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TUESDAY, MAY 10, 2022

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FaultLine

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

Acumentrics
TRUSTED POWER INNOVATIONS®

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

Technical Directors: Brenden Smerbeck (ELECOMP '17) | Consulting Technical Director: Najib 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. However, these require modification to the product and are neither easily deployable nor maintainable.

All electronic devices require energy to operate - which can be derived to a voltage and current value. In these electronics, power consumption changes over time; consuming a varying amount of power depending on the intended action. By analyzing the consumption of power, a system can not only uniquely identify a specific device amongst others, but also learn how that device operates. Through learning this "power signature," a system could identify when a device is behaving abnormally and notify a user before such abnormalities become catastrophic.

Acumentrics' products have a commonality - clean, reliable, and rugged power. Regardless of condition, our products operate at the highest level. These systems are, however, not immune to failure. And in mission-critical operations, these failures are not tolerable. Additionally, our systems are deployed in secure environments which do not permit data collection for analysis. Therefore, most cases of failure analysis occur when a system is returned to the company; after a fault has occurred.

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 FaultLine ultimately yield a fully deployable product with pretrained models and on-device training capabilities, there is a growing market for predictive maintenance across all industries, including but not limited to the military industries 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.

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 similar to 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.

Local model implementation and Inference System Design: The system has been designed to enable efficient data collection, on-board training, and model inference to be able to predict whether a given power signature is faulty. The system is 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 is set to only train on "good" functionality.

Generated Human-Readable Data and Graphics On-Demand from Tested Models: Utilizing MatPlotLib and other python libraries, model results and metrics were compiled into graphics. This enabled our team to more easily assess the accuracy of the model and the divergence of power signatures coming from different device faults. Prior to this, all data and metrics for the models was more or less entirely encapsulated within the FaultLine environment. This made data and results much less human-readable and therefore harder to communicate to those outside our team, including our technical directors.

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.

Project Outcome

The best anticipated outcome was met, as we were able to demonstrate on-device training on the SmartPDU using its embedded systems. The specialized machine learning model used to facilitate transfer learning is able to detect faults in two devices. These devices are the WindMachine™ floor fan and DIrt Devil Endura Lite bagless vacuum cleaner.

