ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 21, 2021

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

FaultLine

On-Device Training and Inference for Power Signature Analysis and Fault Detection

Acumentrics
TRUSTED POWER INNOVATIONS®

Team Members: Sean Maglione (CPE), Matt McAdams (CPE)

Technical Directors: Brenden Smerbeck (ELECOMP '17) | Consulting Technical Director: Nijab Ishaq

Project Motivation

Predictive maintenance is a growing field of interest across all industries. The goal of predictive maintenance is to reduce the likelihood of catastrophic failure by detecting variances when compared to equipment's normal operation. Successful implementations of these solutions operate by analyzing data collected by an array of sensors attached to the device.\

Machine learning is an incredible data science that has numerous advantages across countless industries. However, machine learning is limited by the amount of time and processing power required to train a model. The greater complexity of the model or the more data required to process, the longer the training process will take. The motivation for this year's project is to push the limits of modern single-board computers to determine if on-device training is possible and feasible. That is, training the model on an embedded device, rather than training on a powerful machine externally and transferring the model onto an embedded device.

Anticipated Best Outcome

The Anticipated Best Outcome is to successfully implement on-device model training using the embedded computing platform within the SmartPDU. The prototype system shall be able to infer the state of connected appliances and detect abnormalities based on variances in the power signature of the appliance. On-device training aims to allow embedded systems to train models locally. This type of training allows for data collected locally to directly influence the model's structure. Additionally, these models are unique to the device, and don't require a network over which to communicate. This process is referred to as transfer learning, which we seek to implement for the FaultLine system.

Key Accomplishments

Constructed custom virtual environment for building and training models: The Software provided from the previous year's team had been shuffled around since the beginning of the project and as such had become buggy, outdated, and obsolete. To resume where the project left off, a new working environment was necessary. Using a fresh installation for the Jetson Nano **(Fig 4)** , a new environment was implemented.

Appliance selection: The plan to continue to use the device selected by the previous FaultLine team seemed obvious, yet not enough to prove transfer learning as a concept in this way. A vacuum **(Fig 1)** was selected as a secondary target appliance due to its low cost, easily induced electromechanical faults, and complex power load. Since the appliance has both real and complex power components, the unique power signature of the device will be easily identifiable.

Improved performance of DAQ: The previous team's project called for 1 sample per second. This year, to support better transferred learning and inference, the frequency needed to be brought up significantly. The code running the ADE7816 and the data collection had to be refactored and optimized to allow for quicker sample return and can now collect at around 40Hz.

Implemented Transfer Learning DAQ with Circular Buffer: A circular buffer is a data structure like a queue that will be used to streamline data collection and processing. When the buffer is full and needs to add an element, it will be pushed on to the existing dataset and the last element will be popped. The circular buffer is a key performance enchantment that will be utilized for on-device training.

Machine Learning Framework Selection: The general model implemented by the previous team may serve well as a general model for the ABO, and so to put together a local model for transfer learning **(Fig 2)**, continuing the use of TensorFlow and Keras proves to be the ideal solution.

Figure 4: The NVIDIA Jetson Nano

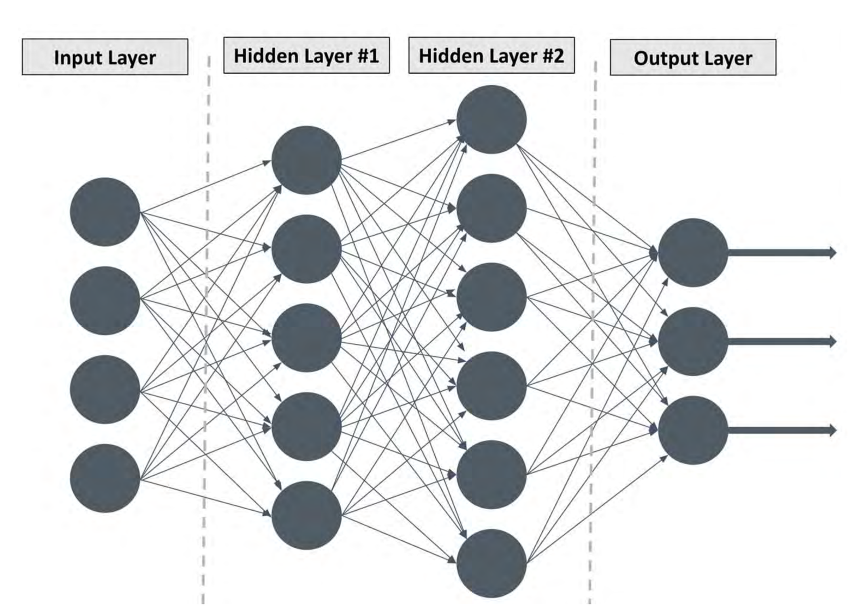

Figure 2: Machine Learning Diagram

Figure 3: Acumentrics' SmartPDU

Figure 1: Dirt Devil Endura Reach and WindMachine floor fans

Remaining Technical Challenges

Data Collection: Using the ADE7816 and the software designed for the Jetson Nano, the power data from the microcontroller can be collected and stored for model training. Given higher rates of collection, more data will be available. Thanks to this, the current team is in the process of collecting as much data as possible to set up for a more successful model. Once data is collected and trained, we can then assess whether the data acquisition system needs to be further optimized to provide proof of concept.

ML General Model Accuracy Improvement: As with any ML application, the main focus of the model development is on improving the accuracy of the predictions. For the intended application, there are a variety of methods that can be utilized to enhance the accuracy of the model. These methods include hyperparameter tweaking, generation of additional feature vectors, and varying the model layer structure.

Local model implementation and Inference System Design: The system needs to be designed to enable efficient data collection, on-board training, and model inference to be able to predict whether a given power signature is faulty **(Fig 3)**. The system must be capable of measuring power data to send to a circular buffer, and depending on whether it is in training or inference mode (which itself will need to be implemented), either train the local model (given frozen lower layers and modification permission on surface layers of the model) or infer based on the current version of the model. The training mode will need a way to determine "good" functionality from "faulty" readings. The current working plan is to implement a switch to enable "correction mode" to correct whether good equipment is, in fact, running faulty, or whether equipment marked running faulty is in fact running properly; followed by a periodically activated "training mode" to further improve performance of the local model.

Implications for Company & Economic Impact

As Acumentrics' products are built to last in normally inoperable environments, integrity is an absolute requirement. As the company extends its knowledge of power systems to autonomous power, the need for data analytics and understanding only grows. Should the project succeed, there is a growing market for predictive maintenance across all industries, not only the military industry in which Acumentrics primarily exists. Therefore, the economic impact is too large to accurately measure. For existing customers, the project would allow Acumentrics to better understand its devices' points of failure and continue to improve the ruggedness and longevity of those devices.

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Self-Diagnosing Machines

Integration of Fault-Detection and Classification to detect bad Galvanometers

CAMBRIDGE TECHNOLOGY
A Novanta Company

Team Members: Brandon Londono (ELE), Nicsaii Men (ELE), Max Mueller (CPE), Max Bublitz (CPE + ELE)

Technical Directors: Jeremy Berke, Ali Golabchi

Project Motivation

Our galvanometer-based scanning systems are integral in very demanding applications such as Laser Additive Manufacturing, Via Hole Drilling, Laser Marking and Coding, and Medical Imaging. In these spaces, the system must be able to complete the job without failing. Imagine having to scrap an entire tray of 3D printed metal on hour 13 of a 14-hour job because the scanner failed!

We want to use machine learning to analyze galvanometer health, classify failures, and predict usable lifetime. A galvanometer, or galvo, has multiple parameters including coil resistance, inductance, torque constant, and back emf, all of which have a nominal value for any given galvo. A broken or damaged galvo could be indicated by a change in any of these parameters, with each signaling a different problem. Furthermore, analysing slight changes in these parameters can be used to update a model for the usable lifetime of the galvo.

Key Accomplishments

Simulation: A three-state galvo was first simulated in Simulink to generate test data (Fig. 3). The galvo model was created utilizing a state space model of the 3-state galvo. Initially, a Luenberger Observer was used to estimate state values, however this was swapped shortly after to a Kalman filter. This change needed to occur as noise was injected into the galvo input and galvo output measurement. A random input is used for the system in order to have the system in a dynamic state and allow for changes in parameters to produce observable changes in output values. The simulation outputs the position, velocity, and current of the galvo, as well as the estimated position, velocity, and current.

Fault Detection: Researching different kinds of fault detection algorithms, we decided on using parameter estimation to detect if there is a fault or not with the galvo. Using this method we had to split into one person putting the galvo data through a recursive least squares function and the other creating a PCA whitening filter.

Recursive Least Squares: A method to approximate the solution of an overdetermined system. We will be using this method to find the parameters of the system from the given input and output, to then estimate the output of the system. A demo of this function was created with randomized data.

PCA Whitening: Randomly generated data that has mean and variance, is put through a PCA Whitening filter to center the data, get zero mean and the covariance of the whitened data to be the identity matrix (Fig. 1). Works in multiple dimensions. This “whitened” data allows us to separate the good and bad data from each other, allowing the classification team to classify the fault.

Classification: Through much research on classification algorithms, we decided that k-medoids would be the best classification algorithm to cluster data into corresponding groups. The use of the mahalanobis distance metric in the classification algorithm helps cluster the data while considering the covariance of each group in the data set (Fig. 2). This helps keep the classification of each data point consistent with the group that it should be assigned to.

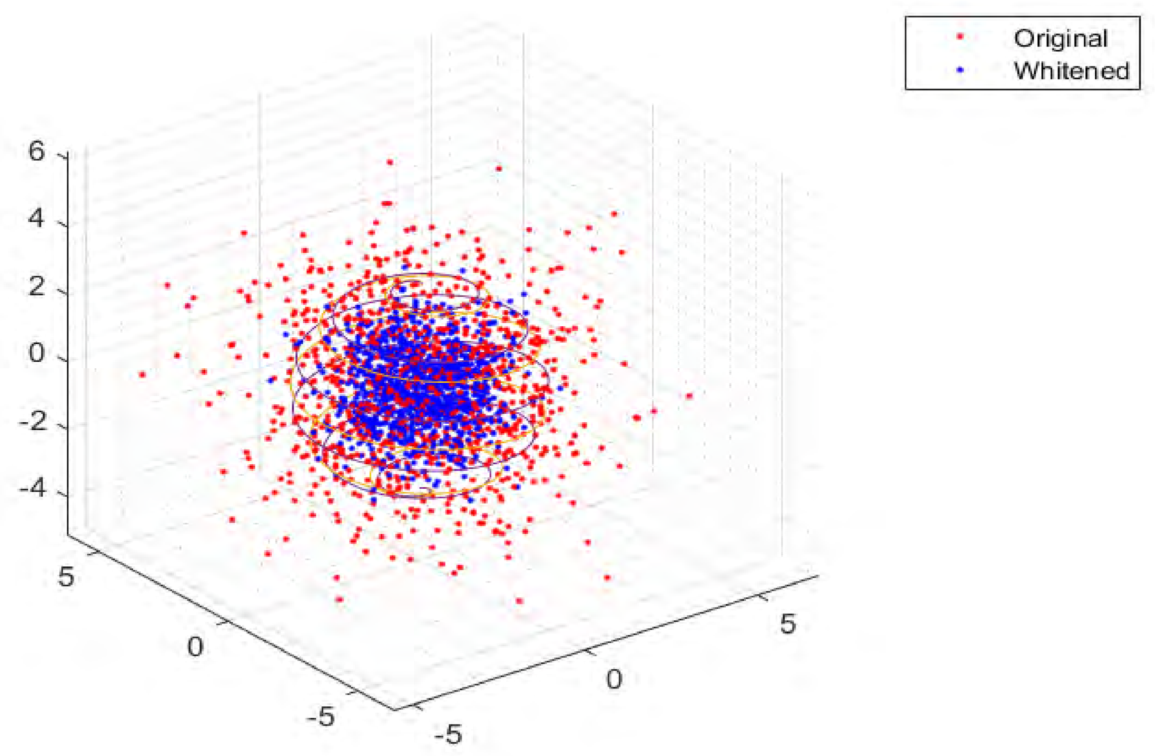

Fig. 1: PCA Whitening filter showing original and whitened

Implications for Company & Economic Impact

Predictive failure analysis will position Cambridge Technology further ahead of competitors and lay the groundwork for future innovation. Yield would be increased by identifying good and bad galvos in the factory before they are built into scan-heads. Rework time would be reduced by determining failure modes of returned product for targeted repair. Quality would also be improved, as well as more accurate lifetime and quality metrics. The Fault Detection algorithms can determine if galvos have degraded through internal testing cycles, if returned product is defective, and how the galvo reacts under intense operating conditions. The Classification algorithm can determine the specific failure modes, enabling targeted rework and faster service cycles.

Anticipated Best Outcome

The Anticipated Best Outcome is :

- A fault detection system capable of detecting errors and transmitting information to the classification system
- A classification system capable of classifying the type of fault the galvo has experienced
- If the above is accomplished, the ideal outcome would be a prototype that can continually calculate the expected life of the galvo.

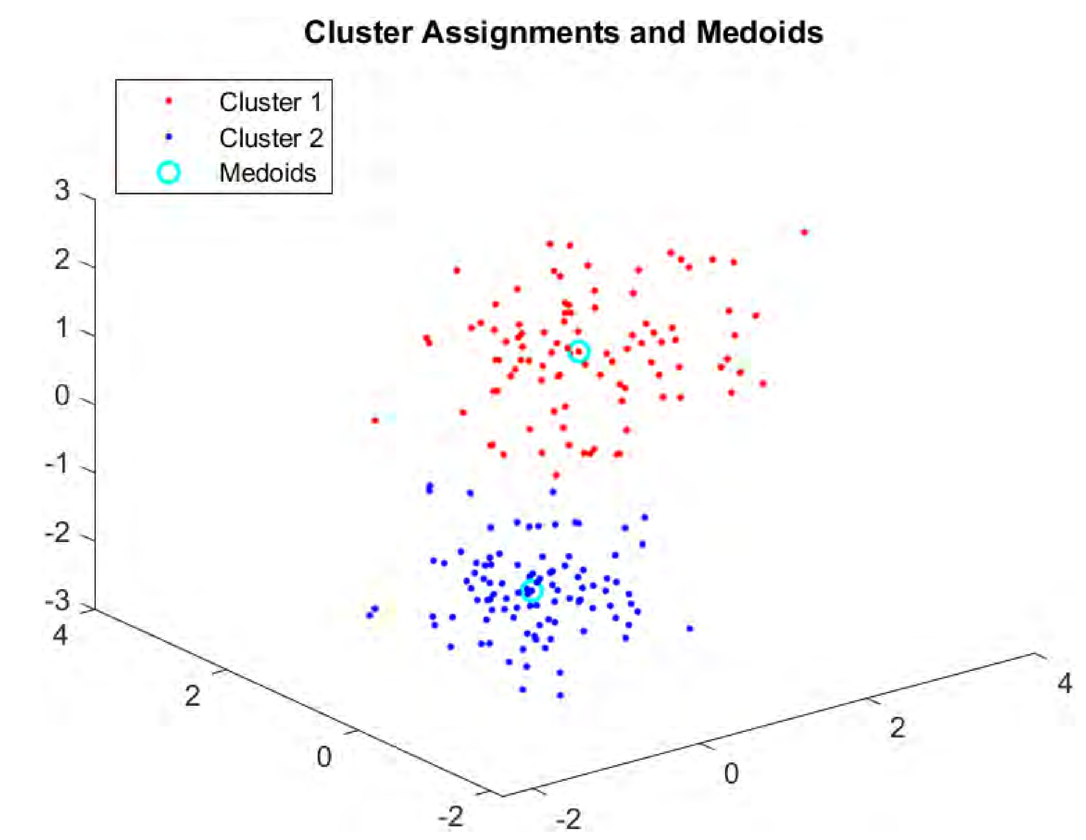

Fig. 2: K-medoids classification for k=2 clusters in 3-dimensions

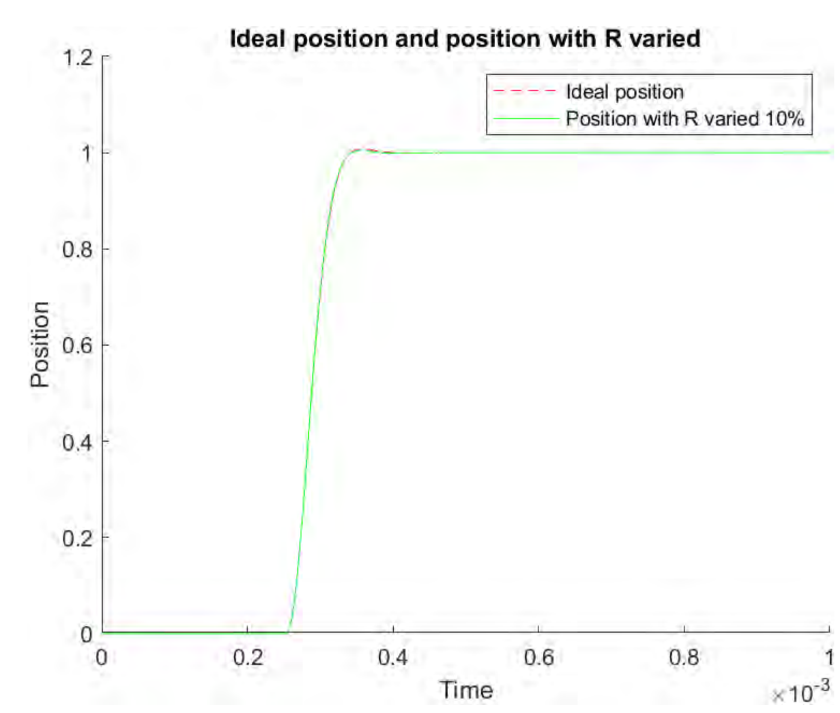

Fig. 3: Galvo simulation data

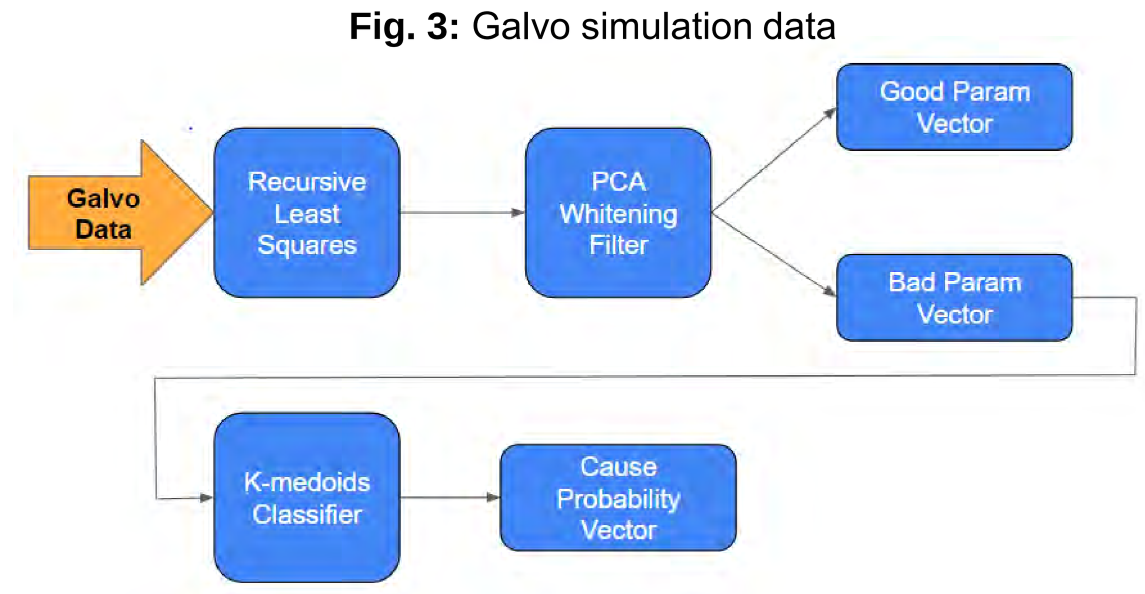

Fig. 4: Galvo Health Monitoring process

Remaining Technical Challenges

Recursive Least Squares: Receive galvanometer input and output data and break it down into multiple windows with overlap to retain as much detail as possible after running the Recursive Least Squares algorithm.

Principal Component Analysis: Since the PCA filter works in multiple dimensions, work on a way to reduce the dimensions. Data from every dimension may not be useful, so it will be useful to thin out the amount of dimensions that need to be computed - reducing run time.

Merge Components: One of the largest technical challenges remaining for this semester is merging all of the individual components: simulation, recursive least squares fault detection, PCA whitening, and K-medoids classification. All of these parts must be completed within the next 2 weeks with integration already begun for PCA whitening and K-medoids classification. Completed components work well individually, however combining them is proving to be more difficult than initially thought, especially when working with more than 3 dimensions. Working in more than 3 dimensions is much harder to visualize, and thus more difficult to conceptualize.

Hardware Integration: After successful completion of merging all the components (simulation, recursive least squares, PCA filter, K-medoids classification) we can implement the methods in hardware using C as our programming language. This language allows the coder to talk directly to the hardware which as a result makes fast and efficient use of the computer. In other words, it is directly understood by the computer which allows for fast speeds. This is a task that will be worked on starting the spring semester.

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AM-BATS Part Deux

Determining battery health

EAGLEPICHER TECHNOLOGIES

Team Members: Anissa Elias (CPE), Christopher Charron (CPE/ELE), Shaun Thurber (ELE), Nick Duarte (ELE)

Technical Directors: Frank Puglia ('93), Daniel Wertz | Consulting Technical Director: Brenden Smerbeck ('17)

Project Motivation

EaglePicher specializes in providing battery solutions for very demanding applications. Their batteries are frequently required to perform at extremes in temperature, vibrations, power delivery and service life. Achieving the performance that their customers demand requires advancements in the tools and methods used to evaluate battery cell designs, integrated with the battery management systems to control them. Tradeoffs typical in BMS product designs create limitations that make laboratory instrumentation challenging. A battery management system with the ability to collect high fidelity performance telemetry could prove invaluable in evaluating battery cell designs. Illuminating the unique characteristics of candidate battery cells will aid in establishing the minimum requirements for a deliverable BMS design. Ultimately, a better understanding of cell characteristics, and how those characteristics can be observed and interpreted by the BMS, is the next step in optimizing the use of the batteries in both first and second life applications.

Anticipated Best Outcome

Our Anticipated Best Outcome for AM-BATS Part Deux, is to design and build a battery management System platform to investigate battery cell performance for demanding applications. This will include the ability to synthesize the charge and load characteristics for a variety of applications. Using the AM-BATS platform, demonstrate the safety protocols and performance of Li-Ion batteries in various applications. EaglePicher will provide usage profiles ranging from electric bikes, to vehicles, to directed energy weapons and hybrid load conditioners. Identify the correlation between BMS measurements and the prediction of aging for various cells and usage profiles.

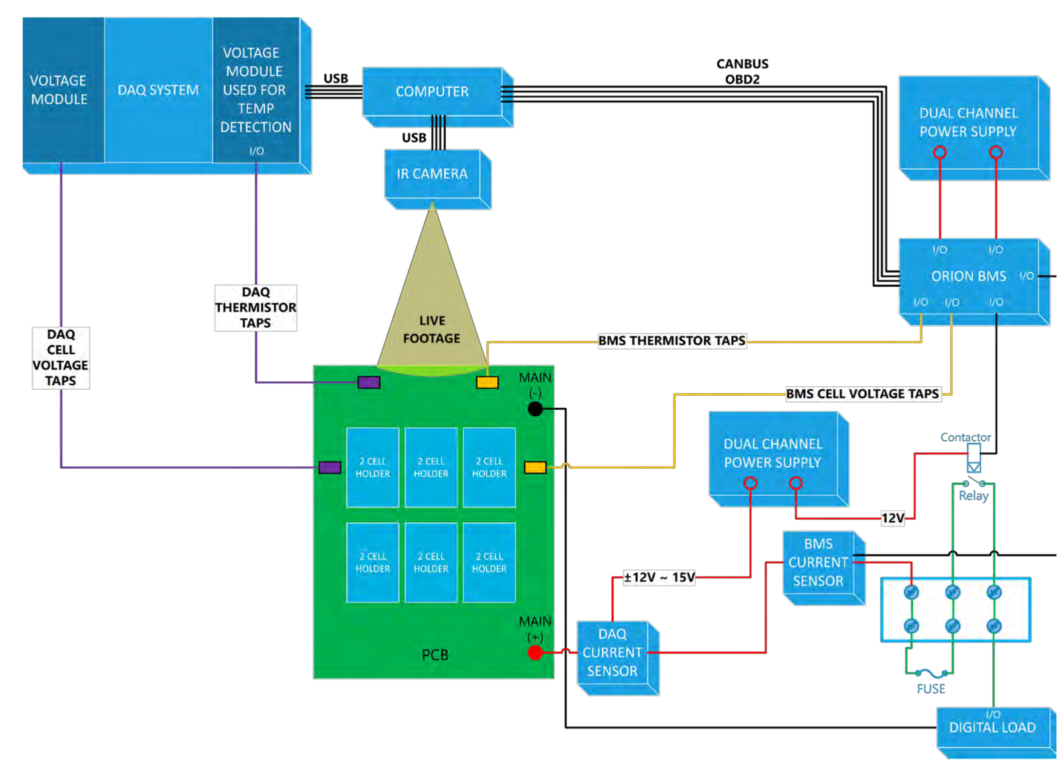

Fig. 1: Overall visualization of our system including all virtual and physical connections.

