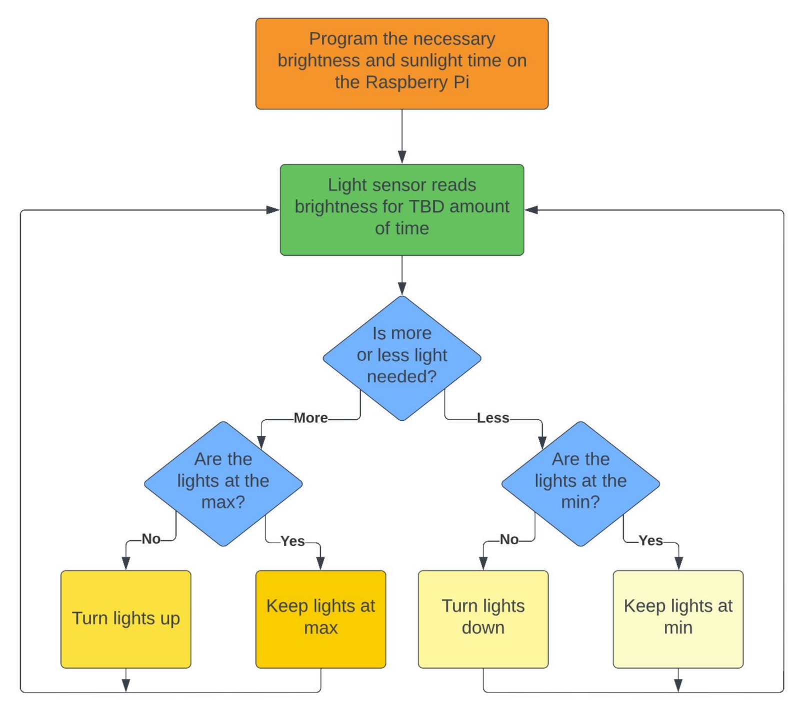

Fig. 1: Logic Block Diagram

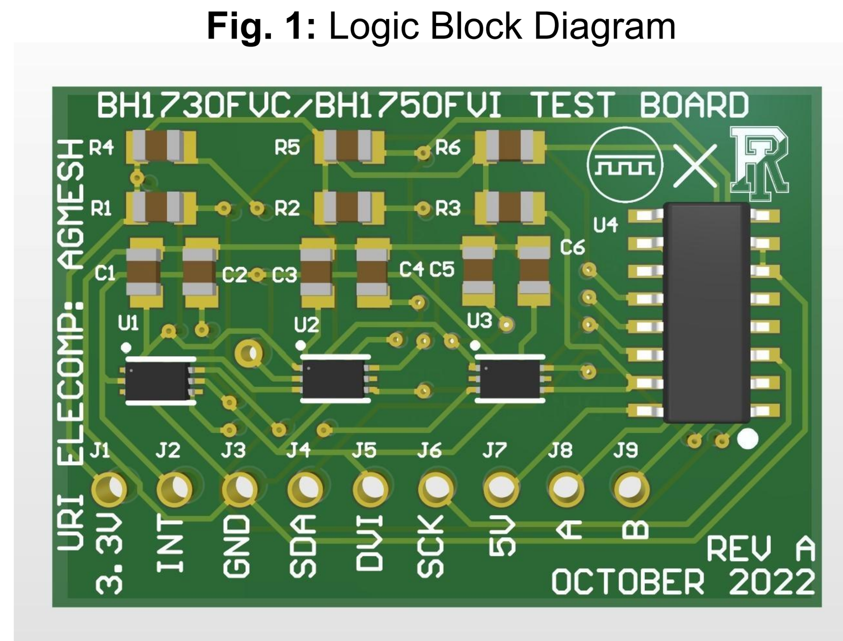

Fig. 2: BH1730FVC/BH1750FVI Test Board

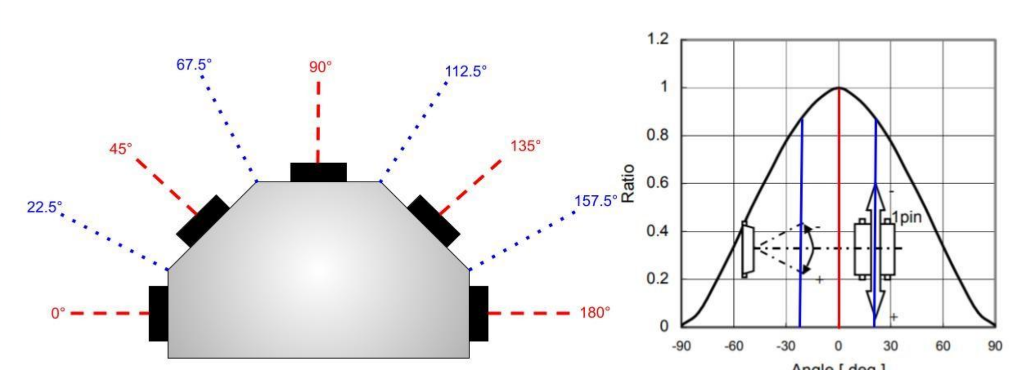

Fig. 3: Sensor layout and response curve

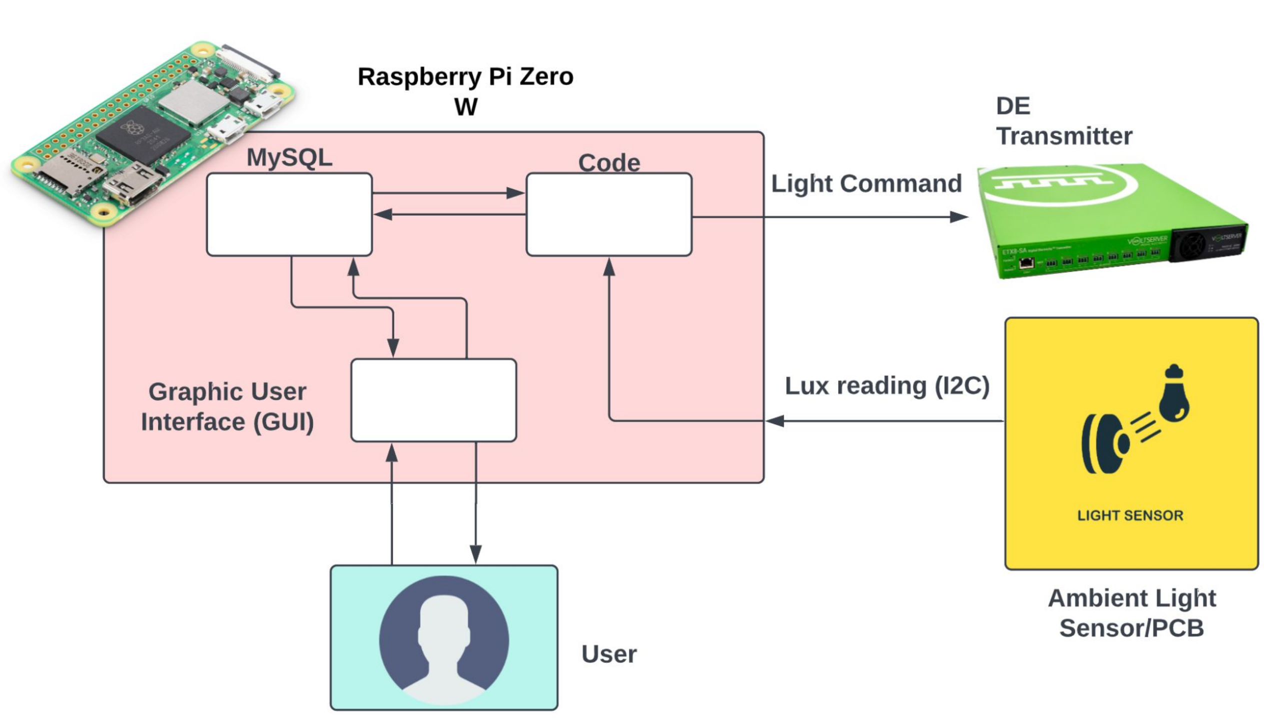

Fig. 4: Software Block Diagram

Remaining Technical Challenges

Testing Logistics:

We have begun soldering our test boards for our three different light sensors. Additionally, we have bought a commercial light sensor which communicates lux readings. With these, we will be able to ensure the sensors are communicating the proper lux reading back to the Raspberry Pi. Plus, we would be able to confirm the datasheet was accurate when testing under certain conditions.

Design of Final PCB:

A version of the final PCB for the main circuitry will be developed using the BH1730FVI/BH1750FVI footprint from ROHM Semiconductor. The individual boards will route to an interconnect board to allow us to have a nine-sensor array connected over I2C to the Raspberry Pi.

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 a 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 use Autodesk Inventor Professional as our software.

Software Development:

Additional software is needed in conjunction with the housing design to factor in a compensatory gain for the angle of light. This could include creating a calibration stage where the system is able to determine the relationship between power to the lights and lux transmitted by them. Both would need to be tested once created.

GUI Development:

The GUI would be how the consumer would interact 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.

Implications for Company & Economic Impact