Figures

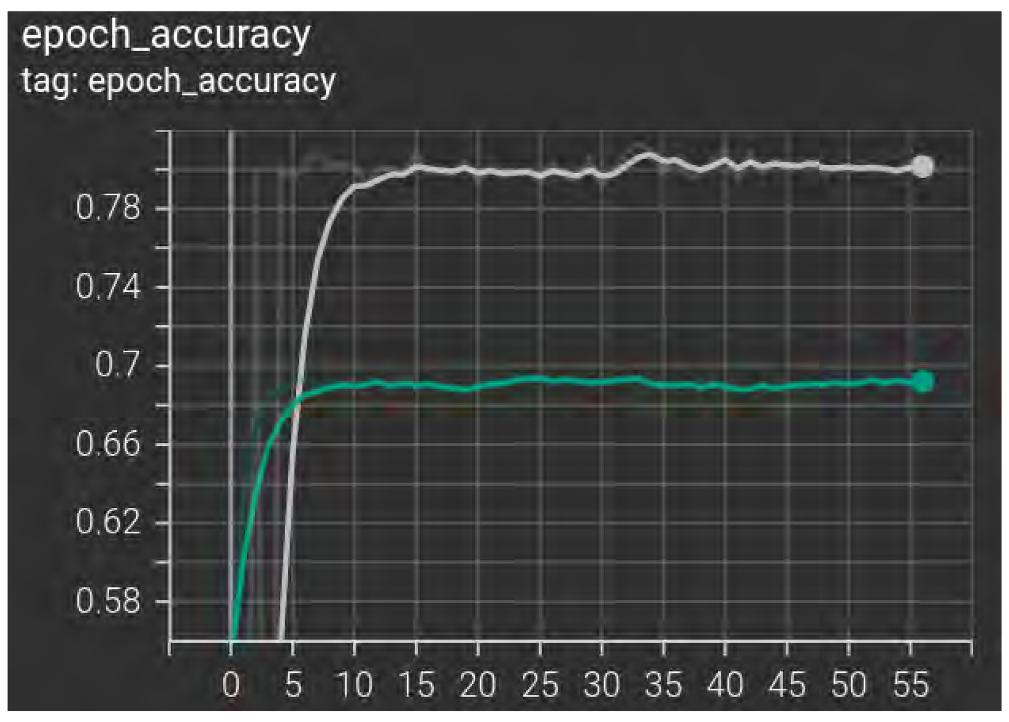

Figure 1: Accuracy in training over epochs

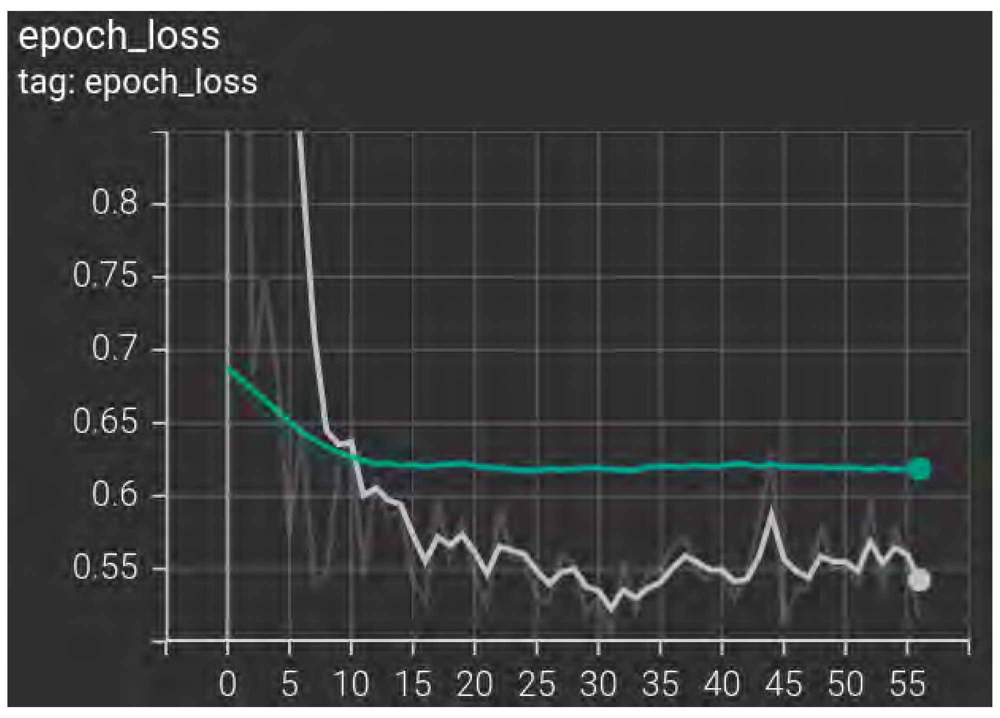

Figure 2: Loss of prediction accuracy over epochs

Figure 3: Dirt Devil Edura Lite vacuum cleaner (Left) WindMachine™ floor fan (Right)

Figure 4: NVIDIA Jetson Nano Develop Kit

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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, analyzing 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 created in Simulink to generate test data. 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 voltage of zero is the system input and a random number generator injects voltages into the system in order to generate a +/- 10 voltage. Gaussian noise is injected into the input voltage and output position to have the system in a dynamic state and allow for changes in parameters to produce observable changes in output values. The input voltage with noise injection, output position, and output position with noise injection are saved to the workspace and sent to the recursive least squares algorithm. The simulation parameters are generated in a simulation object, simdata, which also contains the outputs of the simulation.

RLS Algorithm: A method to approximate the solution of an overdetermined system. This was used to find the parameters of the system from the given input and output, to then estimate the output of the system. Sliding window with overlap was then added to the Recursive Least Squares algorithm. This was added so that it gives the option to change the percentage of overlapping data and therefore increasing the accuracy of the data (**Fig. 1)**. To test the algorithm, a plotting function was implemented to check if the algorithm was running correctly.

PCA Filter: An algorithm used for dimensionality reduction that projects the data set into a few principal components. These principal components contain most of the data and point in the direction of the most variance, simplifying the dataset.