Key Accomplishments

Test Fixture Design: We have created a 3D model **(Fig 2.)** and a block diagram **(Fig 1.)** to visualize how our test fixture will be designed and all the connections that are added.

Key Component Selection: Researched and selected components within power specifications dictated by the design. Completed a bill of materials for the majority of the components needed to run data collection with an electronic load supply.

Data Collection Systems: Our project's main objective is to be able to compare the data collected from a commercial off the shelf (COTS) BMS system to a real time data acquisition system. We researched data collection systems and chose the National Instruments DAQ due to its high 24-bit resolution and high sampling rate. The Orion BMS 2 was chosen over the foxBMS as a good representation of a widely available COTS BMS.

Temperature and Current Measurement: Designed circuitry to allow us to measure the temperature of the battery cells **(Fig. 3)** and the current going in or out of the battery pack. This circuitry includes the necessary signal conditioning required to put the measured output voltages in a readable range. We designed a buffer amplifier and voltage divider circuit to read the temperature. We designed signal conditioning for the current sensor to operate on a 10V scale to represent the range of current (0-10A) from the battery pack.

Equation Sheet Conversion: Our DAQ system will output raw data unlike our BMS, therefore we will need to do multiple mathematical conversions to be able to synchronize and compare our data. We have compiled a list of all mathematical equations needed to do so.

Programmable Load Design: Designed a programmable load **(Fig. 3)** with eight channels that is capable of creating 256 different current levels between 0 amps and 10.24 amps. Simulated a working load profile circuit with non-ideal components.

Graphical User Interface: Developed a GUI to allow us to test different fake generated Battery Cell Data in preparation for our predictive modeling. This GUI will allow us to see how a Battery pack works in parameters identical to what ours will be once we receive all our components.

Battery Board: Designed a PCB **(Fig. 4)** that will contain all battery holders and make all connections necessary from the battery pack and associated telemetry to both the DAQ and BMS. This board also allows connection between the batteries and the programmable load and charger.

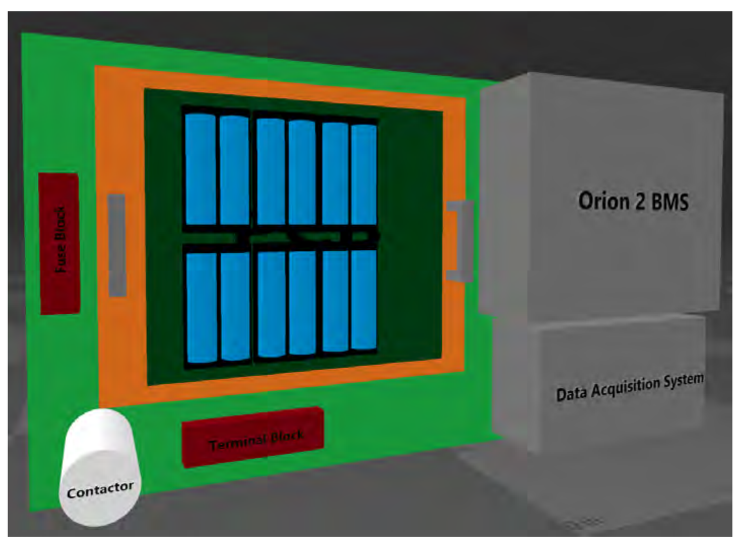

Fig. 2: 3D model of our test fixture

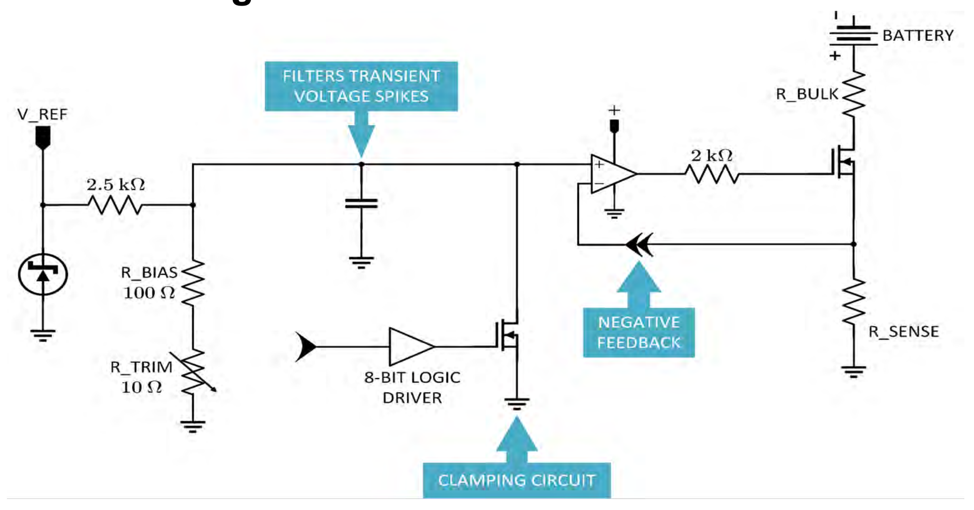

Fig. 3: Load Profile Circuit

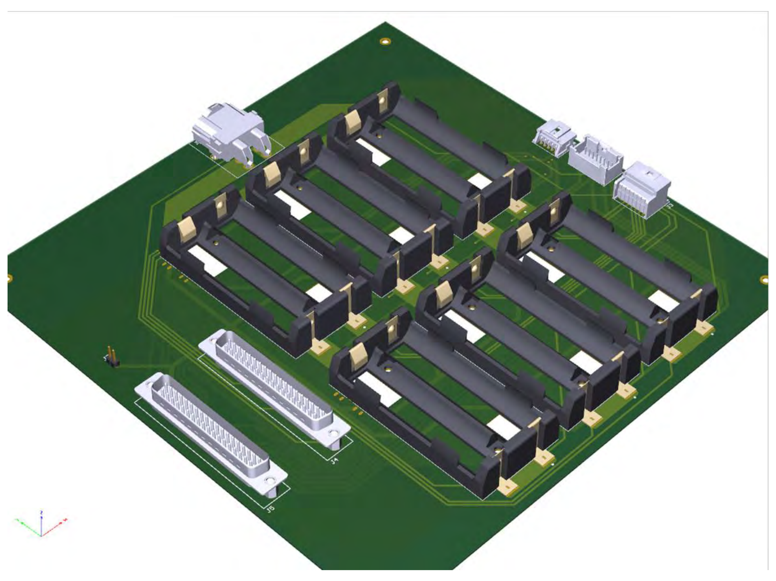

Fig. 4: Battery Board, where our battery cells and all connections to them will reside

Remaining Technical Challenges

Signal Conditioning: There are a lot of different components to this setup that will require different voltage and current levels, which demands a good amount of signal conditioning. A reference voltage for the thermistors will need to be buffered to support 12 thermistor readings to the DAQ. The current sensor will need to be conditioned to obtain a 10V scale to read the current draw from the battery pack from 0 to 10A.

Load Profile Circuit: Components need to be selected that will meet the design specifications. The form factor of the load profile circuit also needs to be determined, whether it will be on protoboard or PCB. Specifically, the high power bulk resistors are too large to be placed on a circuit board, and we need multiple, so we need a stable setup branching off a protoboard or PCB for each channel of the load profile circuit.

Test Fixture Assembly: The battery board PCB needs to be populated and the swappable battery blocks need to be assembled, along with the rest of the fixture.

Data Collection: Completing a cycle of running a discharge profile and recharging the battery pack will take several hours, and will need to be monitored throughout the process. Obtaining a lab space where the physical setup can complete this process without interruption is not fully determined.

ML Data Synchronizing Model: The BMS has a much slower sampling rate compared to the high speed DAQ, which will complicate the process of synchronizing the data in order to determine what the BMS is seeing when significant data points appear on the DAQ.

Predictive Models: As we collect our data one of our final achievements will be creating predictive models that will be utilized to forecast individual cells' parameters and how their life cycles will look like. This is a complicated process that requires a large amount of data and ML, but it will be what our project is working towards.

Implications for Company & Economic Impact

Some of EaglePicher's batteries are currently on Mars and delivering cutting edge performance, as you read this. Achieving the performance that their customers demand requires advancements in the tools and methods used to evaluate battery cell designs, integrated with the battery management systems to control them. EaglePicher would be able to advance their studies into the usefulness of worn batteries and what they can be used for after their primary use has been exhausted. The technology would be capable of being mass produced and be capable of detecting damaged/malfunctioning battery cells that otherwise would not be able to be diagnosed in the field. By optimizing the BMS around the most important parameters to measure, for both safety and state of health/charge, EaglePicher Technologies will set the standard for providing rapid solutions for critical applications.

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GDEB - COTS

Consumer off the Shelf Design of a Digital Acquisition System

GENERAL DYNAMICS
Electric Boat

Team Members: Michael Marcello (CPE), Luke Wilson (ELE), Wilmer Chinchilla (ELE), Daniel Ekenavie (ELE)

Technical Directors: Adam White ('14), Art Viola ('84)

Project Motivation

While the initial intent of this project was to replace the antiquated Versa Module Europa bus (VMEbus), the scope has shifted into an investigation into the pursuit of the viability of an off-the-shelf design of an embedded system. This motivation was driven by the desires and interest of the students on Team Commercial Off the Shelf (COTS) to produce an intriguing platform that incorporates the customer's ideals. Mobile solutions demand greater development in the field of embedded technologies. It is desirable to take advantage of COTS products, as influences of the consumer market require that such technologies be applied as a cheap and flexible engineering solution. Notably, utilizing readily available parts for a larger system assembly can assure that a system is readily serviceable and reduce overall engineering costs. Importantly, COTS products typically have increased support for an extended lifespan, which is a strong consideration for military contractors.

Key Accomplishments

Selecting and Sourcing Sensors: To meet the required functionality of our project, a list of sensors was created from a consumer perspective that targeted COTS products. The sensor list is as follows: the SEN0140 Inertial Measurement Unit (IMU), containing a magnetometer, accelerometer and gyroscope. The device will pick up on sudden changes in motion, angular velocity and shifts in magnetic field. Additionally there is a NEO-M8U GPS to track and monitor the location of the RC car, a AFBR-S50LV85D time of flight (TOF) sensor with a range of 3m-100m to detect obstacles in front of the RC car and a phototransistor to detect the light of the environment and to determine when the headlights will turn on. Finally, there is a temperature sensor to monitor the temperature of the RC car battery. The Raspberry Pi 4 will function as the microcomputer, receiving and transmitting data to and from the various sensors in the system.

PCB Design: A total of 3 PCB schematics were designed to accommodate all sensors and connect them to the Raspberry Pi. The first PCB Schematic operates using the SEN0140 board mounted with the GPS. The Raspberry Pi is connected via ribbon cable and acts as the control board. The second schematic design has the TOF sensor which will be mounted in front of the RC Car to detect obstacles in front of the vehicle. The last board design acts as the power source as it will be connected to a 9.6 Volts NiMH Traxxas battery, which will utilize a Texas Instruments TPS565208DDCR chip that acts as a DC-to-DC converter to step down the voltage to 5 Volts. The 3rd PCB design has an inductor and some capacitors to clean out the signals.

3D Modelling of RC Car Chassis: Due to the environment in which these sensors will be tested, it was determined that 3D modelling would be necessary to the design of the system. Therefore, the chassis of the RC Car was modelled in order to determine where sensors should be mounted as this project progresses. In the case of some hardware, such as the SEN0140, this is a critical step as position can affect the data that will be collected.

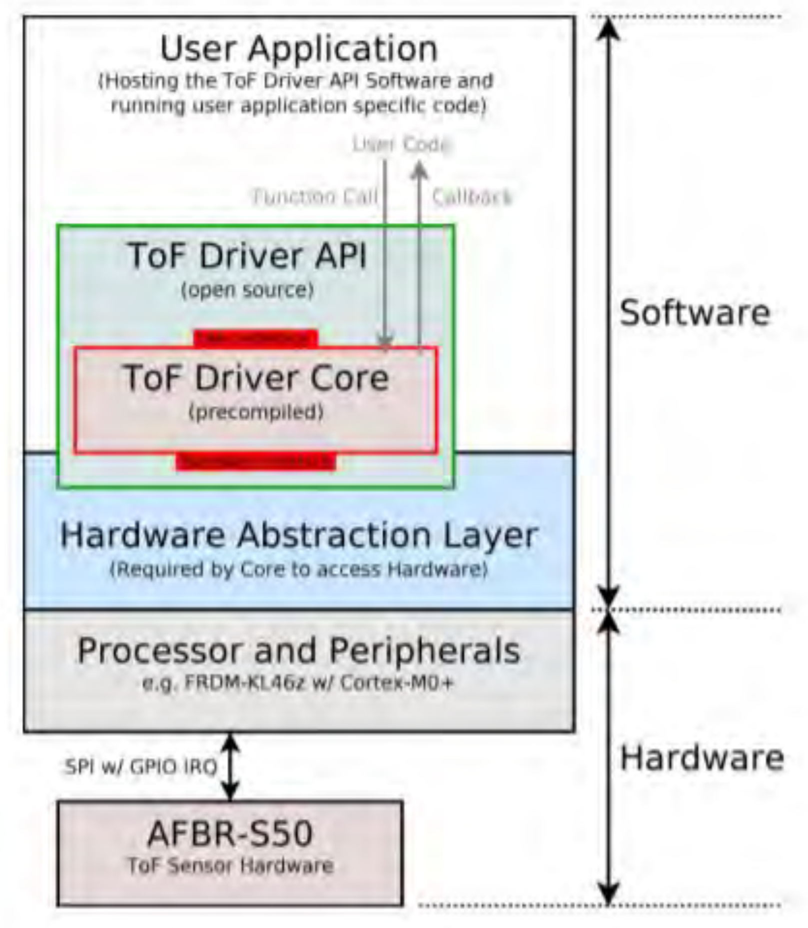

Fig.1: Block Diagram for Time-of-Flight API Integration

Implications for Company & Economic Impact

As General Dynamics Electric Boat is the United States government's contractor of choice for nuclear submarines, the implications of a new, easy to construct, embedded systems solution would be a monumental innovation. The applications of consumer off the shelf technology are being investigated to make use of its flexibility and affordability. If the project succeeds, GDEB will benefit greatly as it gains a significant advantage over its competitors through use of inexpensive, yet capable technologies. While economic impact may be difficult to gauge, a significant amount of funding will be saved in development cost and time if GDEB switches from custom solutions to ready-made device elements. We can solidify the confidence of their existing customers by utilizing products that are produced from established firms.

Anticipated Best Outcome

The Anticipated Best Outcome (ABO) of this project is the creation of a mobile solution utilizing digital and analog I/O acquisition units. These should be capable of transferring data from its sensors over a wireless connection to a client's computer. The client's computer will host a program that will display live data from the mobile solution. Information that is transmitted should also be recorded and stored in a human-readable format on the client's machine to be viewed later. The solution shall include Printed Circuit Boards that will be utilized to mount and interact with the sensor devices.

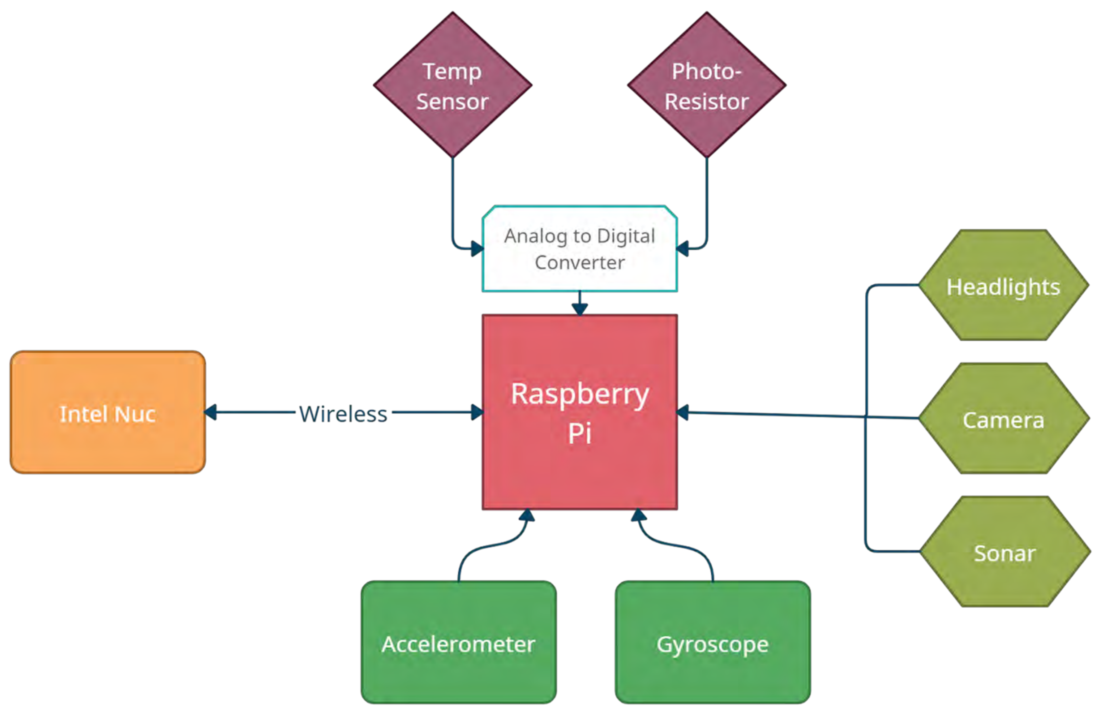

Fig. 4: Communication Interface Pathways

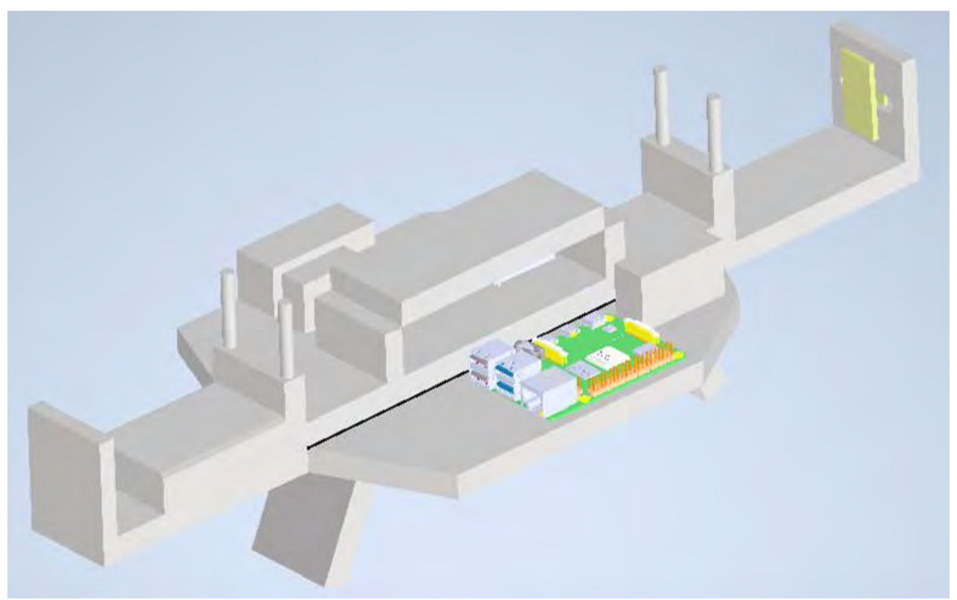

Fig. 2: 3D Model of RC Car Chassis

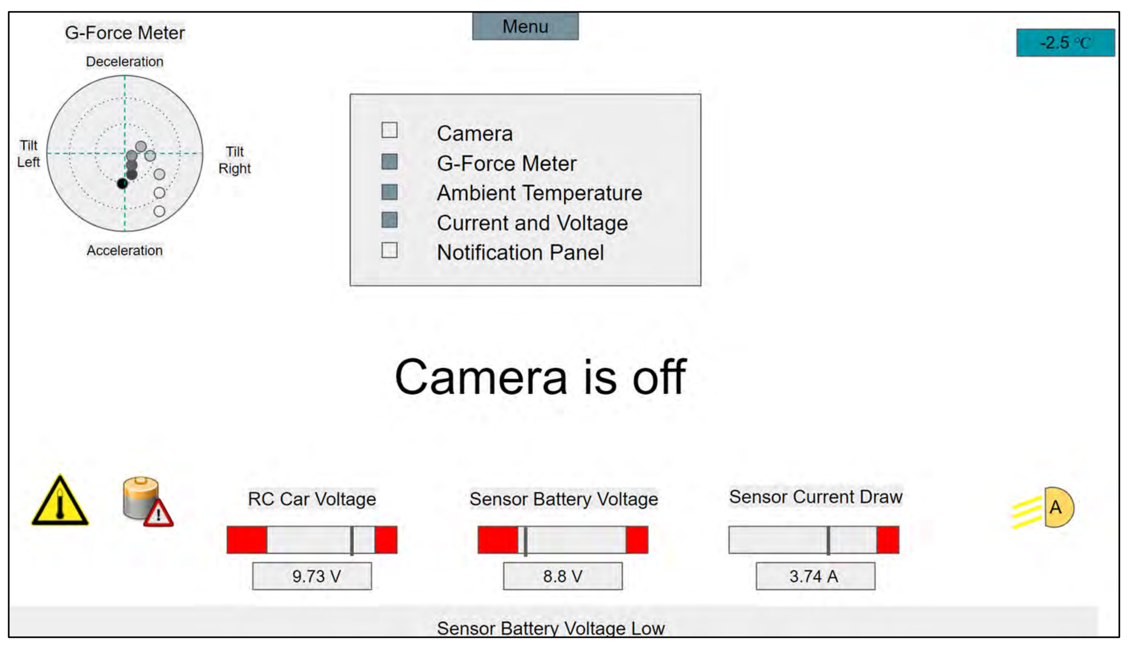

Fig. 3: GUI Prototype Demonstration

Remaining Technical Challenges

In order to achieve the team's anticipated best outcome by April 15th 2022, the team will need to accomplish a number of things, as follows. A functional GUI capable of receiving and displaying desired system data and streamed footage of the RC car's location is an utmost priority as it is the primary medium by which the team will be able to evaluate functionality. Additionally, the system requires some modifications utilizing 3D modelling. Sensors need to be mounted to the chassis of the RC car in order to ensure quality measurements are taken, especially in the case of the SEN0140 IMU as improper placement can lead to inaccurate data is sent from the gyroscope and accelerometer. These sensors will also be integrated into custom PCBs designed over the last several weeks in preparation for ordering early in the spring semester. These will need to be thoroughly tested before integration with the system to determine whether they are of the desired quality. Some of these PCBs will be able to take advantage of existing code and API, simplifying the computer engineering work that still needs to be done. If the team manages to integrate the hardware with existing software before April 15th, attention will then shift towards improving upon it or building new software. In the case of the AFBR Time of Flight sensor, the team will look to remove the Cortex ARM M0+ microcontroller and instead integrate the ToF PCB solely with the Raspberry Pi. Once all of this is done, the team will need to shift it's attention back to the System Design Document in order to ensure we met all of the requirements mentioned within. Given that this project has, and will continue to, evolve heavily as time progresses the document will likely require some significant changes.

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Contactless Charging

Contactless DC Battery Charging in Underwater Environments

GENERAL DYNAMICS
Electric Boat

Team Members: Caitlin Abel (ELE), Timothy Gibbons (ELE), and Arthur Rodriguez (ELE)

Technical Directors: Michael Brawner and Robert Scala

Project Motivation

This project will investigate and assess technology options for next generation contactless ("wireless") Direct Current (DC) Battery Charging in ocean environments. Next generation technology/systems are required to provide the platform with the capabilities to recharge external payloads, tethered and untethered. The ability to reliably charge/recharge externally hosted payloads without the need for physical mating interfaces will enable changing payloads over time without platform changes, increase platform flexibility and enable new missions. System development to provide a capability that can support a range of voltages and charging component distances in a range of sea water conditions including temperature, salinity and pressure (depth) is required.

Key Accomplishments

Research on Background Information - In order to start this project we needed to research a lot of background information such as AUV Background Research and Three Phase Power (**Fig. 1**)

Technologies of interest

EM Induction - Inductive charging is a type of wireless power transfer. It uses electromagnetic induction to provide electricity to devices. The equipment can be placed near a charging station or inductive pad without needing to be precisely aligned or make electrical contact with a dock or plug.

Resonant Inductive Coupling - An inductive power transfer system is comparable to that of a transformer. An alternating current in a transmitting coil generates a varying magnetic field that induces a voltage across the terminals of a receiving coil. Power transmission efficiency is higher when the transmitter coil and the receiver coil are close and aligned.

Microwave Power Transfer - Microwave wireless power transfer with a frequency range of 300 MHz to 300 GHz enables power transfer to long distances up to a few meters. The microwave wireless power transfer system consists of an energy-radiating antenna and a rectenna, which converts the microwave power into DC power.

Magnetic Couplers - A loosely coupled transformer for autonomous underwater vehicle applications is a split transformer in which the primary and secondary are physically separated, with the primary housed in a charging platform and the secondary housed on an AUV.

Linear Coaxial Winding Transformers - LCWTs, also known as sliding transformers, are electrically similar to
conventional transformers but differ in construction with their primary and secondary windings placed coaxially with each other. The main advantage of LCWTs is improved cooling and the ability to charge multiple underwater vehicles simultaneously.

Down-selection using Pugh Matrix - Our Pugh Matrix Down-selection was essential in determining, out of all our technologies, which one we were going to use for our prototype proposal.