Apart from being a cool solution to optimizing luminosity in a greenhouse, a device like this can be implemented into our consumer's solutions for automated light intensity control. With a device like this, we can make sure that the optimal level of light is reaching the plants and avoid over-powering the LEDs in specific applications, which will lead to lower power usage. Optimizing light output at indoor farms can decrease the consumer's utility bill. Using products such as the one being developed has an impact on the company not only in terms of economics but also in exposure and client satisfaction.

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TUESDAY, DECEMBER 20, 2022

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Colored LED Event Automated Reader

VOLTSERVER DIGITAL ELECTRICITY™

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

Technical Director(s): Stanley Mlyniec and Camilo Giraldo

Project Motivation

VoltServer products generally incorporate a combination of 3 LED's, consisting of one blue, one green, and one red to visually display status codes through a series of LED blinks. Each of VoltServer's devices have different status codes but utilize the same type of light blinking sequences which are a combination of the three lights that are utilized through VoltServer's platform. Deciphering the blinks can relay information such as "start up", "software off", etc. The main focus of this project is to improve the efficiency of VoltServer's product testing procedures. Currently, VoltServer employees would be required to manually inspect the status LEDs to interpret the signal which could be considered a redundant task that can become automated. The Colored LED Event Automated Reader (CLEAR) would save time and money by aiding VoltServer's testers. This will be made possible by the development of a mountable sensor system that can be attached to the TX-550. The sensor signal will be able to quickly detect different status LEDs and would be able to decipher these messages and relay this information to a GUI.