Engineering and analysis work using Ansys Maxwell (**Fig. 2**)

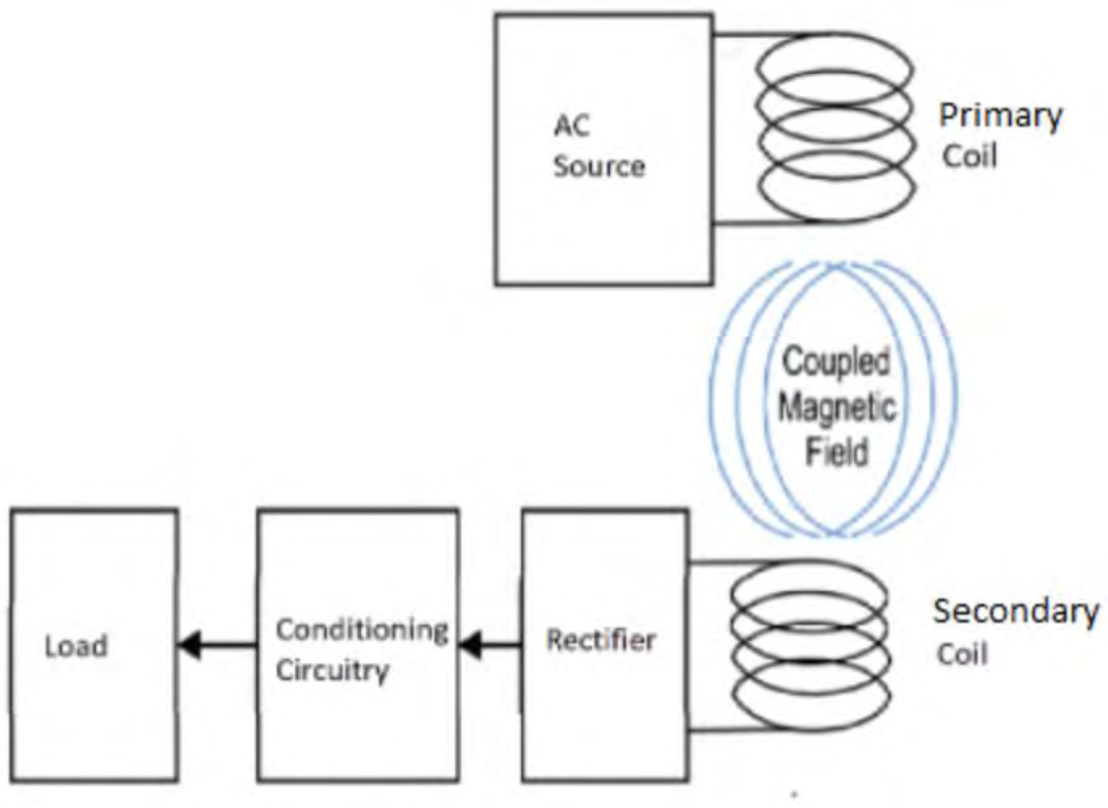

Fig. 3: Wireless Power Transfer System Block Diagram

Implications for Company & Economic Impact

As new unmanned vehicles and platform tethered sensor bodies are being developed and deployed, the ability to maintain DC power systems is becoming more critical. The ability to reliably charge externally hosted payloads without the need for mating interfaces will increase platform flexibility and enable new missions for our military. It will also allow General Dynamics Electric Boat to help guide its development and concept of operation. The development of a prototype wireless charge system is the first step to increasing General Dynamics Electric Boat's ability to reliably deploy AUV's in various missions.

Anticipated Best Outcome

Our goal is to develop a contactless DC Charging system concept model for use in ocean environments including applicable components' Technology Readiness Level (TRL) and potential risks for maturity of that technology. The Sponsor will provide the required documentation and guidance on TRL determination and mapping. Following the system concept model approval, the student(s) will develop a prototype development plan to support a proof-of-concept demonstration. To control the transfer of sensitive information, the Sponsor will utilize commercial system-based information and publicly available oceanographic conditions information.

Fig. 1: Autonomous Underwater Vehicle

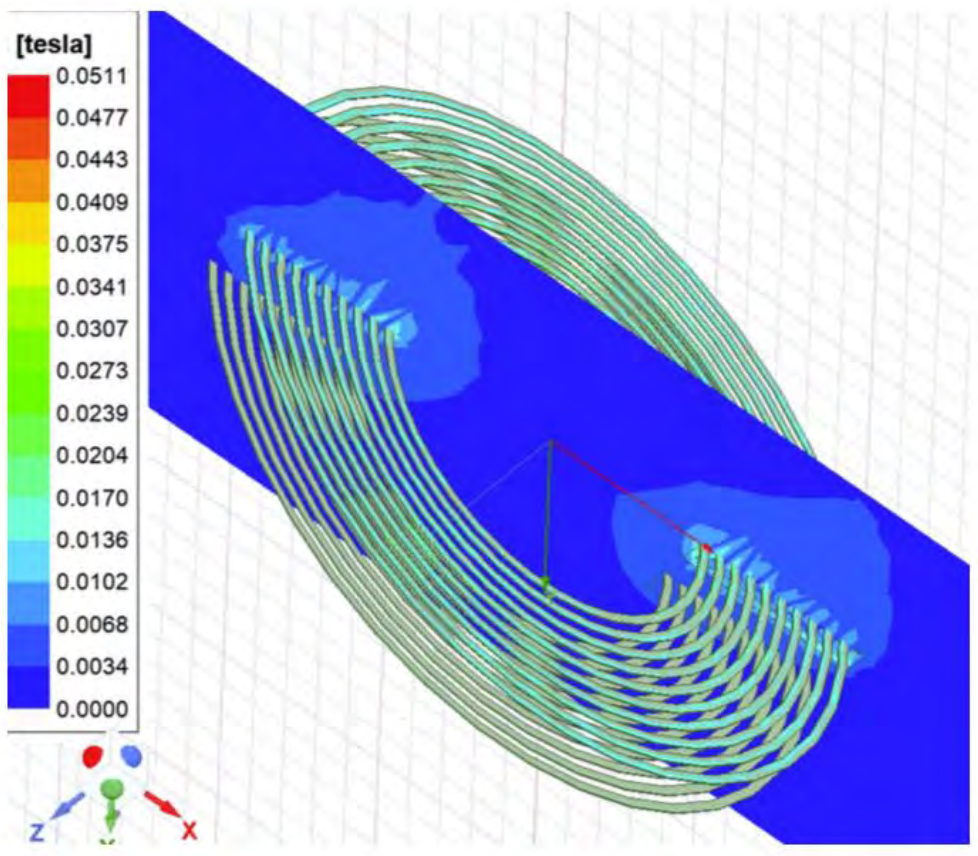

Fig. 2: Ansys Maxwell Simulation of EM Inductive Charging

Remaining Technical Challenges

Pugh Matrix down selection final version:
A final technology down selection will be performed using the data that was collected through the finite element analysis simulations. This final downselection will determine the technology that will be used for the project prototype and how it will be executed.

Data Collection:
Continue work within finite element analysis simulations on the chosen technologies of interest that will be used to simulate the prototype in order to visualize and collect data on how it will operate using a three phase naval ship power source. This data will allow an estimation of the power transfer efficiency, transmission distance, and the wireless power leakage of the project prototype within the ocean environment.

Prototype proposal:
A prototype proposal must be created which includes system components, insulation systems, coil designs, core materials, and technologies used. The prototype proposal will outline the materials required in order to build a prototype wireless power transfer system for demonstration. The prototype must fit within a design space no larger than 24 Inches long x 24 Inches tall x 12 Inches deep (Box) or 16 Inches in diameter and 12 Inches Deep (Disk).

Prototype Development and Testing:
Before building a physical prototype testing a virtual prototype in Ansys will take place. When testing, the prototype will need to withstand the various elements in a real-world environment such as saltwater. When developing a physical prototype for this project discussion of materials that it will be made of is a huge factor as well as the space constraint. The prototype will be developed according to the proposal laid out in phase one of the project. The required hardware will be procured and used to fabricate the prototype. Laboratory testing of the prototype will need to be done in order to ensure the prototype's performance in real world environments.

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TUESDAY, DECEMBER 21, 2021

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Smart Process

Smart Process Planning for Inspection

HEXAGON
MANUFACTURING INTELLIGENCE

Team Members: Juan Corona (CPE) James McHenry (CPE) Leah Golde (ISE) Pat Miller (ISE)

Technical Director: Jonathan O'Hare | Consulting Technical Director: Najib Ishaq

Project Motivation

CMM - Coordinate Measuring Machines: Manufacturing managers that deal with creating weekly work assignments, must be able to schedule work operators and machines to keep production flowing as efficiently as possible. These managers are always wanting to minimize the backlog of work, that is created by constant job-switching and changeover time in setup/ breakdown, to name a few. Usually, this problem is avoided by assigning specific tools and machines to specific operators. However, Hexagon CMM's are quite an investment to manufacturers, due to their number of CMMs owned in said company.

Being a limited asset, efficiency is key; more production, more income. Since the manager's schedule is only as good as the information known, there is huge potential to improve efficiency. It is believed that by monitoring the process of that system and not just the CMM asset itself, we are able to build similar models to improve efficiency for the entire factory.

Anticipated Best Outcome

The Anticipated Best Outcome is:

- A program that can inform customer when the Stylus Tip needs to be calibrated/ qualified.
- A Program that can inform customer how to improve their Overall Equipment Effectiveness.
- A suggestion on how customer can minimize downtime based on the entire system process

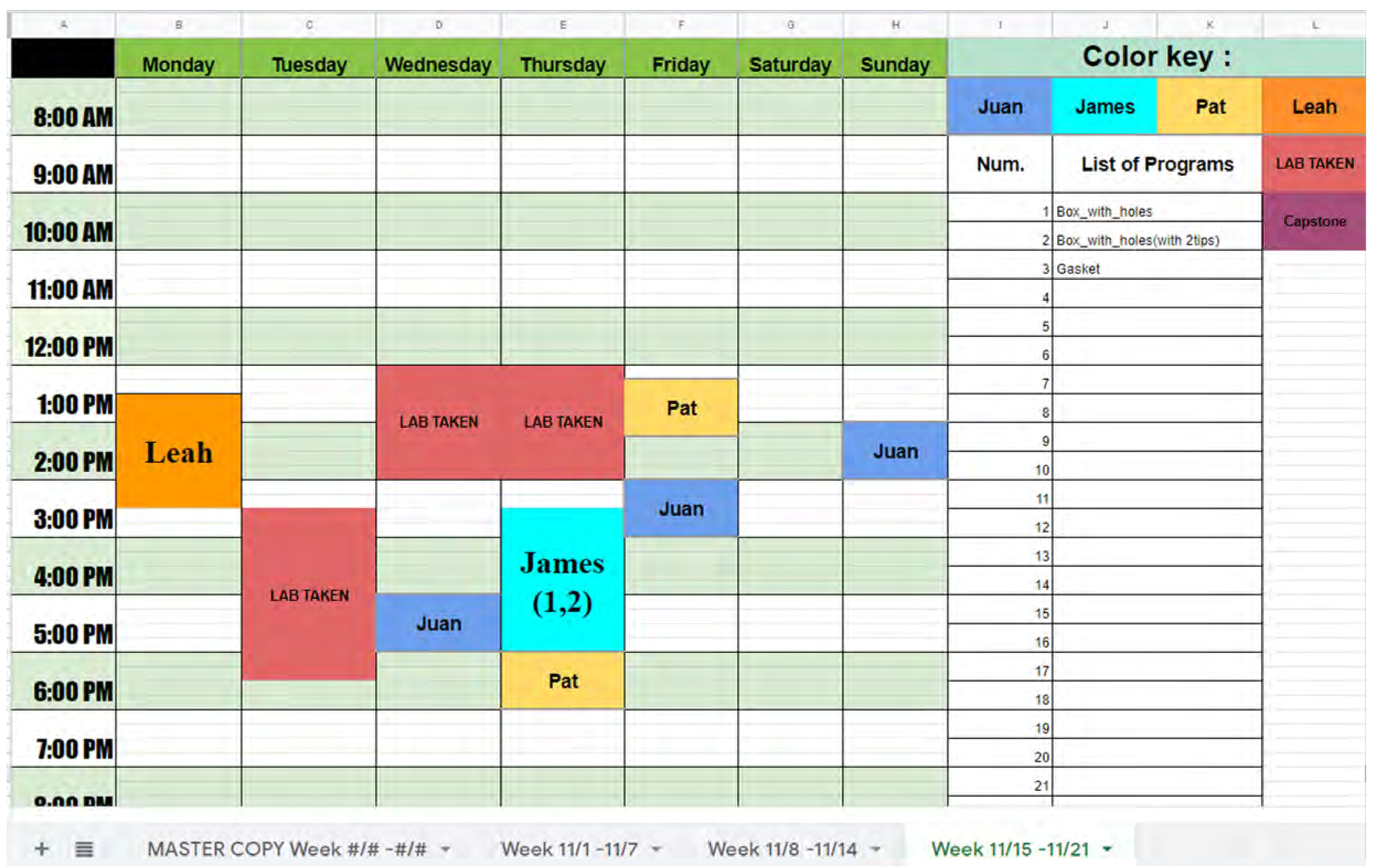
Key Accomplishments

Declaibration: Running multiple routines and checking the deviation of the probe calibration over time by running a qualification on the probes after a few runs of routines. With this information we then relate it to the other data pulled from the RoutineDataExplorer which gets data from the CMM's Controller. with this information we will be able to determine when a probe will need to be calibrated without having to do a qualification check.

Job Schedule: We are using Google Sheets to create time-blocks for representing jobs assigned to each team member image below Once our shared work-schedule sheet is transferred to SFx, at the end of the week we can view the OEE score. We will create our own OEE "equation" to compare these values. We believe there is additional information/ parameters to be included such as calculating minimum/ maximum downtime between jobs, and the measuring cycle time between multiple parts in said jobs.

Data Aggregation: There are a few variables we are going to assume that affect the total timing in operating a CMM. These include, but are not limited to, fixtures used for job setup, setting up fixtures/ their location, finding and loading a routine for a specific job, different operator variations, the frequency of job changes, and environmental changes. Inspecting the entire process of a job work-week schedule and the CMM(s) requires handling multiple datasets. The computer engineers in our team will be responsible for creating this "master database". We takin data from the controller on every routine and combine it with data from Sfx and Pules to make One master database in one file type which we currently have as a CSV.

	Date	Time	datetime	EachActionTimeStamps	Action
0	2021/10/29	15:59:11	2021-10-29 15:59:11	NaT	Large_part.PRG
1	2021/10/29	15:59:28	2021-10-29 15:59:28	0 days 00:00:17	manual
2	2021/10/29	15:59:28	2021-10-29 15:59:28	0 days 00:00:17	5
3	2021/10/29	15:59:29	2021-10-29 15:59:29	0 days 00:00:18	5
4	2021/10/29	15:59:29	2021-10-29 15:59:29	0 days 00:00:18	T1A0B0
...	...	...	...	...	...
124	2021/12/07	17:56:05	2021-12-07 17:56:05	39 days 01:56:54	CIR6
125	2021/12/07	17:56:14	2021-12-07 17:56:14	39 days 01:57:03	CIR6
126	2021/12/07	17:56:14	2021-12-07 17:56:14	39 days 01:57:03	CIR7
127	2021/12/07	17:56:22	2021-12-07 17:56:22	39 days 01:57:11	CIR7
128	2021/12/07	17:56:23	2021-12-07 17:56:23	39 days 01:57:12	Box_with_holes-1.PRG



Visual representation of job schedule

Coordinate Measuring Machine (CMM)

Stylus Tip

Implications for Company & Economic Impact

There is an enormous opportunity for awareness using implementations of intelligent software systems. Providing such a software solution that will achieve the same overall gains compared to adding or replacing an existing asset.

The smart manufacturing findings will be able to implement high value-added features in the next release of SFx Smart Factory software. Obtaining an overall effectiveness analysis will also greatly increase the volume of sales of CMMs within our existing customer base.

It is believed that CMMs and the inspection process, may represent a particularly challenging problem in most operations due to their complexity. Which means, the smart manufacturing process can adopt to solve for similar problems throughout other assets as well.

Remaining Technical Challenges

Decalibration: We are going to need several routines and experiment with similar but slightly different ways. As in, continuously run the same part routine to notice changes in results. There should be an obvious decline as the same routine is run again and again. This is because the Tip will eventually need to be re-calibrated to ensure correct measurements.

Job Schedule Testing: We've discussed as a team running a routine for the first time took the longest. We even ran across a job overlap, due to a job not being completed in the provided time. For this, there is great data to be collected from inspecting the job schedule to improve the company's OEE and minimize their downtime.

Machine Learning Model: One machine learning algorithm we will be implementing, in our program, is DecisionTrees. An algorithm that considers all possible outcomes, following a "root-tree" trace, allows us to comprehend the consequence on each parameter. Additionally, identifying decision "node's" that require further analysis.

Further Data Collection: This project will focus on the collection of data for the inspection process using a CMM and the merging and analysis of that data for process optimization. Data collection will require running a special data collector script, RoutineDataExplorer.

We are going to need more simple measuring programs using several test parts will be required along with holding fixtures and designated probe styli. These simple programs will be written in PC-DMIS' native language for the CMM and will give the participating students better insight into the operation of the equipment and typical process observed by manufacturers.

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UATR Tool

User Acceptance Test Report Tool

Team Members: Michael L McCue (CPE), Brent Moynahan (CPE)

Technical Directors: Daniel Nugent, Patrick Moran, Patrick Lieffering | Consulting Technical Director: Nicholas Rommel (ELECOMP '17)

Project Motivation

The iXblue INS is based on the FOG technology which calculates rotation by measuring phase shifts between counter propagating light waves, known as the Sagnac Effect. The INS includes one FOG per axis (X, Y, Z) as well as three accelerometers on these axes to create the inertial measurement unit of the INS. The INS achieves high accuracy attitude and position data.

The overall project motivation is to create a test program for these INS units that can be used to accurately evaluate whether units are within working parameters. This is necessary between missions, before the installation of an INS to a new vehicle or after potential damage occurs. The current test is not efficient and requires much human interaction to complete. Each INS is different and requires slightly different procedures to test, so the focus of this project is to make a generalized tool that can be used to test any iXblue INS product for general consumer use.

Key Accomplishments

Text Parser For Repeater Data: A text parser was created to read in data exported from the INS system, and record relevant data that needs to be tested. The text parser searches the log file for important headers, and splits the data by each comma found in the line, and prepares the numbers as floats to be graphed on the GUI. **(Fig. 2)**

UATR Procedure Block Diagram: The UATR block diagram was a useful accomplishment to establish the team's scope and tasks for the year. It includes every module needed for the program and outlines the necessary steps taken by the INS and user. The figure depicted shows off the main functions to be implemented within the software **(FIg. 1)**

Graphical User Interface: A GUI was created to display all the input fields and graphical outputs required to test the INS systems. The GUI is used as the primary interface for running the scripts like the text parser to easily display the specifications of the INS device to make sure it is in working order. The GUI has four graphs displaying the position as well as the Roll, Pitch and heading of the INS plotted against time **(Fig. 3)**. It also includes buttons that when pressed allow these graphs to be visible on the main GUI window.

Sending INS Commands: Originally commands must be sent through an external program called Hercules. However, through a Python script, the INS acts as a server and listens for incoming ASCII data. Each command must be sent in the correct format detailed by the INS Advanced Configuration manual, and at the correct time relative to the system's needs. The ZUPT on and off command being sent through the INS test site can be sent through the python code. Progress was made sending proper commands to the INS and adjusting system functionality.

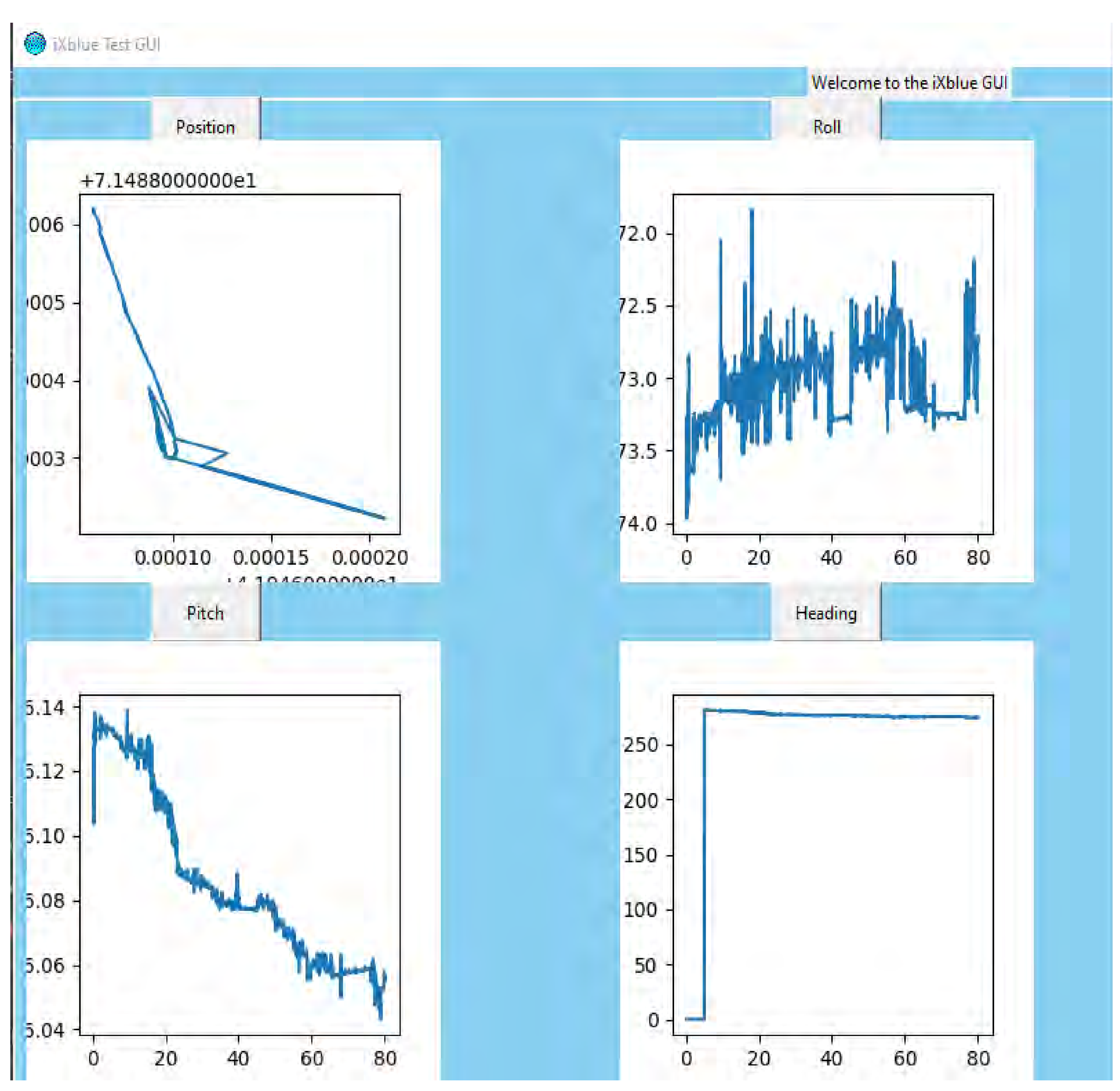

Fig.3 iXblue GUI

Implications for Company & Economic Impact

The system described has potential to improve customer autonomy as well as demonstrate the iXblue FOG technology's longevity to customers. Customer autonomy is very important to iXblue as the company grows, the ability for customers to test their INS units saves shipping and company time. The UATR tool will alleviate downtime from shipping units to iXblue facilities by aiding the customers in testing the units independently. This saves time and money for both the customer and iXblue by shortening overall testing time, and preventing many errors that may present itself due to human error. Broader implications of a well-designed UATR tool include increased customer confidence in the iXblue brand and iXblue products.

iXblue

Anticipated Best Outcome

The anticipated best outcome is the delivery of a software prototype UATR tool commercially ready for consumer use. Successful software will be able to correctly differentiate between units working properly and not working properly. The following deliverables will be developed through the course of the project including a user guide for the tool so that customers can fully understand and utilize this new testing tool. It also includes Software design document, software documentation detailing the operation of the prototype software and a final report covering all results, test data, project progress, and suggested next steps.

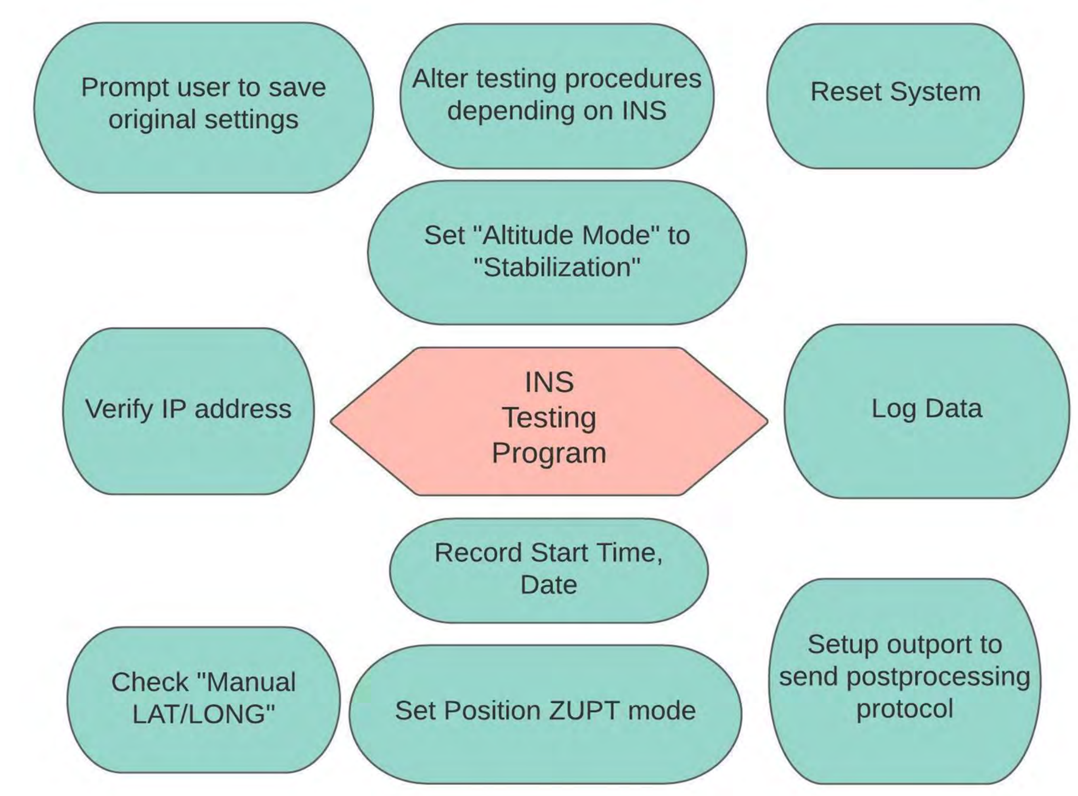

Fig.1 Block Diagram of Defined tasks

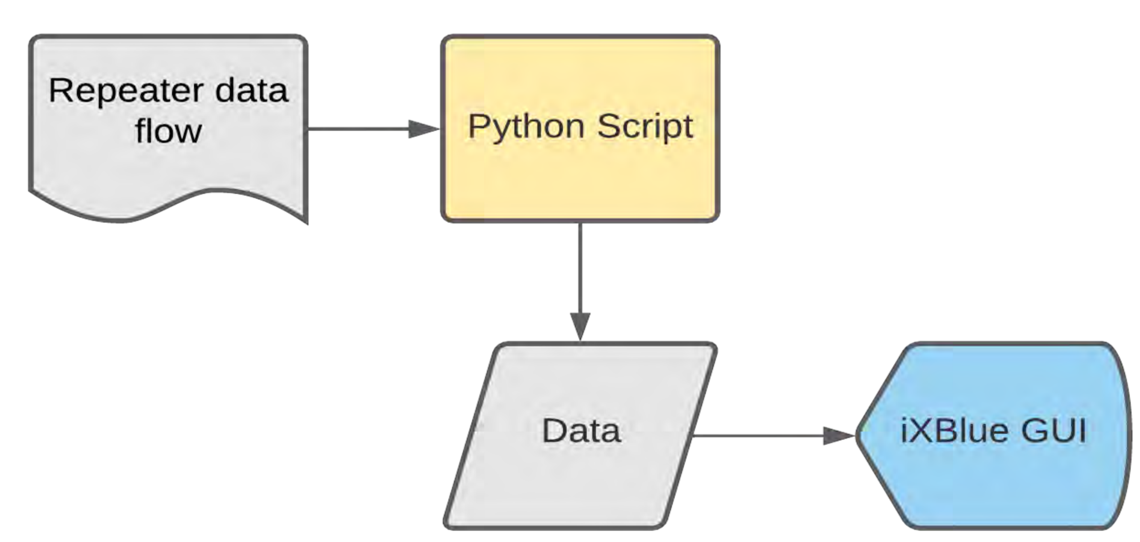

Fig.2 Parser Diagram

Fig.4 A few of the wide range of iXblue INS to be tested

Remaining Technical Challenges

Additional Unit Types: iXblue Defense Systems offers a wide array of FOG inertial navigation systems. The software must be applicable to all INS devices, some which take different commands and testing lengths. The program must include an area for users to pick their INS device and have the program run the correct tests accordingly. This goes with the GUI, due to functionalities that must be represented for the users to view rather than just in the python script. The text parser and GUI only functions with a single type of INS, however for this UATR tool, all INS devices must be tested for commercial use.

Email and Text functionality: Currently, the user tests provide no functionality for updating the user along the way. Whether the test is successful or fails halfway through, the program will notify the user for necessary actions to take. Within the Python code the new UATR tool will constantly check whether the INS is correctly functioning to save additional time. This notification system allows the user to know where the testing process is at and reduces wasted time if the test fails and the user is unaware.

Professional Graphical User Interface: For the best anticipated outcome, the GUI must be professionally created for ease of interpretation. This includes the addition of input fields to select the correct INS unit, as well as inputting the IP address to connect to the INS when running the testing procedure. The new GUI must have multiple text fields for the user to input all necessary information to connect to the INS that needs to be tested. This includes displaying the current time on screen and grabbing the time from the user's computer to be included in the test report. Meaning the GUI must be upgraded to be commercially used with iXblue customers.

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Fiber Optic Annunciator

PEC Phoenix Electric Corp.

Team Members: Daniel Reyes (CPE), Vithavath Vongsay (CPE), Thomas Kresevic (ELE), Nataly Karnaukh (ELE)

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

Project Motivation

Phoenix Electric Corporation monitors their circuits using third-party annunciators. By developing a custom annunciator, the company would have more control over the design of the device. This would allow the annunciator to tightly integrate with company equipment. The goal for this project is to build from a 12 to 48-channel annunciator. The annunciator would have one main board containing the microcontroller. This board would then connect to four display boards. Each board contains 12 channels of NO/NC circuits with their LED's. The annunciator would be reprogrammable. This feature allows for adding different alarms into the annunciator as well changing time delays and any circuit from normally open to normally closed. The annunciator would include Modbus and Fiber Optic communication to access data stored within the device remotely. Upon completion of the project, this would diversify the company's product portfolio, save time and money, and allow the company to be more competitive in the industry.

Key Accomplishments

Implementing alarm sequences A and M: Following the ISA standard for each sequence's specifications both the automatic and manual resets have been programmed successfully.

Channel time delays: Using the RTC and the internal delay function of the Arduino, a 4091 ms time delay has been added to each channel. This allows for a tolerance before a detected abnormal condition is declared. This helps avoid reporting minor glitches in the signal as errors.

Reconfigurable settings: The ability to rewrite a channel's time delay, horn usage, and configuration has been added. This allows for changes to be made without needing to re-download the program into the Arduino. This also extends to sequence selection, allowing the user to access any of the alarm sequences from the same program. It was done using the serial port of the Arduino but will eventually be controlled by a GUI.

Understanding the circuit schematics: The first task was to understand the simplified annunciator schematic with the display schematic. The annunciator schematic consisted of an Arduino and breakout boards for the RTC, FRAM, and I/O expanders. The display schematic contained all the LEDs and the buzzer.

Replacing breakout boards with their necessary components: After reading all the data sheets and understanding each schematic, the next task was to integrate necessary components from the breakout boards together to build the basic annunciator. During this time, the goal was to integrate the display and main board onto one single PCB board.

Board redesign: After deciding on a vertical layout, the annunciator board with the display board were redesigned **(Fig. 3 and Fig. 4)**. The annunciator board contains the memory, RTC, buzzer and Modbus communication. The display board contains the I/O expanders, LEDs, and the NO/NC circuits. This design allows for cascading four display boards together to monitor 48 channels of NO/NC signals.

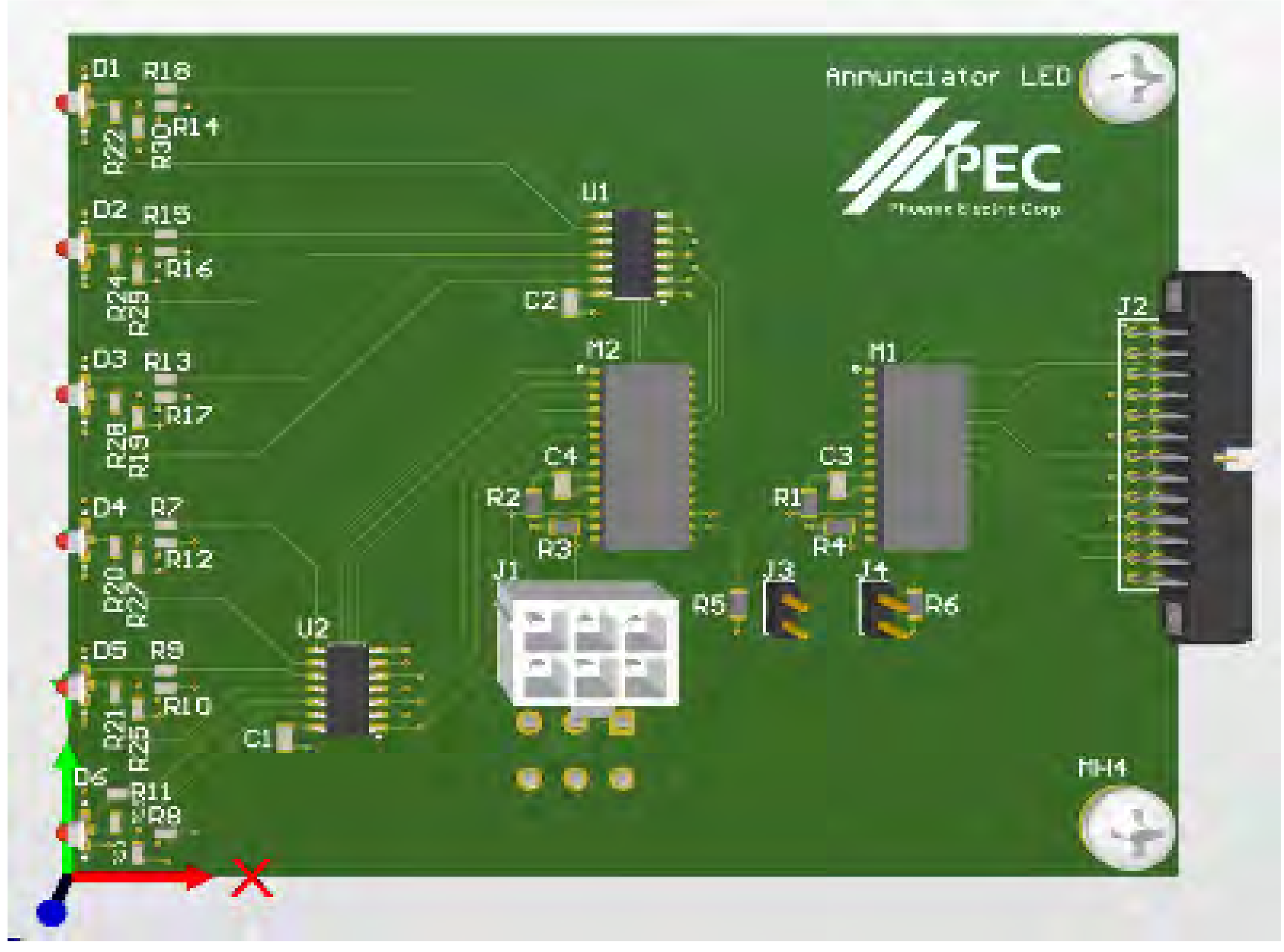

Fig.4: Display Board

Anticipated Best Outcome

The ABO for this project is to design an annunciator that monitors up to 48 NO/NC channels. The annunciator uses LED's and a horn to draw attention to normal and abnormal operation of the monitored signals. The annunciator will cycle through four programmable alarm sequences, namely: A, M, F1A, and F3A. The signals on the annunciator will also be reprogrammable, such that a NO channel may be switched to a NC and vice versa. The main method of reprogramming the annunciator will be done through a GUI. The data stored within the annunciator will be accessible from remote locations.

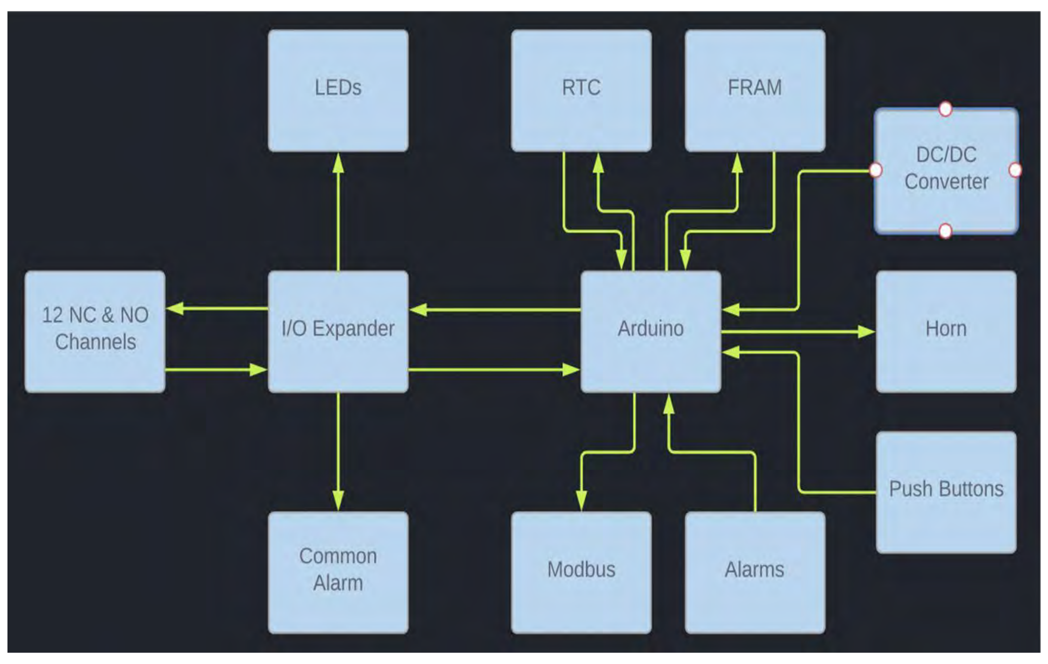

Fig.1: Annunciator Block Diagram

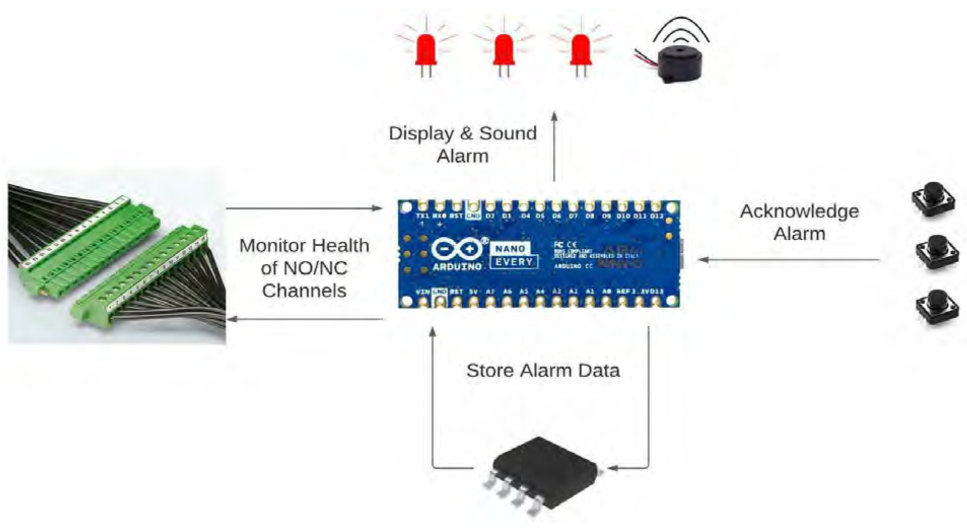

Fig. 2: Block Diagram of Alarm Implementation

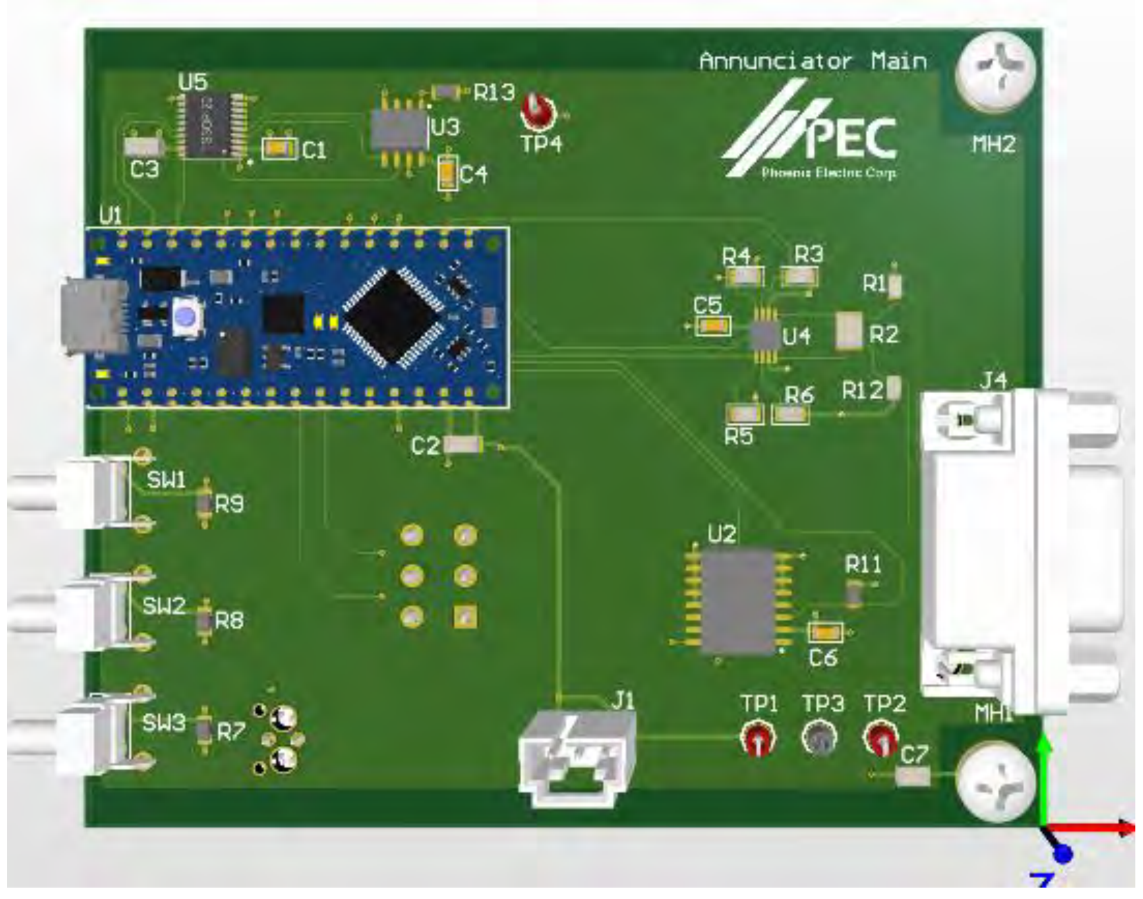

Fig.3: Annunciator Main Board

Remaining Technical Challenges

Alarm sequences F1A and F3A: Currently, the F1A and the F3A are the last two sequences to be finished. Once these two are completed, most of the embedded software tasks for a 12-channel system will be completed.

Channel Expansion: The original proposal described a 12-channel annunciator **(Fig.1).** However, the current aim is to supervise up to 48 channels. To implement this, the program will need to be modified to monitor and store data for this new design. This will require updating variables, logic, and providing the ability to detect whether the setup is 12, 24, 36, or 48 channels. The current aim is to ensure that a basic 12-channel system and GUI is working properly before expanding the program.

GUI: The graphic user interface is a central feature for the annunciator which will allow the user to configure system parameters more elegantly. This will be implemented using Python and is the planned second phase of annunciator development for the CPE students.

Ordering the new boards: Ordering new boards is the next goal. This would allow for software to be written for the new design rather than for the current COTS hardware setup.

Modbus communication: In our design, Modbus communication is used to access data from within the plant. Two breakout boards containing serial to RS485 converters were used as an example for our design. Once the new boards are built the new RS-485 transceivers will be used for testing.

Fiber Optic Communication: Another means of communication which the annunciator would include is Fiber Optic. This would be used alongside with the Modbus for remotely accessing data. However, this type of communication would provide long distance communication to the annunciator.

Implications for Company & Economic Impact

Phoenix Electric Corporation strives to be an innovative leader in the power industry. With such standards they tailor solutions to their customer's needs. By designing a custom-built annunciator, the company's dependence on third party products would decrease. The company would also decrease their expenses of buying third party products while making profit on their own design. The company would also be able to customize their annunciator to seamlessly integrate with their equipment and tailor their product to fit the customer's requirements. Producing such an annunciator would also increase power grid safety and improve the reliability of numerous electrical applications.

Hand Gesture Classification

Data Labeling of Gesture Based Biosignals

Team Members: Colin Davis (CPE), Jamie Gagnon (CPE)

PISON

Technical Directors: Matthew Fleury, Xiaofeng Tan | Consulting Technical Director: Brenden Smerbeck (ELECOMP '17)

Project Motivation

When collecting gesture-related biosignals for researching, developing, and training gesture classification models, one of the most important preprocessing steps is identifying which regions of the signal correspond to the intentional performance of the gesture (known as "onset detection" or "activity detection"). Purely signal-based onset detection methods exist but are often susceptible to noise such as electromagnetic interference (EMI), and they generally perform poorly with low signal-to-noise ratio (SNR) signals. Further, these methods provide no information about which gesture was performed. Thus, we are leveraging computer vision (CV) methods to perform activity detection of biosignals based on recorded videos of the user's hand while performing the gesture. Onset detection is used to ensure accurate labeling of the samples used to train these models: in particular, it is important to capture as much of the active signal as possible, and even more important to avoid labeling "inactive" or "resting" samples, surrounding the true active region, as "active". **(Fig 1)**

Key Accomplishments

Key Point generation of previous collected data: In the data collection, the users were given the Pison Device to wear during the collection process which was recording their hand gestures. The task for the keypoint generation was to process every video file collected for the data set, and pass it through an already existing algorithm. This program essentially looked through each video frame by frame looking for certain key points, which were previously defined as cases where gestures were done by the user.

CV Labeling and verification on all data: The DTW algorithm was used to synchronize the EMG data to accurately train and test the machine learning model. Using different confidence thresholds resulted in interesting results. (**Fig. 2**) Finding a compromise between highly accurate data samples and an abundance of data samples was required to train the machine learning model effectively.

LDA Research and Implementation: Doing the LDA research, what was come across was how this predictive model is implemented, was that it divides the data into two classes and draws a line in between the classes, this predictive model can be done multiple times, however the accuracy was bad this time with a 55 percent prediction accuracy, which is not good.

Random Forest Research and Implementation:
Doing the Random Forest research, it was found that the random forest was a decision tree structure that conducted a popularity vote, thus the predictive model took more time, but was very deceiving advertising 99 percent accuracy, but was later found to have around 45-51 percent **(Fig 4)**

Map video Data Offsets and Merge Data: Running through the ALGO-463 script the data was preprocessed and then ran so as to synchronize the time stamps of the device data and the video data so as to correctly map out the video-based offsets. This was useful in testing checking the predictive power considering the data was all synchronized. **(Fig 3)**

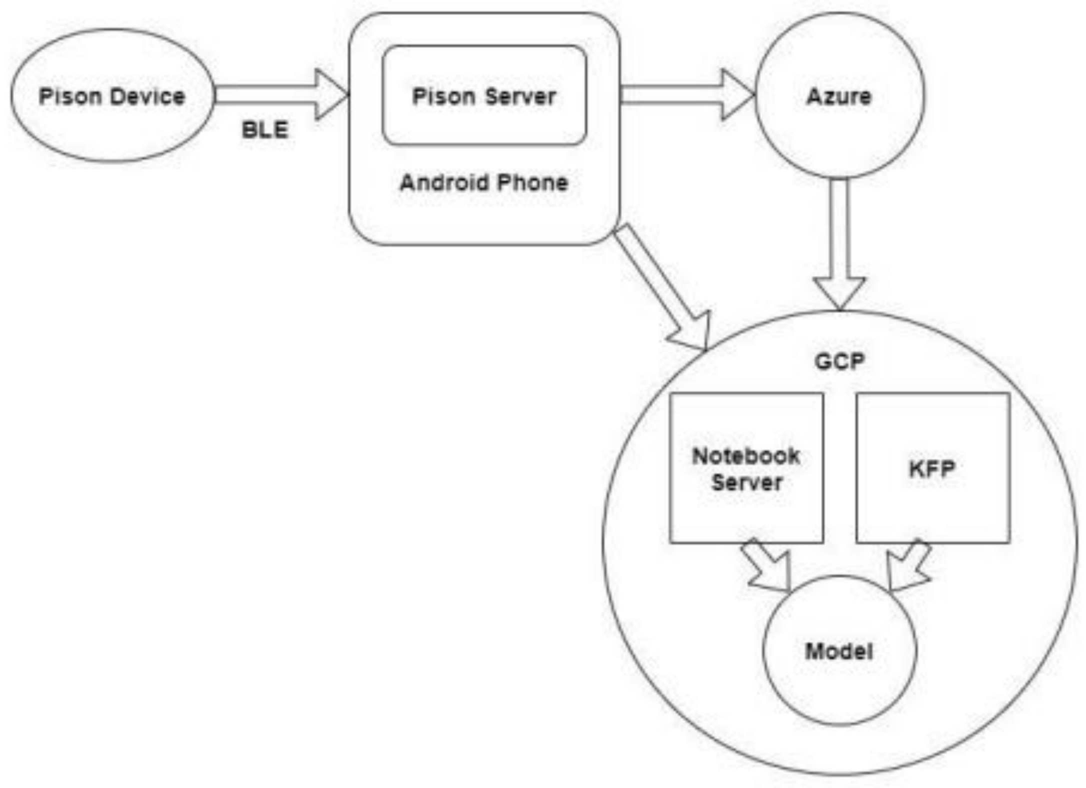

Fig 1: Development Block Diagram

Anticipated Best Outcome

The anticipated best outcome of this project is the development of a fully automated labeling algorithm by April 2022 that can accurately provide classifications of gestures presented by a user through some sort of recording device. Note that this project is funded by a grant from the National Science Foundation (NSF). We are aiming to achieve robust accuracy (99+% overall classification accuracy across all users in the test set), but in terms of the contractual deliverable, this is not strictly necessary.