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.

Key Accomplishments

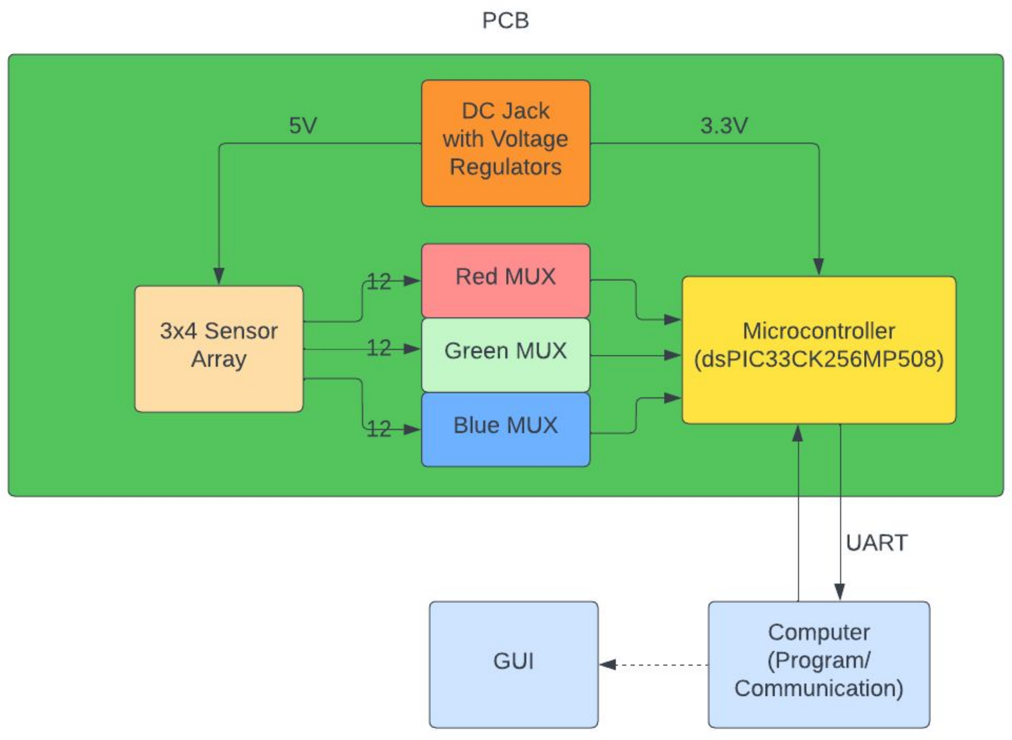
Sensing Algorithm Flowchart: A flowchart was created that portrays how the LED Sensor Algorithm will operate. The sensing algorithm would search for light. Upon reading values for light it would then attempt to determine which color LED would be present based upon which RGB Voltage is higher at that 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 thick cardboard cut to allow for a LED light to be inserted either being Red, Blue or Green.

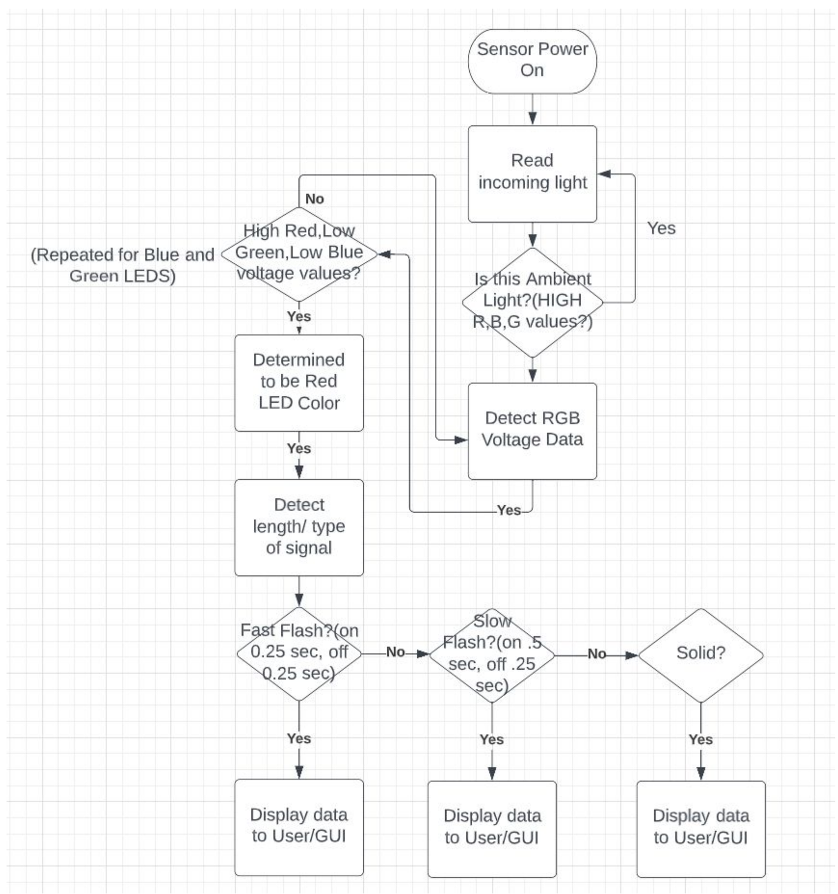
Photodiode Testing: Utilizing the CLEAR 2021-2022 team's testboard, LED sensor testing was conducted utilizing the 3-channel APS5130PD7C Photodiode. During the testing voltages were collected and used to calculate current values with differing LED colors and distances.

Schematic Redesign: LED sensor schematic was redesigned from 2x3 array of APS5130PD7C Photodiodes to a 3x4 array. After extensive component research, the MAX1627 DC-DC converters were replaced with two LD2985BM50R voltage regulators. The 8-channel NX3L4051 Multiplexer was replaced with the 16-channel CD74HC4067 Multiplexer to account for the six added photodiodes.

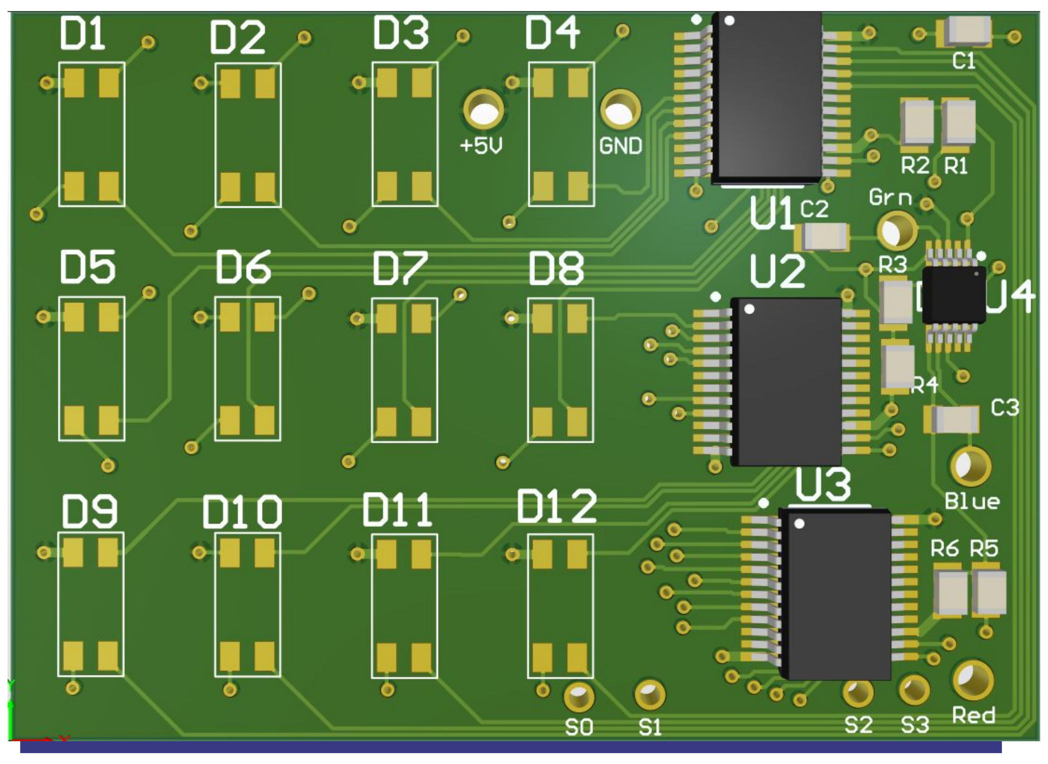
LED Sensor Test Board PCB Design: A test board was designed for LED sensor testing, including a 4x3 array of APS5130PD7C photodiodes, where each RGB signal was separately routed to 1 of 3 CD74HC4067 multiplexers based upon sensor color. The output of the multiplexer was then routed to the AD8244ARMZ OP Amp which connected to three test points for data acquisition.



Block Diagram of Overall Design



Sensing Algorithm Flowchart



Sensor Array PCB Testboard

Remaining Technical Challenges

Development of Mounting System for TX550: In order to house the sensor PCB, a mounting system will have to be developed. It will contain a hole big enough for the light from the LEDs on the TX550 to shine onto the sensors as well as holes for power and communication cables. There will also need to be a way to easily insert and remove the PCB. This will most likely be designed in a CAD software and 3D-printed.

Redefine Sensor Algorithm: In order to accurately determine the state of the LEDs, the algorithm must be refined and recalibrated as lighting conditions change. Existing and new sensor testing data will help achieve this.

Create GUI: The GUI will be used to display the on/off state of the LEDs to the user, as well as translating them to status messages. It will also display the live voltage data coming from the sensors as well as send commands to the microcontroller.

Redesign PCB: The PCB board will have to be redesigned to account for the new components. The board will have to have a 4x3 photodiode array, three CD74HC4067 multiplexers and two LD2985BM50R voltage regulators. The PCB board will be restricted to 1.5" by 1.5" which may pose a challenge when designing.

Determine Location of LED: If all other aspects of the anticipated best outcome are achieved, then the firmware can be adjusted to determine the location of the LED that is on. This will be made possible because of the 4x3 sensor array. The sensors in the array which have the most voltage across them will determine the location of the LED (left, right or center). This will be of low priority until the anticipated best outcome is achieved.