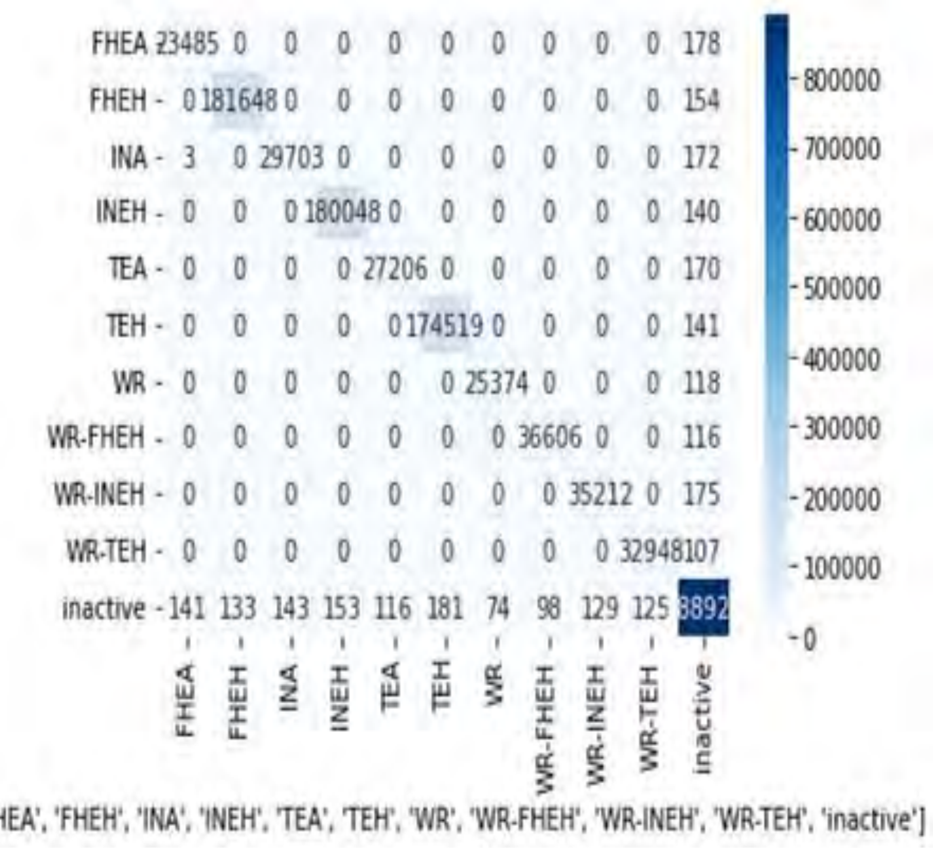

Fig 4: Confusion Matrix of Random Forest

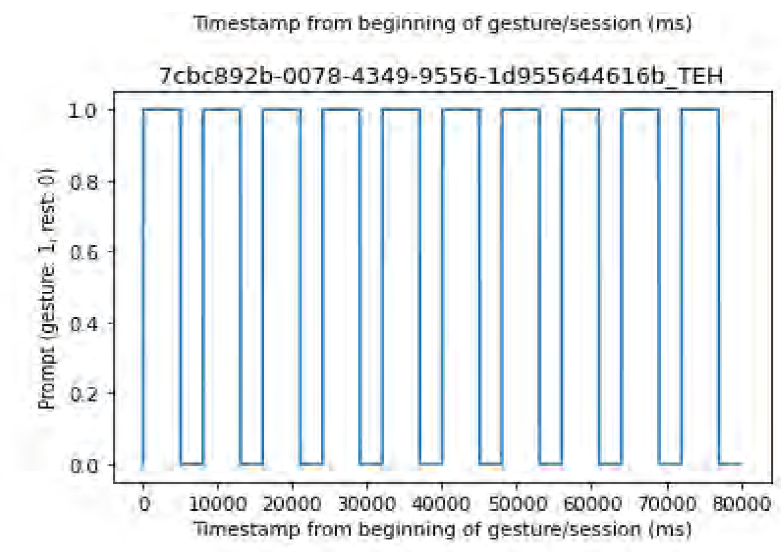

FIg 3: Testing out Merged Timestamps

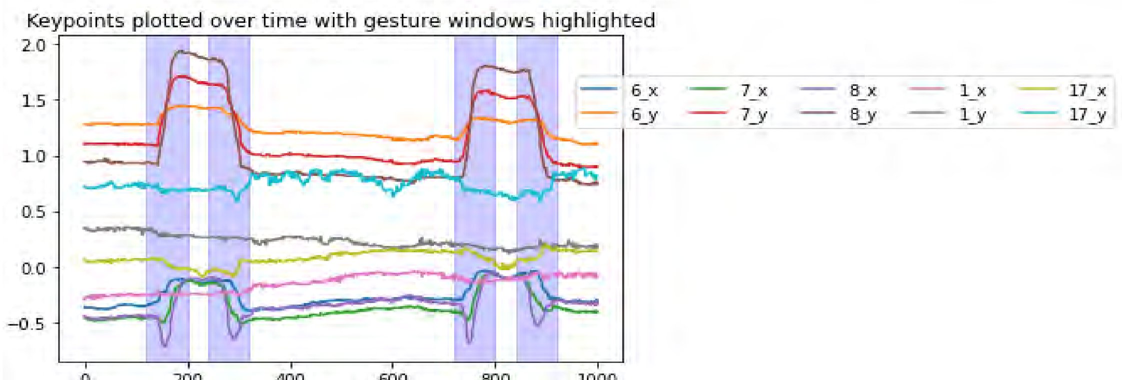

Fig 2: DTW algorithm test for the INA Semi-pronated gesture

Remaining Technical Challenges

Collective Database: One of the remaining tasks before moving onto the automated algorithm is to generate a data frame which includes each user that has generated data samples, their individual dtw avg and std. Displayed, as well as their KWL onsets and signal to noise ratios. All this combined will allow a comparison between the data samples and to find issues that may need tweaking to more accurately display the data, such as the training confidence threshold. This confidence threshold is a value where a certain amount of data from the entire set of samples is taken as the training set to train the machine learning system. Determining the perfect threshold is a key to a good training set and will lead to more accurate results and better overall performance of the machine learning model.

Fully Automated Pipeline: The process of which we need to follow in order to complete this algorithm is still kind of vague, but we will generally have most of the remaining tasks given to us related to the development of this fully automated data labeling algorithm. In order to reach our goal of creating a fully automated data labeling algorithm, that adjusts seamlessly to each user, instead of virtually having a new session every single time something is adjusted as per what the semi-automated algorithm does. We are still in the research phase of the fully automated data labeling algorithm, but the process will most likely have us understand separate parts of the semi-automated as a reference and aid in the design of the process of the fully automated version. It might need to be re-evaluated how this data-labeling algorithm is reading data. We might need to research ways for the accuracy to be increased based on what was seen with the semi-automated.

Implications for Company & Economic Impact

The best outcome of this project would provide Pison with a first fully automated labeling algorithm to be deployed to future data collection apps. The larger amounts of data streaming in from such low-barrier-to-collection apps would magnify the amount of research, development, and product-market exploration that Pison could perform, thus enabling the company to not only make its technology more robust for existing use cases, but also rapidly expand into new use cases as product-market-fits are identified. This would enable Pison to generate more self-sufficient streams of revenue, and bolster existing ones, allowing the continued growth of the company.

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Virtual Reality Bridge Trainer

Standalone Ship Bridge Trainer using Virtual Reality

Team Members: John Bevilacqua (CPE), George Bowen (CPE)

Technical Directors: Thomas Santos, Michael VonGonten, Akintoye Onikoyi

Project Motivation

For many of Rite Solutions' customers (commercial and DoD/Navy), a well-trained workforce is essential. Accidents at sea are unfortunately all too common, and the lack of adequate training has been identified as a key contributor on many occasions. Finding a way to improve the overall efficacy of training for the various scenarios that can play out while at sea or onshore is difficult, as there is a great lack of availability of training facilities and resources for individuals that require such experience. This project addresses the challenge by developing a standalone training system which utilizes new technologies such as virtual reality and gaming engines. The goal is to develop a ship bridge trainer to improve the navigation skills of junior officers and navigation technicians by providing a realistic virtual training environment. Being able to operate this training system with just a laptop and VR headset results in a low cost, portable, and individualized training solution.

Key Accomplishments

Set Up Development Tools: Researched, selected, ordered, and received an appropriate laptop that met established hardware requirements from project proposal. Learned and set up key development tools--Unity and Blender--and set them up on the physical environment **(Fig. 1)**.

Virtual Reality Functionality: Performed research on Virtual Reality implementation in Unity. Selected VR framework (OpenXR), installed, and implemented it in Unity project. OpenXR provides fundamental VR controls for several VR headset brands including HTC Vive, Oculus, and Valve Index. Additional XR Interaction Toolkit package provides a framework for 3D environment interactables and UI interactivity through Unity's input events system.

Basic Ship Handling Physics: Ship handling physics simulated using a C# based script and the Unity physics engine. Interfaces with evaluator GUI to receive user inputs for desired thrust, course, and rudder angle. Operator VR environment moves seamlessly with ship movement. Uses a combination of variable inputs from evaluator and constants based on specific ship specifications to simulate ship handling physics.

Secondary Evaluator View: Separated laptop monitor and VR headset views in software build for operator and evaluator. Evaluator view includes menus for scenario selection on startup and minimap and supporting GUI for scenario customization and execution. Evaluator GUI and 3D game environment run through the same application **(Fig 2)**.

Evaluator GUI: GUI for secondary evaluator includes ability to customize, create, and plot the course of secondary contacts for the operator to interact with, and ability to set ship movement orders received from operator.

Secondary Contacts: Secondary contacts can be created through evaluator GUI during scenario setup or after scenario start. Contacts can be created in larger groups such as merchant transit lanes or fishing groups or as singular vessels. Evaluator can select spawn location based on coordinates or using the cursor as well as set and edit a course and speed for the contact to follow through the contact GUI.

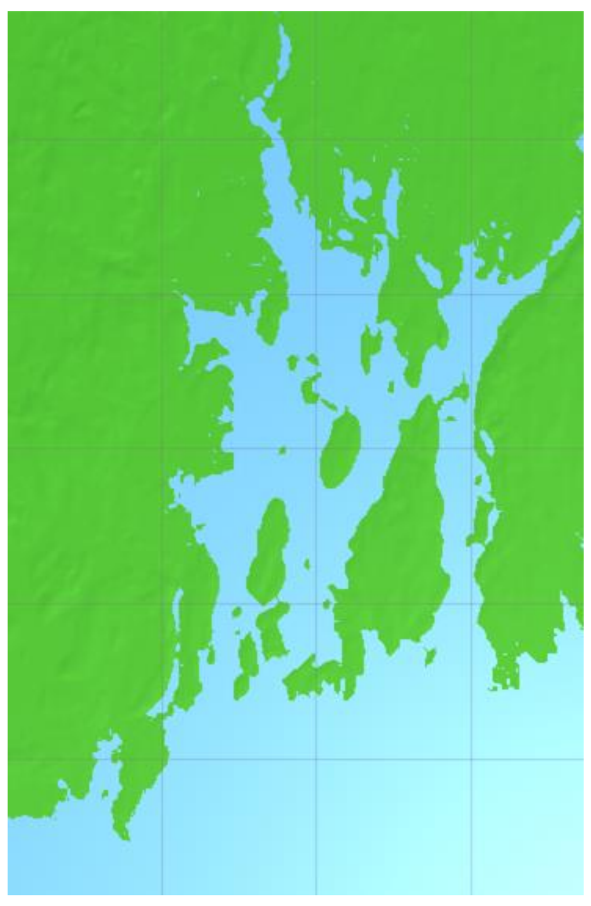

Fig. 3: Rhode Island / Narragansett Bay 3D Model in Unity

Implications for Company & Economic Impact

Rite Solutions is continuing to expand their training system capabilities for their DoD/Navy customers. There is a growing demand for standalone trainers for use at sea and onshore to address immediate Navy needs to improve skill sets in numerous areas. The virtual reality trainer addresses a need identified by the Rite Solutions staff who were recently active Navy service members. Rite Solutions views this capstone project as an opportunity to expand their training capabilities into a new and growing market as well as demonstrate the use of new and emerging technologies such as gaming engines and VR to provide training in new ways for a new generation of students.

Anticipated Best Outcome

The best outcome anticipated to be delivered by April 15th of next year is a realistic and immersive Virtual Reality training program with the ability to effectively train maritime operators how to handle and navigate their ship through Rhode Island's Narragansett Bay. The primary objectives to be met include realistic ship-handling physics and implementation of secondary contacts for the operator to interact with, in addition to the accurate geography and navigation aids. This application will be able to run on a laptop, and it will be modular to enable accommodation of other hardware and software, which would allow for easy upgrades, such as support for multiple training scenarios.

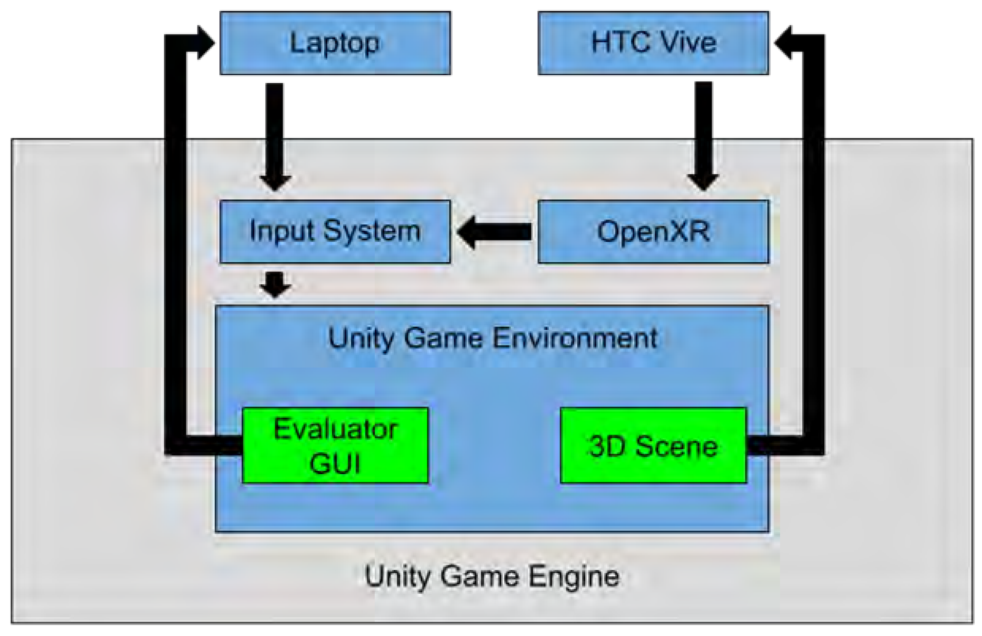

Fig. 1: Functional Block Diagram

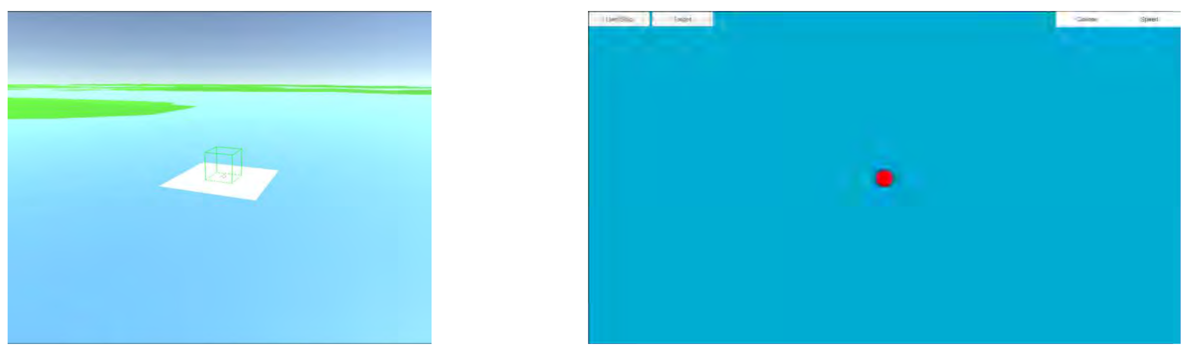

Fig. 2: Unity Project in Editor application (Left: Scene View w/ placeholder boat & water, Right: Evaluator GUI with real time map)

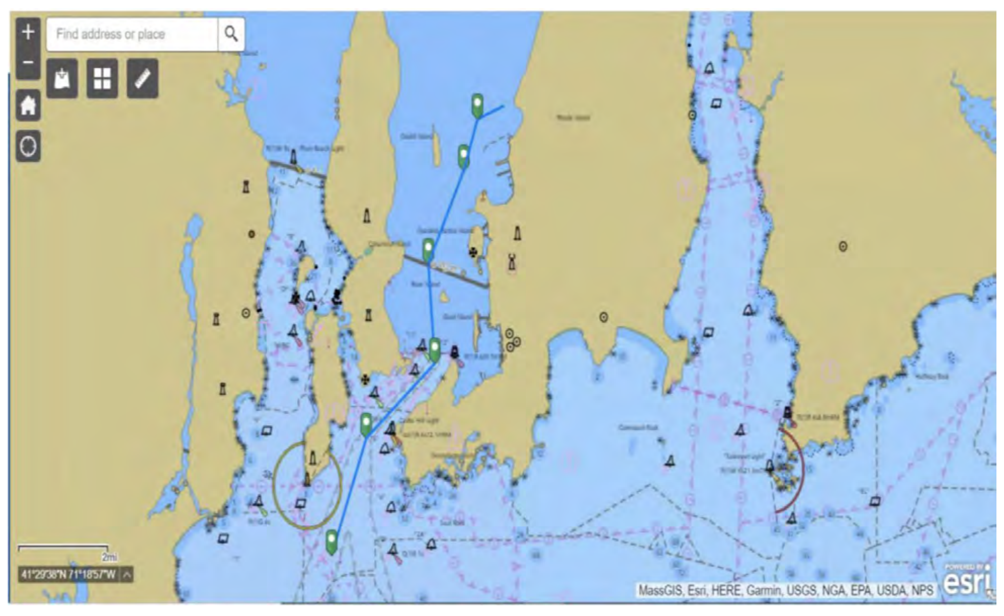

Fig. 4: Example Newport Approach

Remaining Technical Challenges

Audio and Visuals: Audio requirements include interactive sounds from the environment, operator ship, and secondary contacts, such as motor, ship whistle, water, and weather effects. Visual assets, such as 3D models for land and port features, operator vessel, and secondary contacts, must also be implemented into the project. Audio and visual assets, such as the Narragansett Bay geography model **(Fig. 3)** will be created or sourced from open sources and implemented into the Unity project.

Accurate Geographical Simulation: Accurate 3D simulation of the Narragansett Bay area **(Fig. 4)**. Important land and port features modelled and accurately placed in the 3D environment. Navigational aids and buoys plotted based on Digital Nautical Charts. Other nonessential land features implemented as necessary to create an immersive environment for the operator to interact with.

Weather: Ability for the evaluator to set varying weather environments in the simulation, including rain, snow, hail, fog, and wind. Weather elements will be accurately simulated in the 3D environment and interact with the ship handling of the operator vessel and secondary contacts.

Water Simulation: Ability for the evaluator to adjust the sea state in the simulation. Water current and speed impact ship handling physics.

Bridge Interactables: Interactables for the operator to interact with in the VR environment, such as radar, DNC chart viewer, Automatic Identification System, ship whistle, and controls for throttle and steering. OpenXR interactables package will be configured to allow the hand controls from the Vive Cosmos headset to be used to interact with these elements in the 3D environment. Interactables will be modelled and placed with the bridge environment.

Recording: Recording feature will allow the operator and evaluator to review a training scenario after completion and review the session. Session recording should include basic features such as the ability to pause or skip through the recording, as well as include views from both the operator's direct perspective as well as an overview of the vessel.

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TUESDAY, DECEMBER 21, 2021

THE UNIVERSITY OF RHODE ISLAND

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SPBBTR

SmartPlug Bluetooth Button Transmitter and Receiver

Team Members: Andrew D'Ambrosca (ELE), Daniel Sossa (CPE), Matthew Moreno (ELE), Michael Corriea (CPE & ELE)

Taco Comfort Solutions® A Taco Family Company

Technical Directors: Phillip Manning, Robert Kellicker, Nicholas Costello | Consulting Technical Director: Mike Smith

Project Motivation

There are regions in the United States that increasingly require the conservation of water as a resource. In many residential and commercial locations, those in the state of California not being the least of them, there is a need for on-demand recirculation of water. All too often, we see gallons upon gallons of water wasted down the drain as a faucet runs cold water until the water becomes hot. This project aims to eliminate that waste. TACO Comfort Solutions' current product has been deemed inefficient by TACO. The new product will provide the efficiency that the last product lacks, as it will utilize Bluetooth technology to facilitate the demand for hot water. At the press of a button, water will recirculate throughout the customer's residence or place of business, providing hot water to kitchens and bathrooms across the country, all while mitigating the amount of water wasted.

Anticipated Best Outcome

The ABO is a functional prototype that employs hardware and firmware that has been developed to create a Bluetooth Low Energy (BLE) connection between the button and the SmartPlug, allowing the devices to interact with each other and facilitate the recirculation of water. A BLE module in the button will detect and transmit the button-press which is received by a similar module in the SmartPlug. Alongside that information, the button will report to the SmartPlug its battery level and signal strength. The button will periodically enter a low power mode in an effort to extend the life of the product.

Key Accomplishments

Connection between SEGGER, Feather, Prototype Button Board: Formed connection between SEGGER J-Link and Adafruit nrf52840 Feather Express module, as well as a connection between a second SEGGER J-Link and Prototype Button Board, and then connected each connected set via a breakout board. With these connections, we have been able to upload code onto the modules through the SEGGER debugger software as well as Arduino. **(Fig. 2 & 3)**

Install and Update Bootloaders: Without bootloaders, which are comparable to an operating system, the modules on the boards would not be able to operate as desired. They would not recognize USB connections nor any code commands. Installing and updating this core software to the latest version ensures optimal performance. **(Fig. 2 & 3)**

Bluetooth Low Energy (BLE) Test on all Adafruit Feathers: Uploaded BLE sketches onto the Adafruit Feather modules in order to test and confirm their Bluetooth capabilities. **(Fig. 4)**

Verified prototype sketches for SmartPlug and Button: Compiled and verified sketches inherited from the previous TACO team. Confirmed the sketches enabled the Smartplug and Button to interact with one another and transmit button-presses. The sketches were further analyzed to understand what had been accomplished, what was left unfinished and what needs to be added. **(Fig. 4)**

Soldering and Desoldering: Pins were soldered onto boards for compatibility with breakout boards. Resistors R1 and R8 were desoldered from the SmartPlug. R1 was replaced by a larger resistance and R8 will be replaced with the Adafruit Feather's built-in pullup resistor which is activated via code. The USB port on the Prototype Button board was removed and a new one was soldered in its place.

Corrections to SmartPlug Schematics and Calculations: Modify resistor values and circuitry to reflect changes made on the physical board via soldering and desoldering. Calculate resistances, currents and voltages to ensure safety of components and design.

Fig. 1: Functionality of the SPBBTR System as a Whole

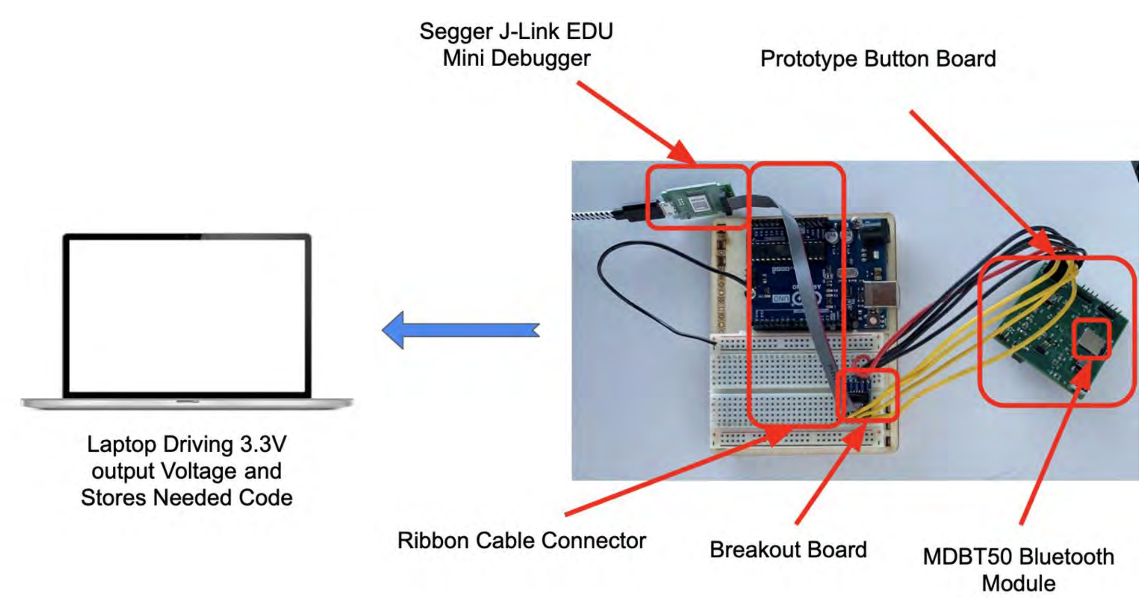

Fig. 2: Connection to Make Updates and Add Code to Prototype Button Board

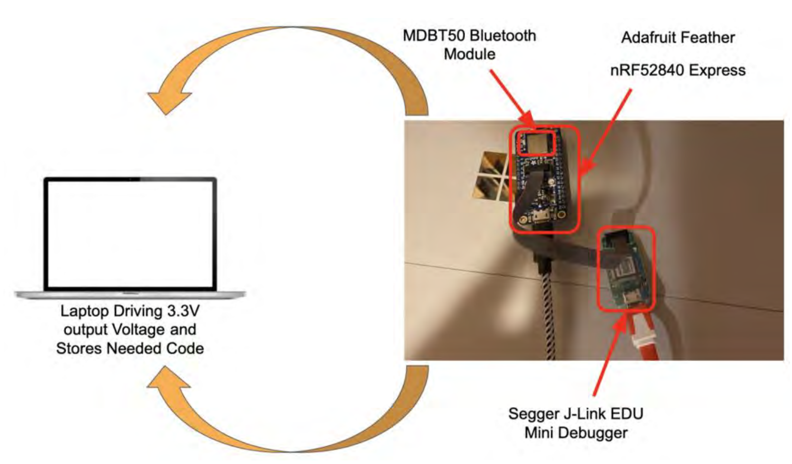

Fig. 3: Connection to Update Bootloader on Adafruit Feather

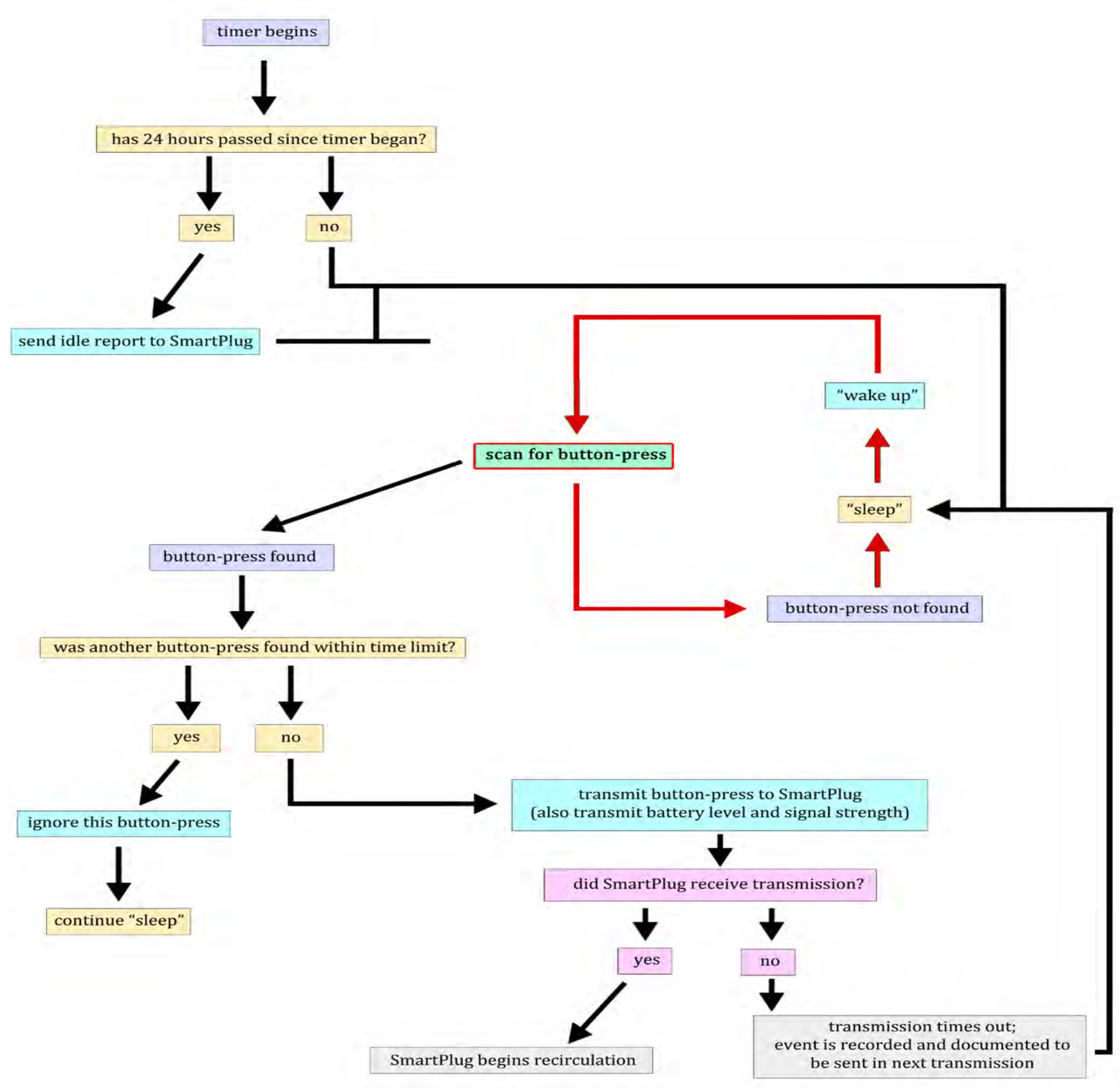

Fig. 4: SmartPlug Bluetooth Button Transmitter and Receiver Firmware Flow Chart

Remaining Technical Challenges

Troubleshoot, Update, Test Prototype SmartPlug and Button: Test for the correct output voltages. Make sure all components operate at safe temperatures. Update BLE modules on SmartPlug and Button **(Fig. 1)**

Edit Schematics on PADS: Update digital schematics used for ordering PCB to reflect future changes to be made to physical design.

Complete Prototype SmartPlug and Button PCBs: Upon completion of calculations and digital schematic design, we will then implement the modifications and additions to the physical design. There may be a need to order a new PCB. **(Fig. 1)**

Implement Low Power Mode: Use delay function in Arduino to extend the battery life of the Button. The Button will periodically "sleep", "wake up", scan for a button-press and then "sleep" again if no button-press is found. **(Fig. 4)**

Transmit Battery Level and Signal Strength: Establish transmission of battery level and signal strength of Button to SmartPlug for monitoring purposes. **(Fig. 4)**

Implement Connection Timeout: In the event that the Button has transmitted a button-press to the SmartPlug that has not been received after a specific amount of time, the connection will time out. **(Fig. 4)**

Implement 24-hour Idle Message/Report: When the Button is idle for a period of 24 hours, it will send a report to the SmartPlug with its battery level and signal strength, effectively telling the SmartPlug that the Button is still functioning. **(Fig. 4)**

Time Limit for Prohibiting Additional Button-Presses: In the event that the Button is pressed after the recirculation of water has already begun, the Button will know that it should disregard any button-presses after the initial button-press, for a specific amount of time. **(Fig. 4)**

Use Code to Activate Feather's Built-In Pullup Resistor: Supplement a physical pull-up resistor with the Adafruit Feather's built-in pullup resistor.

Counter for Errors and Timeout: Record, document, and transmit the number of errors and timeouts and the nature of each from the Button to the SmartPlug. **(Fig. 4)**

Implications for Company & Economic Impact

As global warming continues to threaten our natural resources, there is an increasing demand for the conservation of water and other resources, particularly in the regions of the United States that have been affected the most. TACO Comfort Solutions aims to evolve its product to meet the demands of this day and age. In doing so, TACO would realize increases in consumer demand of their recirculation product line. The increase in sales, of course, will increase the amount of annual revenue for TACO, allowing for further production, research, and development.

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TUESDAY, DECEMBER 21, 2021

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VICOR

Probe Interface Hardware Checker

Team Members: Boston Le (ELE), Giuliano Biondi (CPE)

Technical Directors: Al Binder, Daniel Hartnett, Nathan Shake

Project Motivation

We would like to develop custom Test Hardware Checkers to better support internal and off-site testing. The Hardware Checkers would also help to reduce test development time. The product engineering department has created a new test method for verifying probe card hardware called, “the hardware checker.” The hardware checker verifies all passive or active components on the probe card before it is used to test production material. The hardware checker uses the test system and test program paired with a Resistor Ring. The resistor ring provides electrical paths from pins on the Probe test fixture to ground. These electrical paths are comprised of specifically designed resistor values. The resistor ring attaches to the circular grouped pins on the top of the probe card. By terminating the probe card outputs with the resistor ring, we can verify the probe card is built correctly

Anticipated Best Outcome

The anticipated best outcome is:

- create multiple hardware checkers that will be able to rigorously test each of their intended probe cards in order to confirm hardware functionality and completeness.
- be able to fully understand each line of code and how they function
- Fully learn the eagle test systems program. So when writing code, we are able to utilize the tools that are involved to ensure our code is correct when writing it

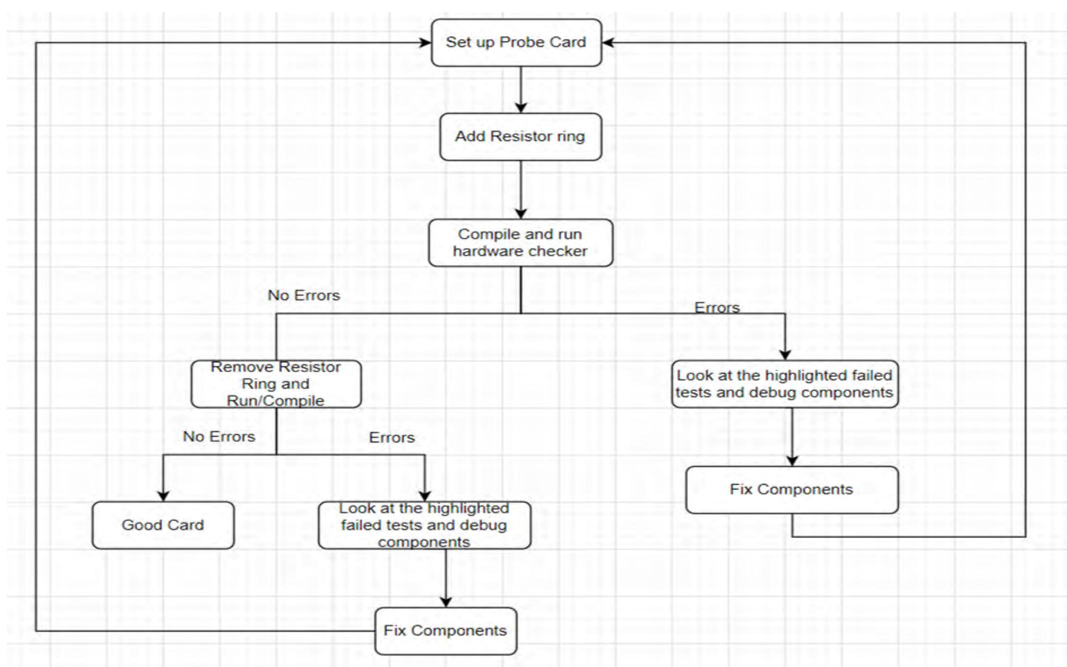
Key Accomplishments

Contract tracing of P012, P014, P052, P069 hardware checker: Used contract tracing referencing the schematic to test paths of various pinouts to read current, apu’s, and voltages. This was useful to verify all the components on the paths were verified on the pcb to ensure it functioned properly. The schematic contained numerous pages correlating to each other. It’s separated by the main page, timing page, and driver page. The main page refers the visible part of the pcb where the pinouts are visible. With the timing page it typically has a TMU A and TMU B, it often refers to the paths taken by certain pins and relates to the main page. Lastly the driver page to ensure that both the high and low sides of the drivers are working appropriately.

Software coding of P012, P052, P069 hardware checker: With the use of schematics and testing paths code was created for certain hardware checkers. The code is used for certain probe cards assigned to verify the schematic is viable and correctly operating. With the P012 the first code was created for the “BUMP” system. However starting with the P052 and P069 code was created from scratch with each probe card distributed between designers. With the creation of the code came up subsidiary support code or rules in terms of the PDS files and resistor rings.

Flowchart for Hardware Checkers

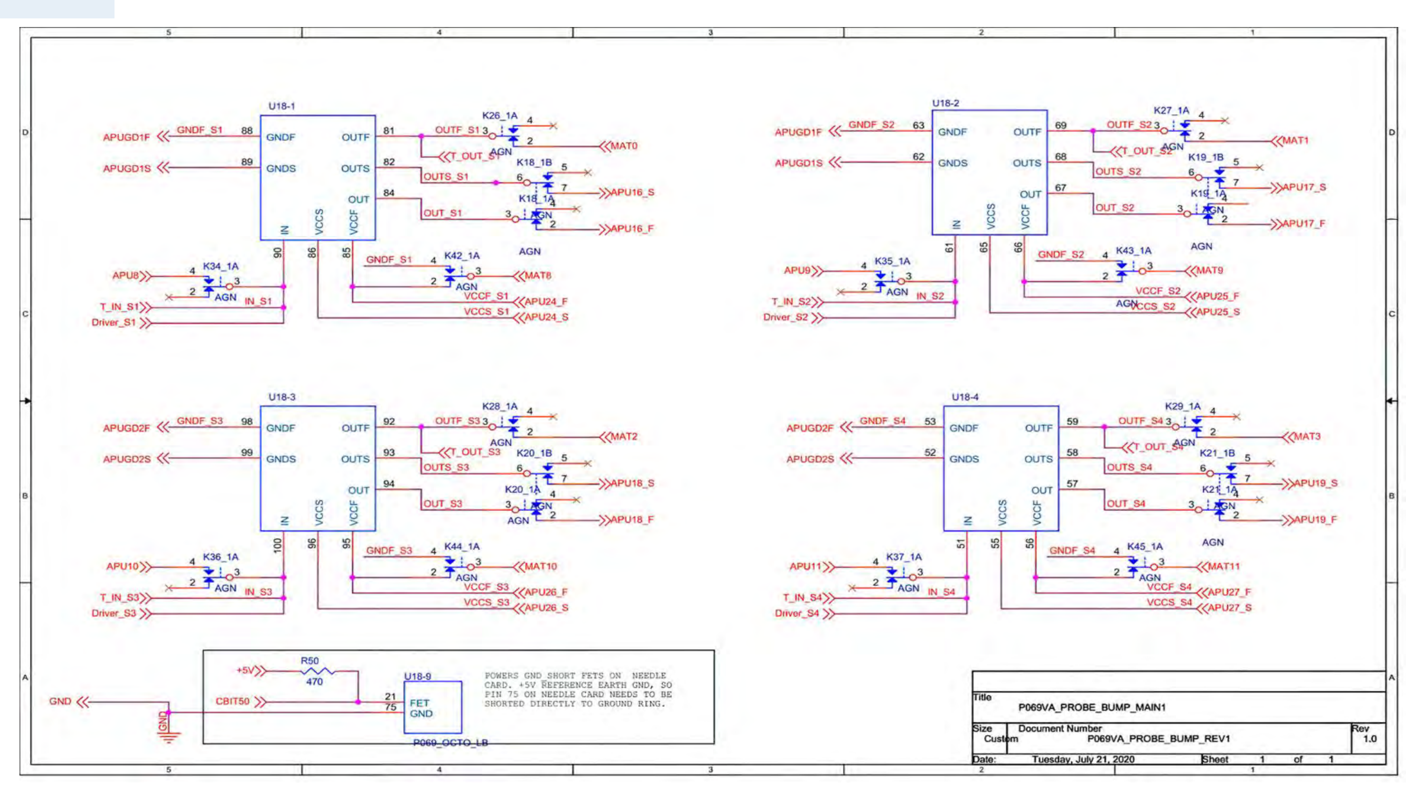
Hardware testing of P012: Worked with operating systems in the testing room. Used probers to assemble and disassemble various connected needed to be plugged into probe cards to ensure the correct voltages is distributed to the correct port. Live testing of P012 using the probers and resistor rings. In the beginning the test is ran through the probe card using the P012 code to ensure all systems are operational. After the resistor ring is added to reduce any errors of resistance values in later test. Debugging took place using the ets raid tool when problems arose.



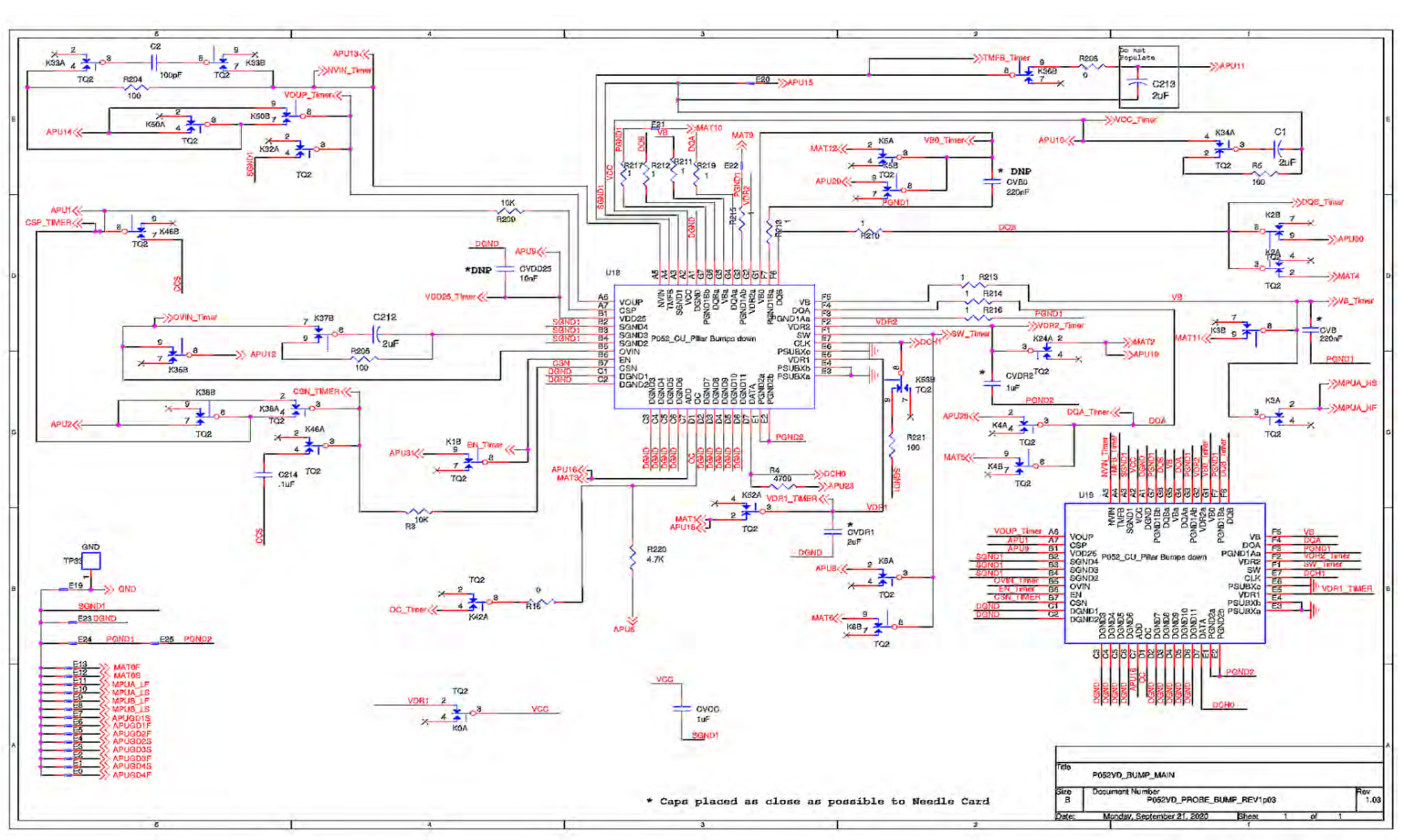
Flowchart for Hardware Checkers

```
//OC test

    apuset( GP_OC , APU_FV, 4.7, APU_10V, APU_10MA, PIN_TO_VI );
    lwait( 1000 );

    APUOC=apumi( GP_OC, 10, 10 ); // expect 1000uA
    APUOC *=1e3;

    apuset( GP_OC , APU_VIOFF, 4.7, APU_10V, APU_10MA, PIN_TO_VI );
    lwait( 1000 );
```

Test code for the P052



P069 Main Page



P052 Main Page

Remaining Technical Challenges

The remaining technical challenges for our team is to create more hardware checkers that are more efficient and professional. With more knowledge and practice we are anticipating to produce more logical and organized code, increase our knowledge of schematics, and greater comprehension of testing hardware. First off starting with creating more logical and organized code. This is a technical challenge since hardware checkers all differ and different code is required. However, the challenge is to format the code similar to the ones already written so it’s viable for any designer to understand.

Next is knowledge of schematics and how to approach them. With a better understanding of pathways creating code for the test will be more efficient. Lastly use of the probers in the testing room as well as ets raid to ensure that our code is functioning properly with the hardware. This is important skill to acquire since the testing room is often occupied heavily by engineers for various products. Time is essential while testing, the faster the set up and familiarity with the programs, and probers the more productive and effective our team can develop of additional hardware checkers. The reason behind this is with the tester we can see certain problematic areas. The places of error vastly decreases when using the tester since it can tell us whether there’s a problem with the code or the hardware itself. If any alarms are given than the error is with the code however if certain voltages and reading are off, we could use volt meters to view the volts being held or produced by certain resistors, capacitors, LEDs, etc. If there is any error, we would have to replace the component to certify that it’ll be operating correctly.

Implications for Company & Economic Impact

The best outcome for the company is that we complete numerous hardware checkers. With our help to complete as many as possible it’ll help the company focus on higher priority projects. The quicker a probe card can be debugged and approved, the faster the company can move onto the next project. This would have a good economic impact because due to the chip shortage and VICOR being one of the world’s best power supply companies, it is essential the company directs their focus on other tasks while we work on the lower priority projects that need to be done.

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TUESDAY, DECEMBER 21, 2021

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CLEAR

Colored LED Enhanced Automated Reader

VOLTSERVER DIGITAL ELECTRICITY™

Team Members: Nicolas Hatzis (ELE), Kelsey Reed (ELE), Tobiloba Awoyle (CPE), John Mendez (CPE)

Technical Directors: Camilo Giraldo ('17), Nate Roth | Consulting Technical Director: Mike Smith ('01)

Project Motivation

VoltServer products incorporate varying combinations of at least three different colored LEDs, the most common being red, green, and blue to visually display status codes through a series of LED blinks. Deciphering the blinks can convey vital information such as ensuring that LEDs are properly positioned, and the product is functioning as intended. Currently, an employee counts the blink sequences of the LEDs and then further translates the sequence in order to obtain the status codes.

The main motivation for this project aims to improve the efficiency of VoltServer's current product testing procedures. The Colored LED Enhanced Automated Reader (CLEAR) will allow VoltServer to save time, money, and resources. This will be done by developing a mountable sensor system that can be attached to the VoltServer's TX550 product line. The sensor system will be capable of quickly detecting and deciphering the status LEDs to determine if the product is functioning properly in real time.