Implications for Company & Economic Impact

Completing the best outcome of this project would assist VoltServer in building automated LED tests for their End of Line testing during the manufacturing process. This would greatly reduce the amount of time that an employee uses to check every LED on each device that is manufactured and allow them to be more efficient with their time. Our best outcome would also allow VoltServer to convert LED based error messages and status codes into a readable format for the user on an on-demand basis. Not only would this make the manufacturing process even more efficient, but it will also prevent human error when attempting to decipher the type of status or error messaging being displayed.

ELECOMP CAPSTONE SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Smart Baby Monitor

With Integrated White Noise

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

Technical Director(s): Dr. Andrew Cavanaugh, Steven Anzivino, and Kiran Thakur (Consulting)

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.

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.

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, however, as of 11/20/2022 we have yet to receive a response.

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.

Combined Designs of PSU and Codec: As shown in Fig. 4, the left-most area of the board is our designated power-supply section, while everything else to the right is the audio codec's section.

Fig. 2
XMOS Explorer Board

Fig. 3
XMOS xcore.ai Chip

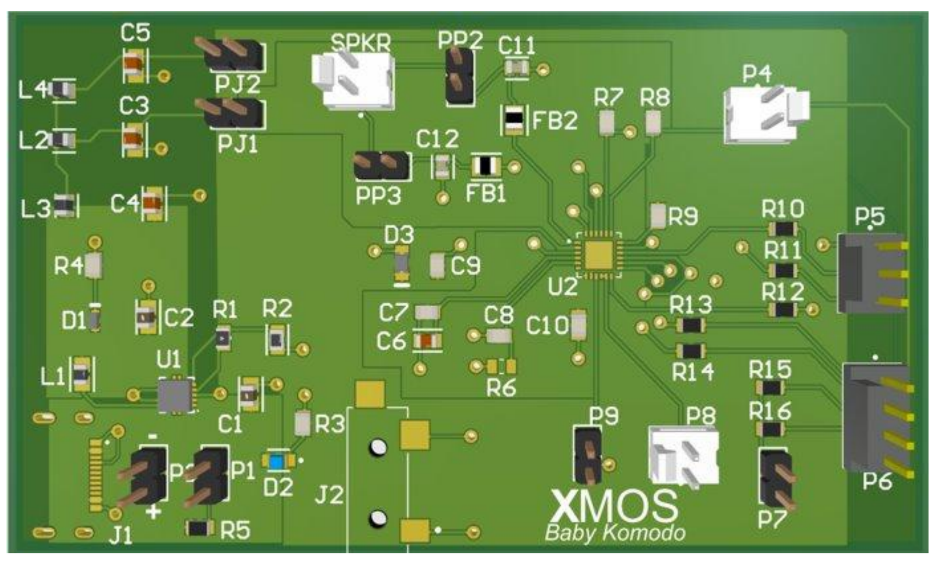


Fig. 4 New Daughterboard Design

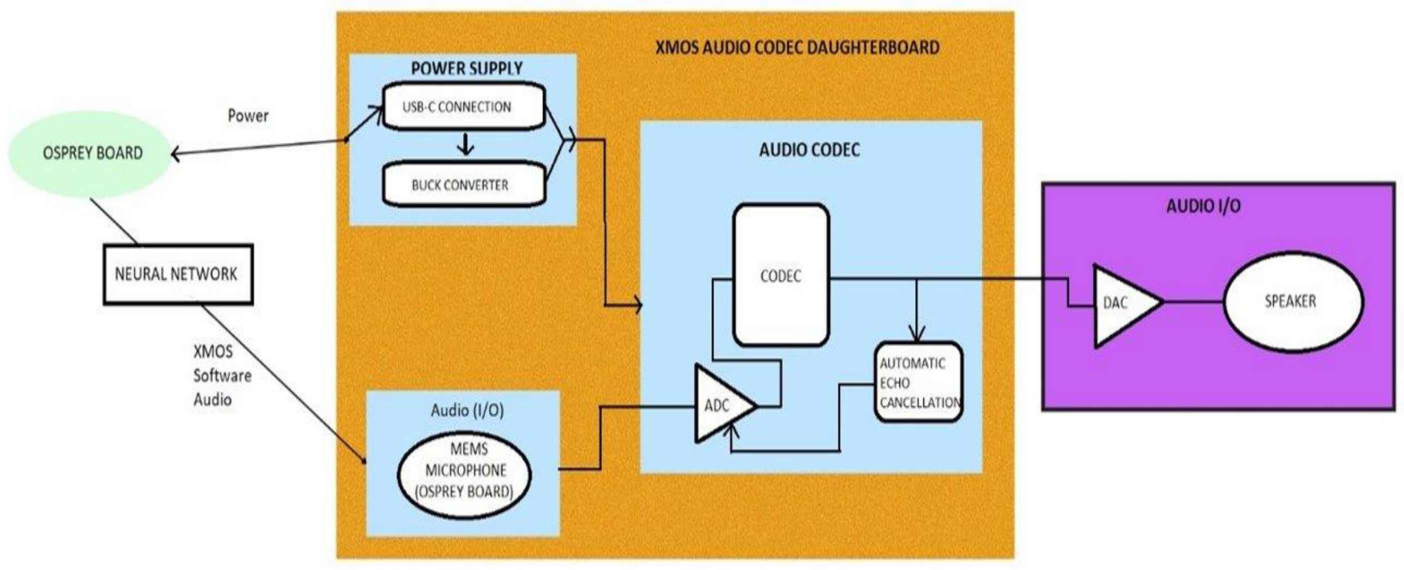


Fig. 1 Daughter-board Block Diagram

Remaining Technical Challenges

Compile Test Audio Data: For training of the neural network, a comprehensive library of sounds we want to detect is crucial for ensuring we have enough datapoints to have a high confidence value for each event we come across.