Anticipated Best Outcome

The anticipated best outcome of the project is to deliver an automated prototype that has the capability to view the three colored LEDs that are incorporated in VoltServer's products and record the blink sequence and the durations of the LED blinks. After recording the series of LED blinks and the durations, the prototype will decipher the information that is received and display the status code to the viewer in real-time. In addition to the ABO being achieved the following items will be delivered:

- Prototype hardware including a mounting solution
- All circuitry schematic layout and files associated with the sensor head and main controller PCB
- Corresponding firmware and software source code and compiled binaries
- Complete Bill of materials and system manual

Key Accomplishments

Initial Circuit and System Design

- Red and green light sensors use phototransistors in active mode combined in series with a load resistor to calculate the photocurrent produced by the LEDs by measuring the voltage over the load resistor and applying Ohm's law
- Blue light sensors use reverse biased photodiodes instead of phototransistors but same method
- Initial data using sensors with overlapping spectral bandwidth ranges gave non distinctive responses for algorithms, therefore Test PCB for various distinct bandwidth ranged sensors needed
- Components selected for the prototype PCB already include a DC/DC converter, multiplexers, DC jack, and temperature sensors
- Designed 2x3 grid of 3 light sensors (1 for each color) in each grid within sensor head (**Fig. 1**)

Sensor Characterization w/ Test PCB

- 12 different phototransistors/photodiodes, 4 options for each color with varying viewing angles and spectral wavelength ranges (**Fig. 2**)
- Best combination chosen based on which provides the most differentiable results across each color for use in algorithms (D1, Q1, and Q3)

Software Communication

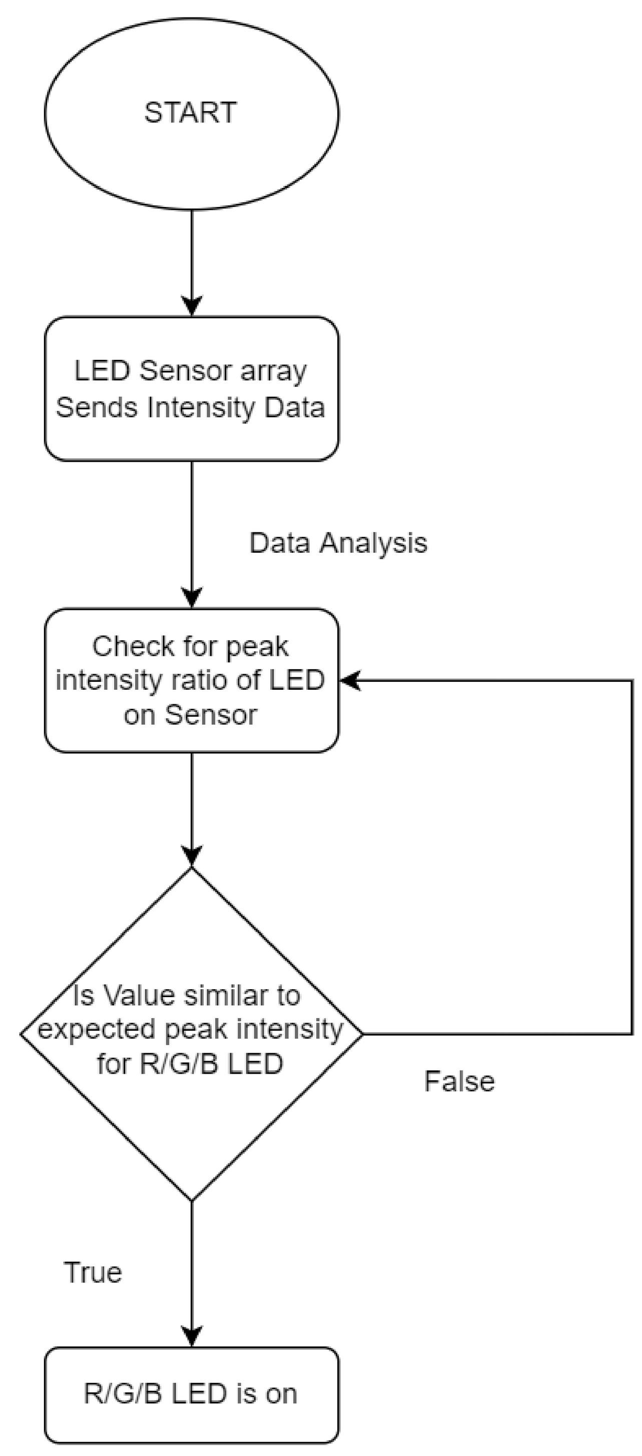
- Currently using an Arduino microcontroller to mimic receiving data over serial communication- will eventually be replaced by the microcontroller on the PCB
- Used PuTTY interface to debug and verify data was being received from the Serial Port
- Microcontroller Selected = dsPIC33CK256MP508

User Interface Development (Visual Studios C#)

- Incorporated Drop-Down Menu listing all COM Ports available for user selection
- Implemented text box allowing user to specify desired baud rate
- Programmed "Open Port" Button establishing serial communication connection based on user selected COM port and Baud rate
- Developed method to read data from serial port, display information in "Data Read" section once "Read" button pressed

Algorithm Development

- Created LED ON/OFF detection flowchart (**Fig. 3**)
- Created LED Color Identification flowchart (**Fig. 4**)



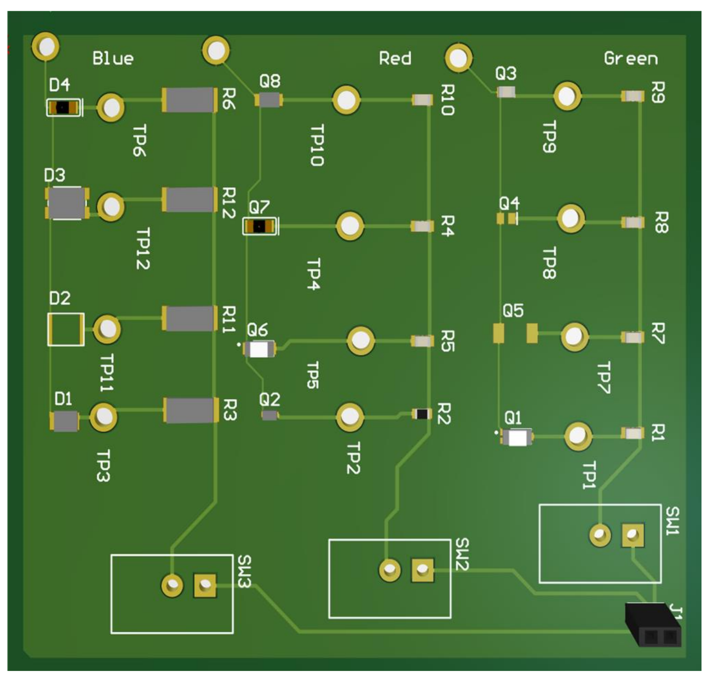


Fig. 2 : Test PCB used to gather data for LED sensor characterization

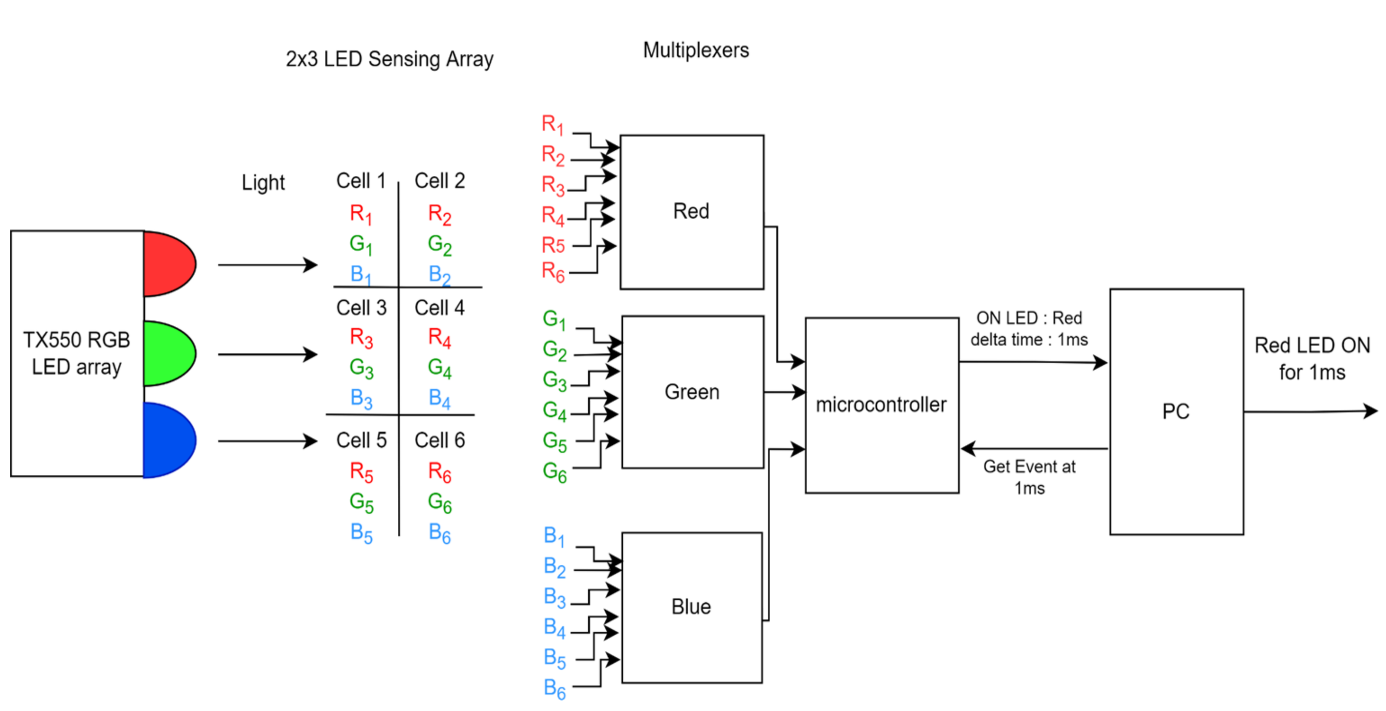


Fig. 1 : Overall System Block Diagram

Fig. 4 : Color Identification Algorithm Flowchart

Remaining Technical Challenges

Finish All in One sensor characterization-Basic sensor characterization has been completed on all single-color sensors- 4 different All in One Sensors left to be tested.

Identifying LED ratios: Once sensor characterization is completed, the highest response for each sensor will become the baseline, normalizing the response of each sensor in respect to its max output. Ideally, once the response has been normalized, it will give a clear indication of which LED is ON/Off and which color LEDs they are. (**Fig. 4**)

Color Identification Algorithm Development: Although the team has collected data, the team is in the process of finding methods on reducing the sensors responsivity to the blue LED

ON/OFF Detection Algorithm Development: Algorithm will be developed once sensor characterization is completed alongside the method of implementing noise filtering, giving the team an indication of the threshold values

Firmware coding and Implementation: Most challenging obstacle due to team lacking much experience in firmware development

Final Prototype PCB schematic, layout and fabrication: The prototype PCB is partially complete, major components pending are the specific light sensors chosen (will be determined in sensor characterization phase)

Improve User Interface for communicating between a PC and the microcontroller

Noise Filtering – Noise filtering will be used in Color Identification and ON/OFF algorithms to establish thresholds once sensor characterization is completed. It will prevent cases where an LED such as Red is ON but it is determined it is OFF because the ambient light is too strong compared to the Red LED

Blink Sequence Detection – An algorithm must be developed to convey series of blink sequences to status message

Create enclosure for prototype components

Develop a general mounting solution for prototype hardware that will work at least with the TX550 VoltServer product line

Prototype Testing

User Manual and Bill of Materials

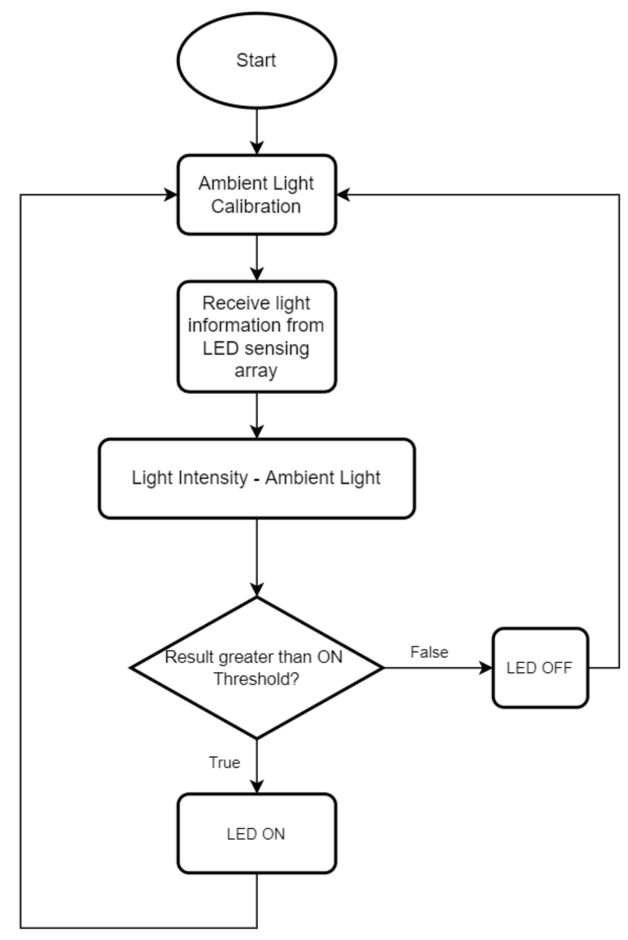


Fig. 3 : ON/OFF Detection Algorithm Flowchart

Implications for Company & Economic Impact

The Colored LED Enhanced Automated Reader (CLEAR) will allow the company, VoltServer, to save money and time. Currently the company has an employee hand counting the blinking sequences of LEDs. This method is long because once the counting of the sequence is completed, the user is still required to translate the sequence in order to obtain the status codes. The impact of this project will be a game changer for VoltServer as it will allow the company to save time by automatically counting the blinks and translating the sequence instantly.

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Volvo 240 Modernization

Updating the Volvo 240 with a Digital Controller Area Network

Team Members: Cameron Major 1 (ELE), Jamie Hollands (CPE), Spencer Kubicki (ELE), Timothy King II (ELE)

Technical Directors: Mike Smith, Brenden Smerbeck (ELECOMP '17)

VOLVO 240 ELECOMP

Project Motivation

Volvo has sold over 2.8 million 240 series vehicles. Many of these vehicles are still on the road. However, the supply for electrical components is diminishing and the available replacement parts are technologically outdated. Currently, a way to upgrade the electrical system on the 240 series does not exist. Vehicle communication systems have changed immensely since the inception of the Volvo 240. Many of which decrease cost while increasing reliability. The Controller Area Network or CAN is a notable vehicle communication system. CAN has proven itself to be a robust and reliable communication protocol and exists in almost all vehicles produced today. Given the current hole in the market for a replacement Volvo 240 electrical system and the accessibility of the Controller Area Network. Producing a 'plug-and-play' Volvo 240 CAN replacement system has the potential to keep more of these vehicles on the road and prolong their service life.

Anticipated Best Outcome

The Anticipated Best Outcome (ABO) is to produce a functional prototype Controller Area Network (CAN BUS) for the Volvo 240 series vehicles. The prototype should be able to process all required switches and signals that exist on an original 1993 Volvo 240 electrical system. It should also include fault identification and increased vehicle data resolution. The vehicle systems will be split across multiple computers that communicate using the CAN protocol. Finally, all the vehicle data will be visible from a digital display that will replace the current analog instrument cluster.

Key Accomplishments

Prototype Board Selection: For prototyping, we decided to use an Arduino Mega as the computer for each individual CAN node except for the digital dashboard node. A Raspberry Pi 4 was selected for this node. We selected the Arduino Mega because it had an available CAN shield that was affordable as well as a large selection of General-Purpose Input/Output pins (GPIO). The Raspberry Pi was selected for the digital dashboard node due to its increased computing capabilities and a larger selection of digital displays.

Test Circuit Design: Using data collected from the vehicle, we designed test circuits that emulate vehicle sensors (**Figure 2**). This would allow us to test our designs on a smaller scale. We designed test circuits that simulate operating the vehicle lighting (high beams, low beams, indicators, etc.). We also designed variable test circuits to simulate the Ignition Coil, Vehicle Speed Sensor, Engine Coolant Temperature, and the Fuel Level Gauge. (**Figure 1**).

Controller Area Network (CAN Bus) Communication: Connecting our test circuits to the Arduinos, we have been able to send and receive our simulated data over our CAN BUS. We have sent periodic and aperiodic data over the CAN BUS containing data from multiple sensors.
We have also sent vehicle control messages from the digital dashboard node, to nodes that operate the vehicle light test circuits.

Circuit Design: With our test circuits and CAN BUS operating, we reorganized and redesigned the nodes. (**Figure 3**)
Our new node designs can now receive a command from the digital dashboard node and operate the requested vehicle component. Each node also has fault tracing for each light on the vehicle and will send an error code back to the dashboard when a light fails. These nodes are self-contained and only need a message from the dashboard node to operate the associated components.

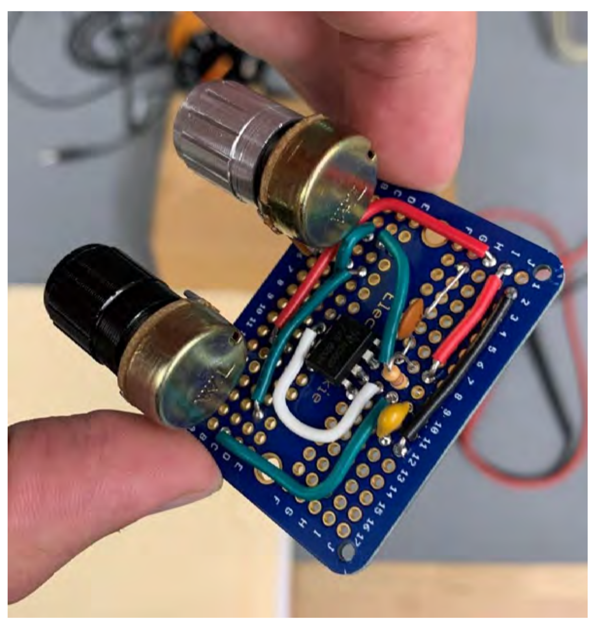

Figure 1. Ignition Coil Test Circuit

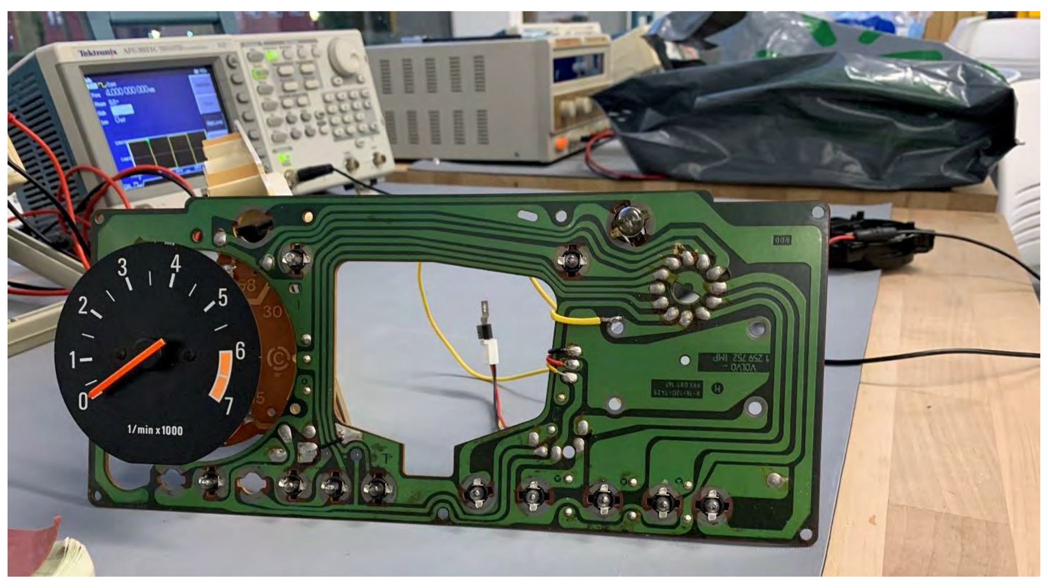

Figure 2. Volvo 240 Instrument Cluster Circuit

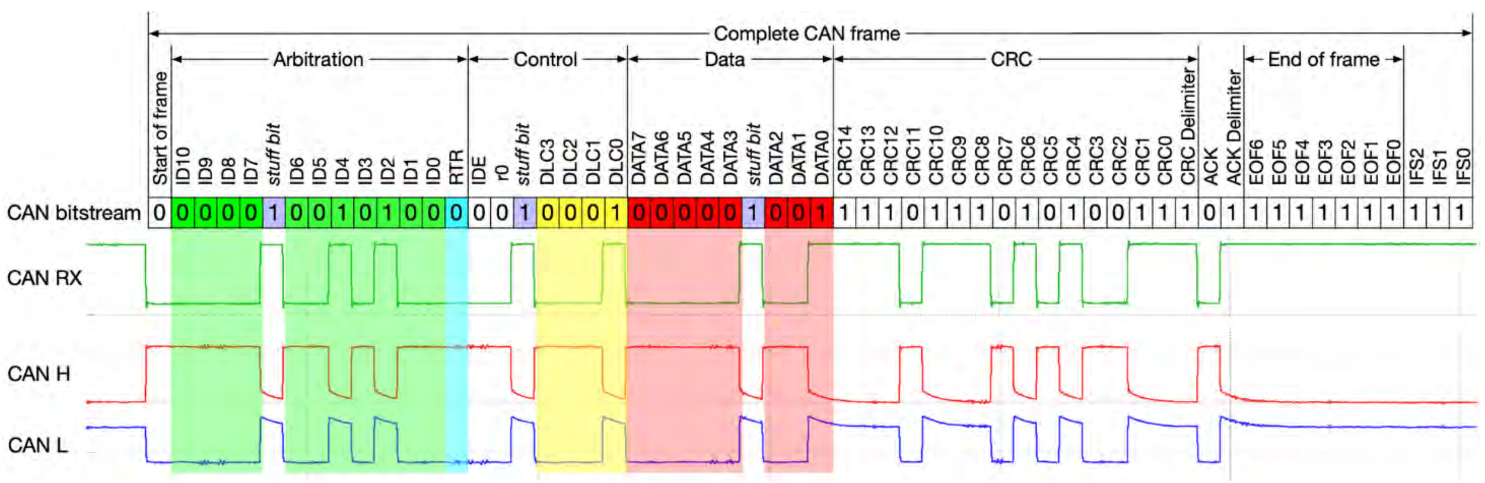

Figure 4. CAN Message/Frame

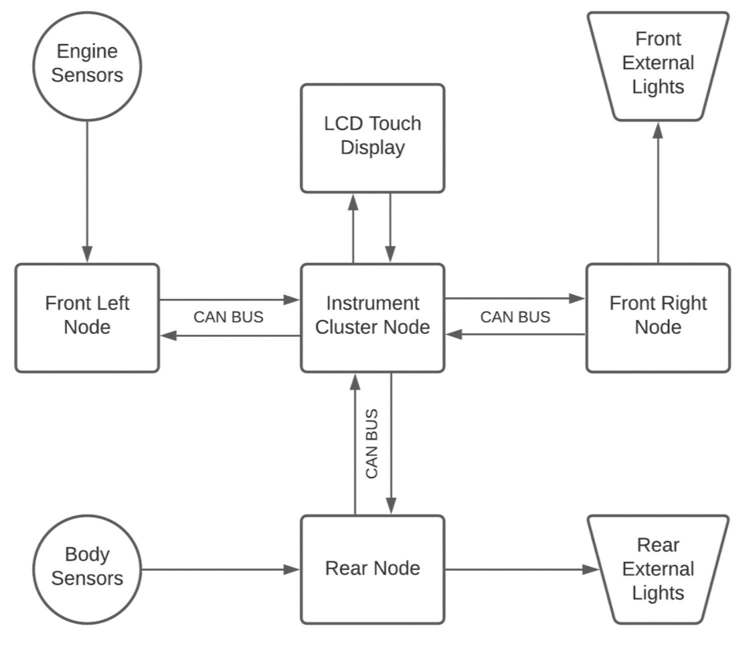

Figure 3. System Overview

Implications for Company & Economic Impact

This project is proudly student led. If we are successful in producing our prototype Volvo 240 electrical system. We could create a company, file for the appropriate patents, get our prototype tested by the appropriate organizations and potentially sell our product. Realistically, the impact on the economy would be small. The Volvo 240 community is small, and the aim would be to sell our product as a comparably priced alternative to scarce replacement parts. There are a few businesses in the United States that sell aftermarket Volvo 240 parts, notably IPDUSA, and doing business with them would be a significant milestone.

Remaining Technical Challenges

Circuit Board Construction: With our new designs, we need to build them on protoboards and connect all the signals to the Arduinos. We have started construction of these circuits and have begun to interface them with their respective CAN node. A few of our circuits that deal with relays that control the higher current circuits need flyback protection implemented.

Controller Area Network Message Definitions: Once the circuits have been finalized, we need to define and prioritize every message that needs to be sent over the CAN BUS. Prioritizing the messages means that we must order the vehicle data from most important to least important. This is because if multiple nodes try to send a message, the most important message is broadcast first. (**Figure 4**).

Test and Fault Tracing: Once we have everything interfacing, we need to test the CAN BUS and circuits to confirm their operation. This will include stress testing, applying signals that are out of range, and exercising all inputs to witness the correct behavior. We also need to make sure that our designs can regulate the vehicle voltage to an appropriate level for the Arduino's and the Raspberry Pi.

Vehicle Interfacing: The last step is to interface our prototype with a Volvo 240. We can test its operation in a controlled environment. Possibly utilizing a similar setup to how we collected our initial data. Vehicle interfacing would require additional circuitry to protect from voltage and current surges as well as modulating the voltage for various components. We would need to include fuses for all our circuits as well. Vehicle Interfacing is not covered in our ABO but we have made significant progress to where this may be a possibility

Smart Baby Monitor

xcore.ai Audio and Environment Monitoring System

XMOS®

Team Members: Tevin Flores (CPE), Jake Mueller (ELE), Isaac Sosa (CPE), Kiran Thakur (ELE)

Technical Directors: Andrew Cavanaugh ('08) and Steven Anzivino ('21)

Project Motivation

XMOS has developed a revolutionary new microprocessor called xcore.ai, which was designed with the specific needs of smart IOT devices in mind. The lightweight xcore.ai is well suited to be the sole processor for any IOT device. A baby monitor is one such device that can benefit from an on-board audio AI alongside its typical audio processing. By combining the white noise machine with the baby monitor we are able to reduce cost, clutter, and complexity, while providing a better experience on the remote unit(s) which will have the noise/music removed from the stream so that parents only hear the sounds being made in the room. With noise reduction an onboard AI can perform more complex tasks like sound detection (cry, fall, glass break, etc.), and send an appropriate alert to parents without the need for an internet connection. With an xcore.ai powered device, consumers are able to both protect their privacy and still have the convenience of a typical smart device.

Key Accomplishments

Explorer Board Audio Streaming:
Created a custom project based off of the example Xcore SDK code that allows for the xcore.ai Explorer Board to stream the microphone audio data to a target device.

Component Prototype Evaluation:
Selected evaluation board and breakout boards for audio CODEC and DAC to develop basic prototype for Daughterboard as well as test three types of commercially available speakers.
The evaluation and breakout boards selected for this are the MAX98357A DAC breakout boards and the Raspberry Pi ReSpeaker 2-Mics Pi HAT Expansion Board.

Audio Receiving Function Implementation:
Created a custom project based off of the example Xcore SDK code that allows for the xcore.ai Explorer Board to receive and audio stream from any device.

Audio CODEC DaughterBoard Schematic Design:
Design of WM8960 audio CODEC used to convert analog audio signals into digital signals that are then transmittable.
Design of BD70522GUL-E2 buck converter used to convert 5 Volts power supply into 3.3 Volts DCVDD and 3.3 Volts AVDD.

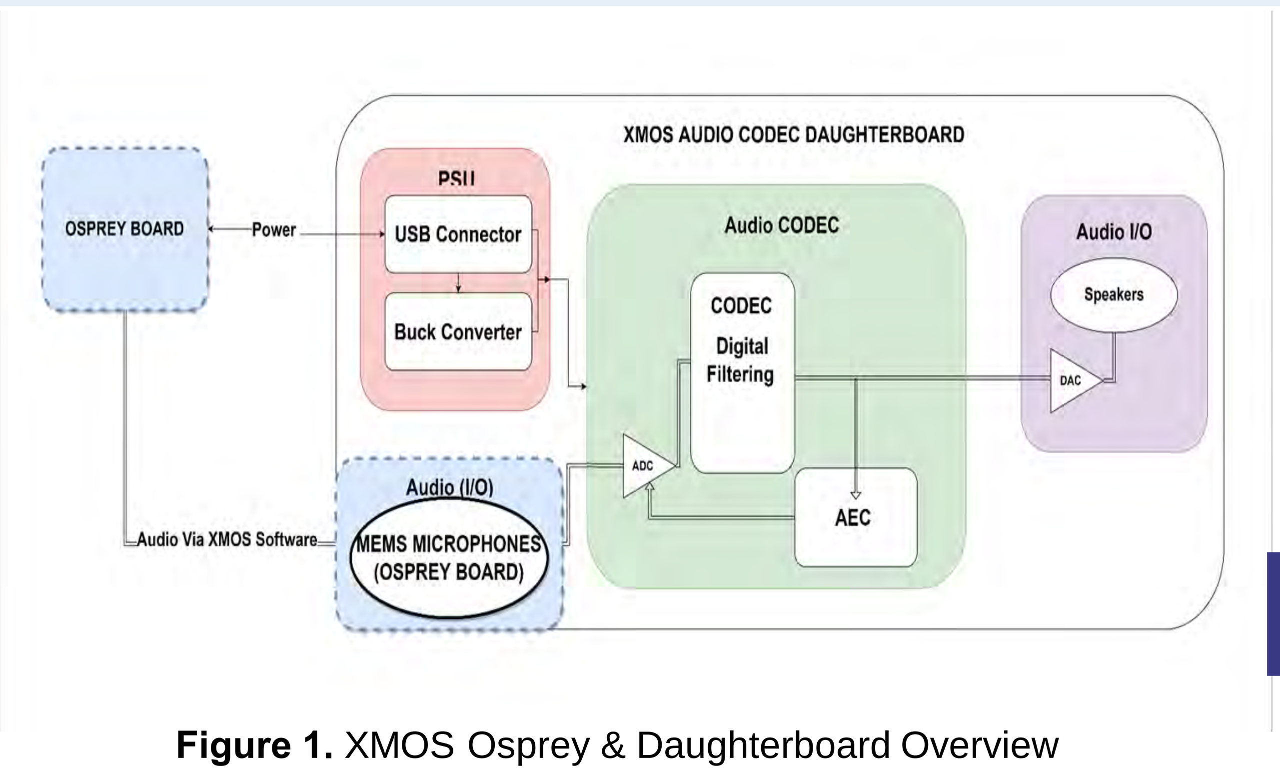

Figure 1. XMOS Osprey & Daughterboard Overview

Implications for Company & Economic Impact

The xcore.ai powered smart baby monitor fills an existing gap in the IoT market by processing AI on-device. This approach preserves the privacy of the consumer, by not needing an internet connection to function. Aside from the onboard AI processing, the baby monitor combines the functionality of a traditional monitor, white noise machine, and speaker, reducing cost and clutter. The xcore.ai SDK is also open-source, allowing other manufacturers the ability to build their own devices powered by the processor.

Anticipated Best Outcome

Demo daughterboard that can compete with current baby monitor/noise machines with the addition of AI to create an open development environment for other potential functionalities to be added upon.

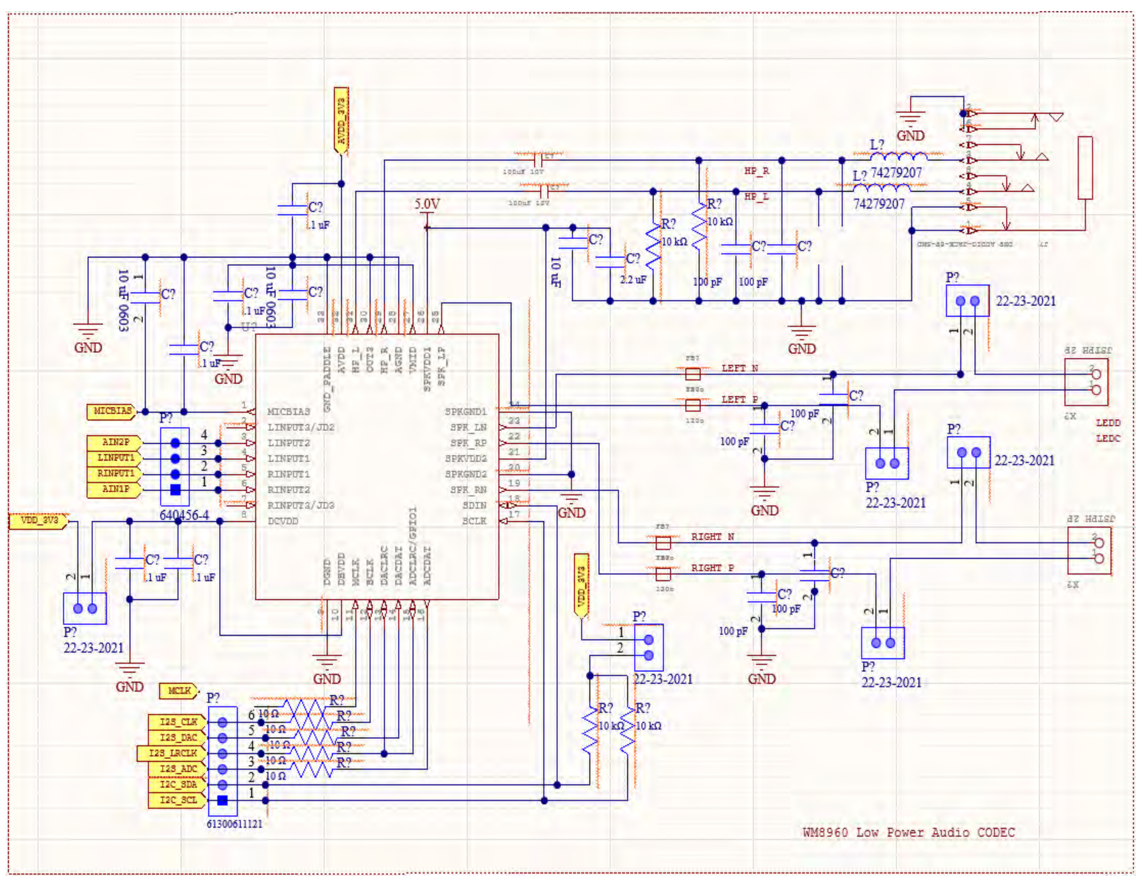

Figure 2. WM8960 CODEC Schematic

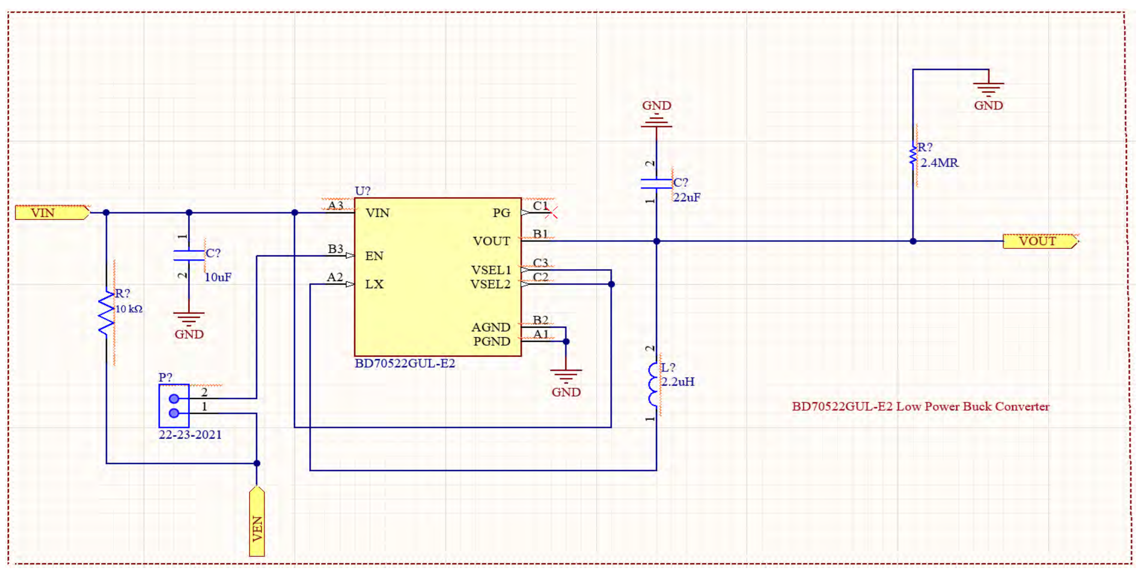

Figure 3. BD70522GUL-E2 Buck Converter Schematic

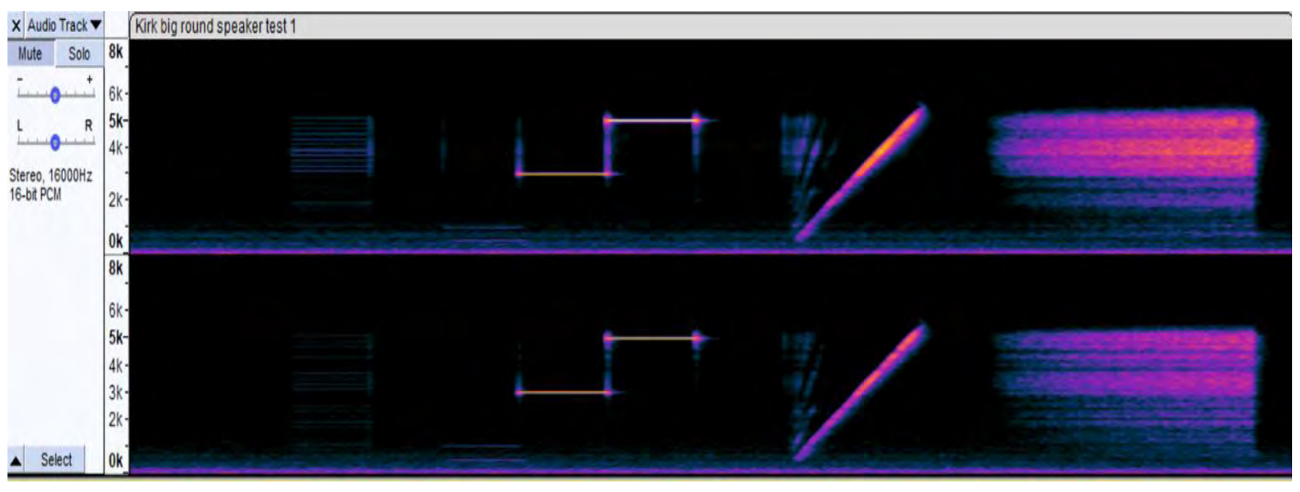

Figure 4. SP-3606 Speaker Spectrogram Waveform

Remaining Technical Challenges

Finish implementation of audio stream to DAC: Code needs to be added to the current project that allows for initialization and communication with the DAC.

Acquire dataset for machine learning model: To train the machine learning model that will determine if a baby is crying and other audio events, a large amount of labeled data must be acquired.

Train noise classification Model: Given an audio sample, the model will be able to classify the noises.

Integrate model into the baby monitor: Using XMOS tools and TensorFlow for microcontrollers the final model must be integrated to our custom project.

Implement audio codec and power supply into the baby monitor: Integrate CODEC and power supply with white noise machine.

Generate necessary components to build PCB for daughter board: Select components to build PCB based off of schematics for CODEC and power supply.

Add AEC to remove any echo and unwanted noise: Automatic Echo Cancellation feature to eliminate unwanted noise.

Design Daughterboard PCB Layout: Generate Daughterboard PCB given components selected.

Daughterboard Evaluation and Testing: Test and verify completeness of created Daughterboard.

ELECOMP CAPSTONE
SYMPOSIUM
TUESDAY, DECEMBER 21, 2021

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Torque Measurement

Printer Realtime Torque Measurement

Team Members: Kevin Suggs (CPE), Dean Grupposo (ELE), Roy Oza (ELE)

Technical Director: Matthew Corvese ('08, '16) | Consulting Technical Director: Anna Skelly('21)

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.

Key Accomplishments

GUI Development: The current GUI was made using python and it's built in GUI interface, Tkinter. The GUI is capable of sending and receiving data from the microcontroller as well as using that data to do background calculations, all while the GUI is running. The GUI itself appears as a window with labels and entry boxes for appropriate data points.

Serial Communication: Serial communication serves as the main method for the microcontroller to interact with the python script/GUI. The microcontroller used in this project has its own IDE which is in C/C++ with the HAL library. This makes coding not as straightforward as coding in basic C/C++. However, after thorough research/testing, serial communication has become possible with this IDE.

Dev-Bench Interfacing: The current Dev-Bench is wired as shown in **Fig 1** and operates as shown in **Fig 2**. In addition, it came with code made from last year's team which had unnecessary functions and errors. This code has since been cleaned up, and due to this, the pinouts had to be rewired and updated. Making the entire Dev-bench easier to understand and more efficient.

Transducer Interfacing: Wires were soldered to the pinouts for testing the device in advance. Data is being collected using an oscilloscope and the microcontroller, which is then formatted in the IDE and outputted to serial. The signals from the transducer will be used to make the graph in the GUI.

Filter Assembly: In order to get consistent and clear readings from the transducer, a filter has to be assembled. After some discussion, it has been determined that a low-pass filter is needed to accommodate the transducer output.

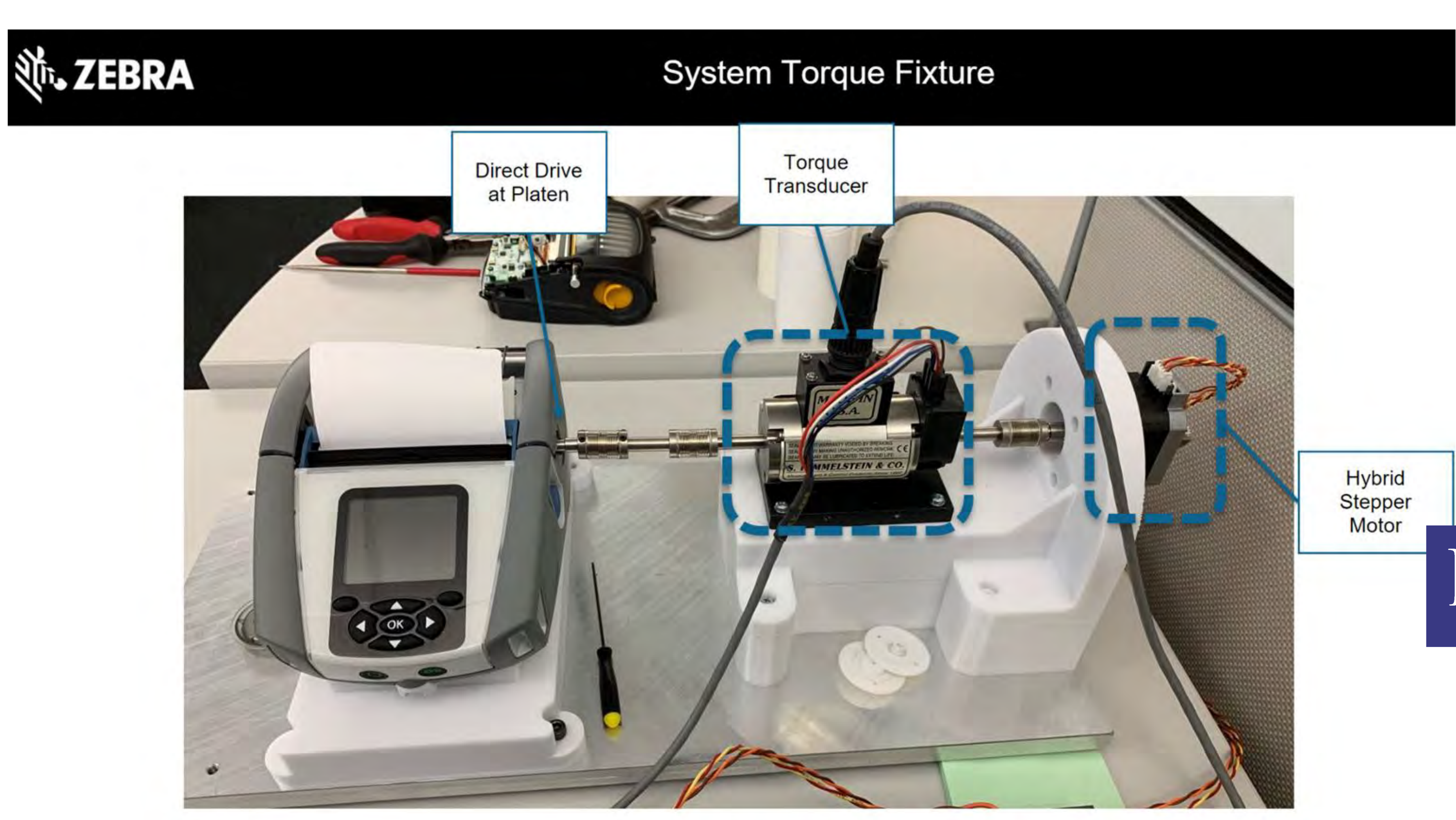

Fig.4: Original Torque measurement setup (to be replaced)

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 and make the customer-specific adjustments to help the current customer conditions.

The Economic Impact is 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.

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.

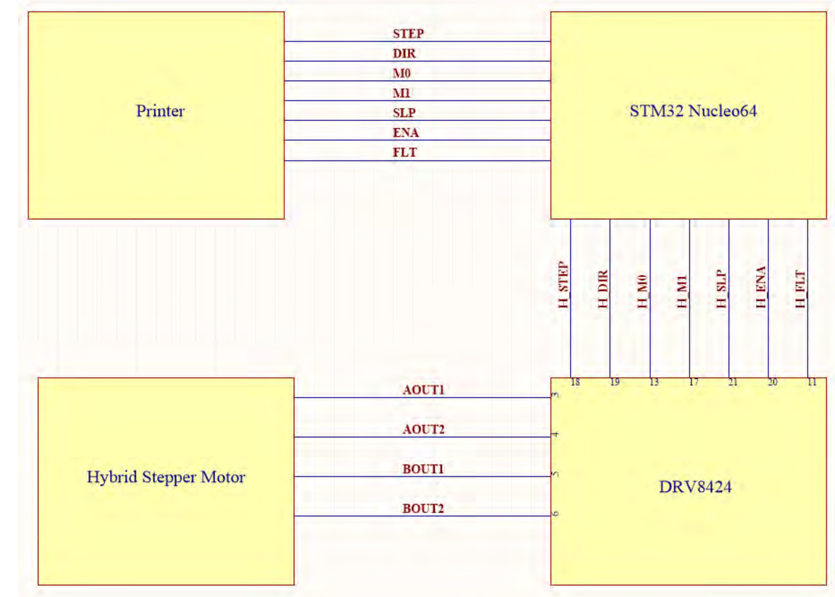

Fig.1: Functional wiring diagram for current dev bench

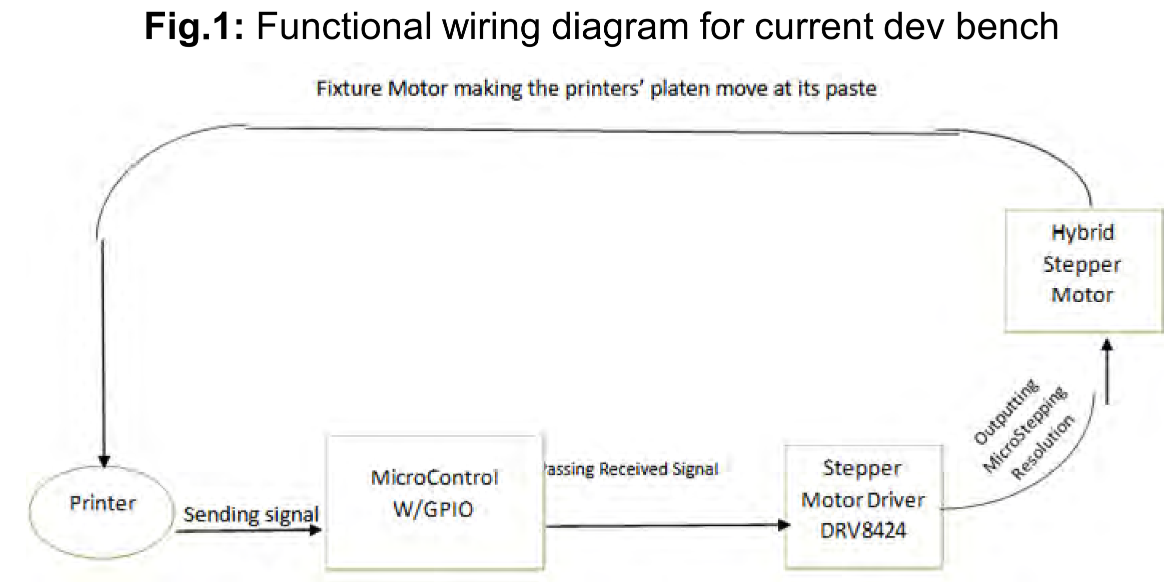

Fig.2: General block-diagram for how the setup works

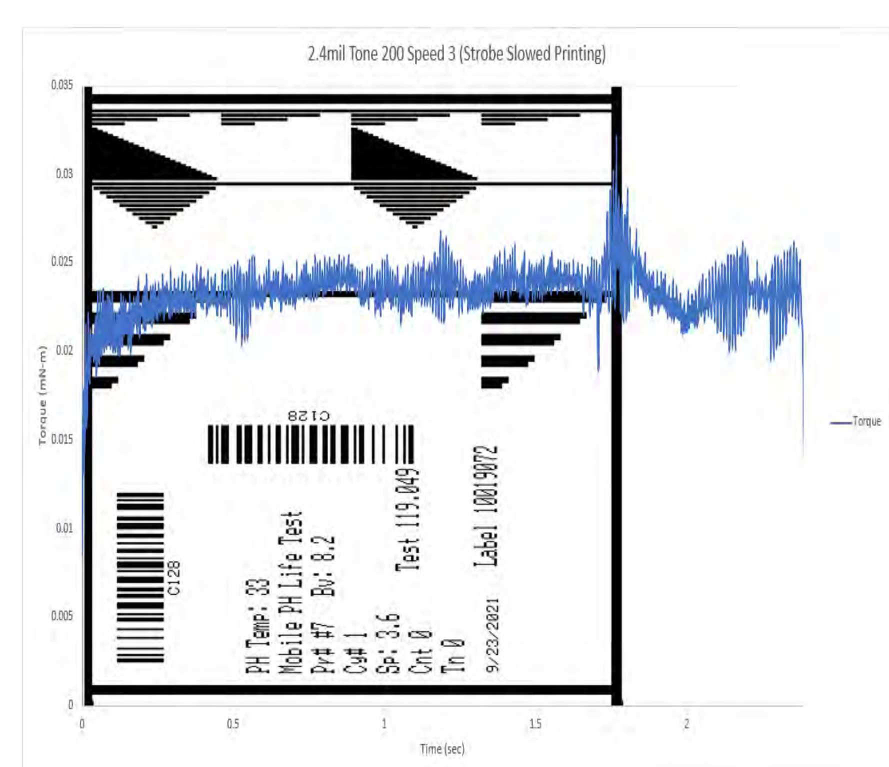

Fig.3: Example of label with torque reading

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.

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. Basically take **Fig 4** and make it more compact to look like the final product.

Transducer Integration: Interfacing the transducer is still in the early stages so there's plenty of work to be done. This part of the project is the most unknown so there are many things to learn and develop as the project progresses. For example, making sure that the microcontroller receives the correct voltage values and that the GUI can pick up those values to be used. Integration of this device is the main point of the project, so it definitely needs to be completed to reach the best outcome.

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.