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.

Sound Detection Test Environment: Relying on the prototype entering the testing phase, we will need to create a controllable environment to test the prospect of using the AI sound event detection. A flat frequency response speaker will be crucial for the initial testing in terms of getting usable synthetic data test points as well as a couple of panes of glass for a more practical test of the "window break" event and maybe even a live crying baby.

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: 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.

Implications for Company & Economic Impact

By creating a package that combines industry leading features without relying on cloud computing, XMOS hopes to be able to create a product that can removing overall network connectivity to increase privacy for its users.

Through this product, XMOS plans to prove that this concept can be done. A smart baby monitor that operates as a standalone device with these powerful onboard features along with combining multiple devices' utilities into one package would put this device in a league of its own in terms of both privacy and features at a price point that is competitive with the other options.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 20, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Torque Measurement

Printer Realtime Torque Measurement

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

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

Project Motivation

Many Zebra mobile printer customers use a wide range of media that come from a variety of different sources, some not from Zebra. This causes technicians to run into torque issues with these medias causing the printers to stall. They currently do not have a way to measure the system torque while printing a label, only while feeding blank media. While printing on certain media, the front sides of the labels tend to stick to the printhead. Zebra technicians would like to be able to print a label on a given printer and measure the torque required to move the head on each print line, providing peak values and details such as printhead sticking as well as the adhesive variation. The mobile division in Lincoln, RI designs direct thermal printers and the heat/chemical reactions are what's causing the sticking issues which is the primary issue they want to address.

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.

Key Accomplishments

Printer Operational: The current state of the apparatus when it was passed off to our team had problems with the boards that were being used. The driver board for example was shorted and would not allow us to test the code to make sure everything was operational.
3D Printed Case for boards: 3D Printed cases for each of the board will allow us to be able to mount the boards to the apparatus. This will allow us to have neat wiring to make it easy to see what goes where for diagnostics. This will also help prevent shorting to the apparatus.
Update Code to use the Input Output Controller: The state of the code from the previous capstone team did not allow us to use the IOC. With updates on how the STM32CubeIDE wanted the code formatted and written, we are now able to assign pins and continue working on adding features like direct memory access.
Voltage Divider: In order to prevent over-voltage of the STM Board, a Voltage Divider is needed for the ADC pins. Understanding what the STM board can receive for voltage values from the transducer is an important step to prevent damaging components.
LPF: A Low Pass Filter is needed for the transducer to get clear and consistent readings. This allows us to remove garbage data coming from the transducer to get accurate readings.
Transducer Readout: We were successfully able to get a read out from the Transducer based on a step pulse and calculate its voltage readings to a torque measurement.
Graphing Output: We were able to take the readings from the transducer and output them into a CSV file which allowed us to create a viewable graph.

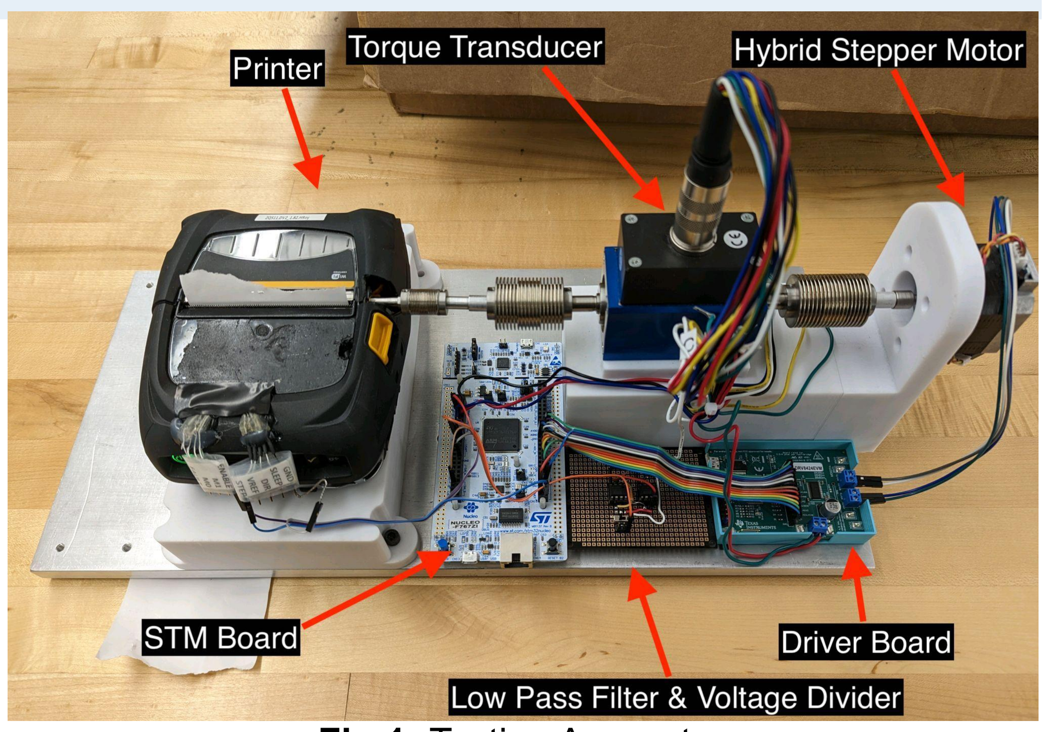


Fig.1: Testing Apparatus

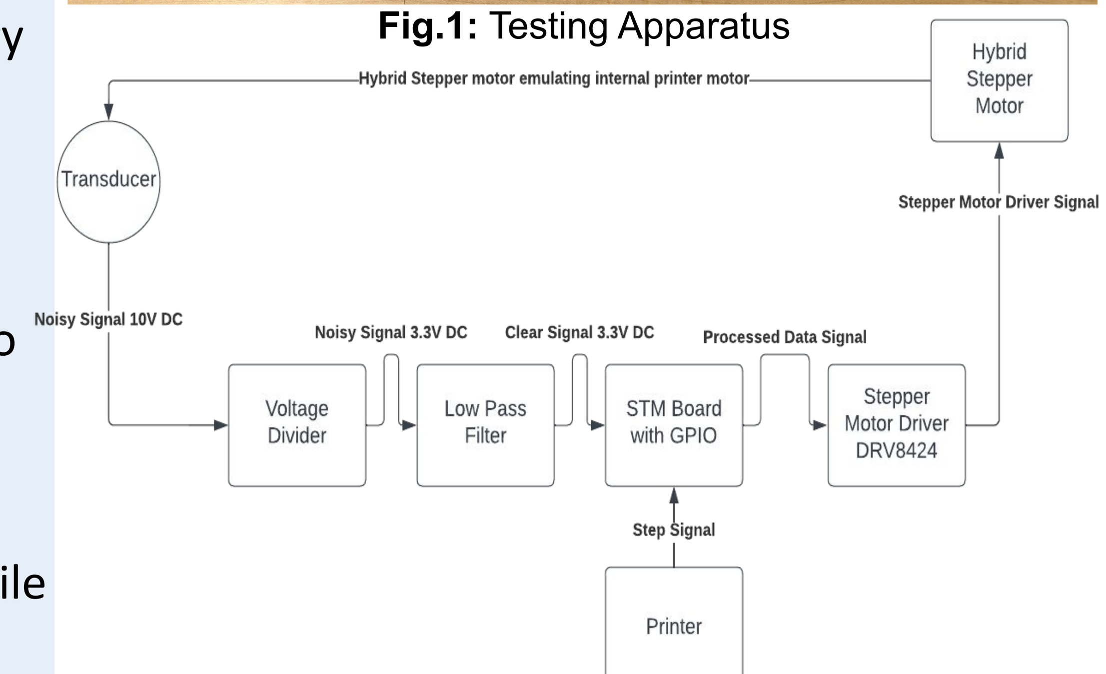


Fig.2: Block Diagram

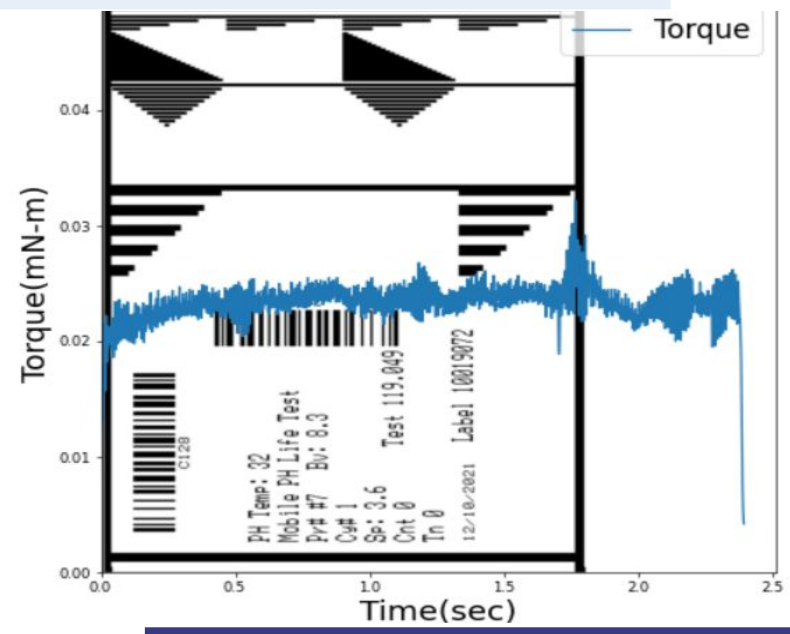


Fig.3: Example of Label with Torque Reading

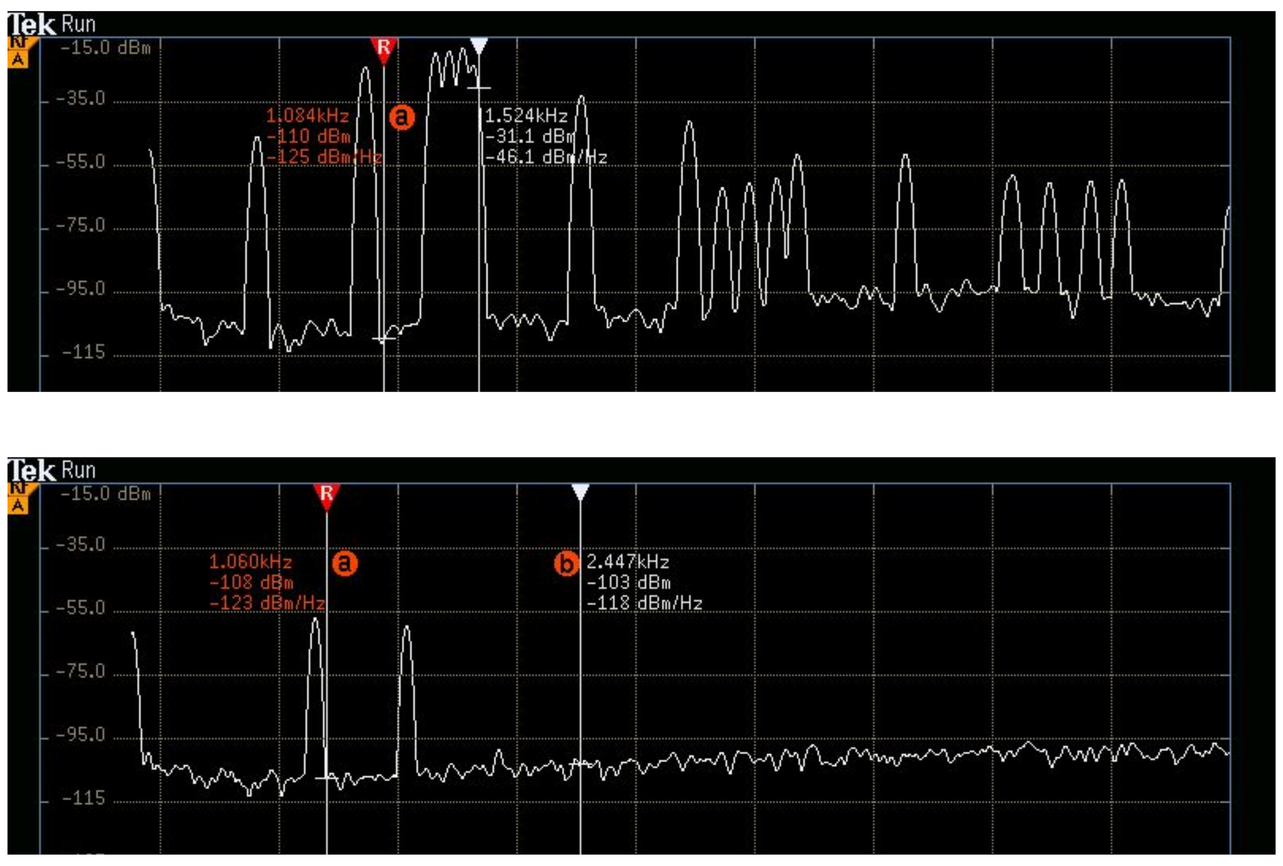


Fig.4: Spectrum analysis showing LPF attenuating undesired frequencies
Noisy Input (Top) Clean Output (Bottom)

Implications for Company & Economic Impact

At Zebra, having a system with fully automated torque measurements will allow them to collect data faster and more accurately troubleshoot customer issues. This project will help make sure Zebra can print what the customer wants on any media type and make the customer-specific adjustments to help the current customer conditions. The Economic Impact that it increases the speed of troubleshooting issues, which allows for a better product that can be manufactured with fewer problems. This also means that Zebra could reduce budgeting towards troubleshooting and reduce the risk of malfunction when promoting a product thus, saving time and money.

Remaining Technical Challenges

GUI Integration: Even though there has been good progress on the GUI, there is still plenty of work to be done on it. Since the end goal is to have the GUI output the label with the torque output as shown in Fig 3, the GUI has to be integrated into the Dev-Bench. Sending data to the Bench and having it return data needed to make the graph. The GUI would also need to send the four specifications of the full step per line, DPI, micro steps, and platen diameter to the STM board.
PCB Design: Once all the components (like the filter) have been added to the Dev-Bench, the project can then move on to being built on a PCB board and look like one cohesive device. This PCB board will have to be custom designed and assembled.
Particle Brake: Using a particle brake to simulate the torque resistance from the Zebra printer, a separate testing apparatus will be built. The implementation of the particle brake will allow for a testing procedure unhindered by sources of random error caused by the printer or the media being printed on and provide more accurate and controlled testing.
Versatility: Once everything is said and done, the device would then move on to be used on different printers. These printers can be from Zebra or from another manufacturer so issues/errors can arise if the code or device hasn't been adjusted for use beyond the current printer on the Dev-Bench. The ultimate goal of this project is to have the device be able to help in troubleshooting printers from any customer, so it needs to be versatile enough to accomplish that.