Outlier Detection: Once the dataset has been put through the PCA filter, it is put through the outlier detection algorithm. For each point we determine the probability of it being an outlier and if it is above 90% then we consider it to be an outlier **(Fig. 2)**. It is then converted back into its point in space and sent to the k-medoids classifier.

Classification: To classify the outliers as faults received from the PCA filter, we must run a clustering algorithm on the data set to label each separate group. Utilizing the k-medoids object, we can determine the ideal number of groups to be created from the data set, and accurately label each group as a separate fault created from the galvo. The object was then fed the data from k-medoids to set the Naive Bayes model using 80/20 train and validation. If the groups are being correctly classified, the "trained cluster" data should be in the same group as the "cluster" data **(Fig. 3)**.

Merge Components: One of the largest technical challenges overcome was merging all of the individual components: simulation, recursive least squares fault detection, PCA whitening, and K-medoids classification. The simulation object, RLS function, PCA object and K-medoids object were all merged in one file. The number of runs is input, usually 100, during which the output of the simdata object and parameters generated by the RLS function are saved to cell arrays before being passed through the PCA filter and K-medoids. The PCA filter is trained on the normal data, after which the error-injected data is passed through the filter. The PCA filter then outputs the outliers which trains the K-medoids and is plotted in 2D space **(Fig. 4)**. Should no outliers be detected, such as when there is no error injected, "No outliers detected" is displayed.

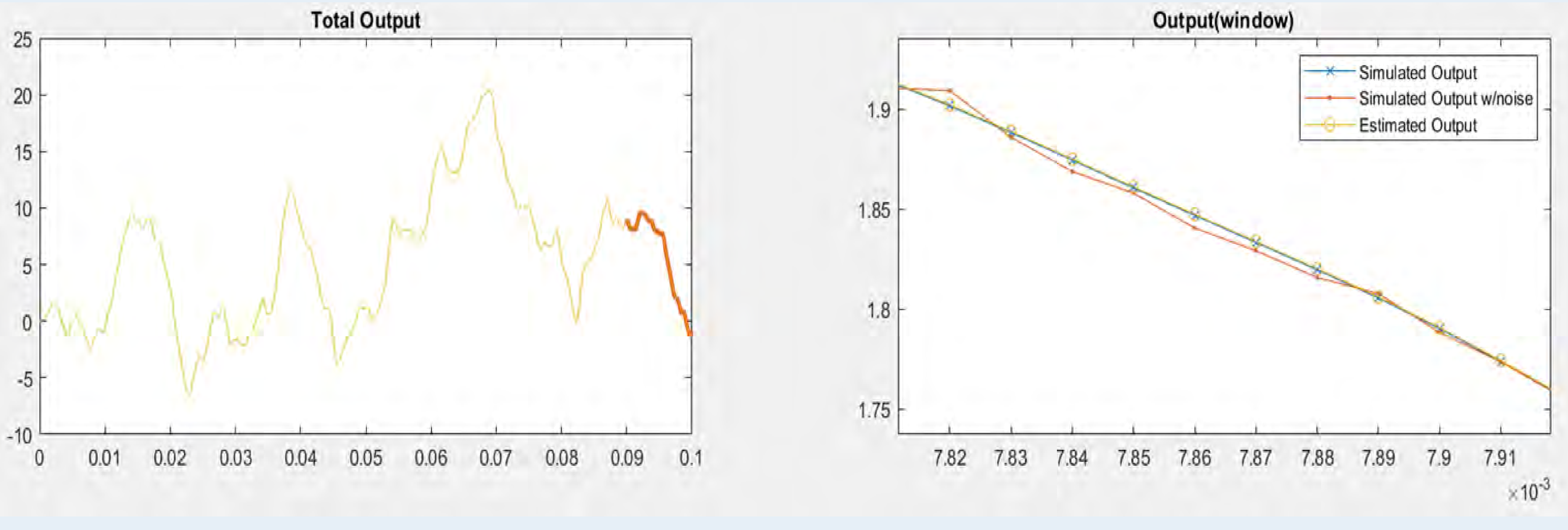

Fig. 1: Output and estimated output plotted

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.

Project Outcome

The Anticipated Best Outcome was achieved. The toolchain was successfully able to generate, diagnose and classify errors in the galvo.

Figures

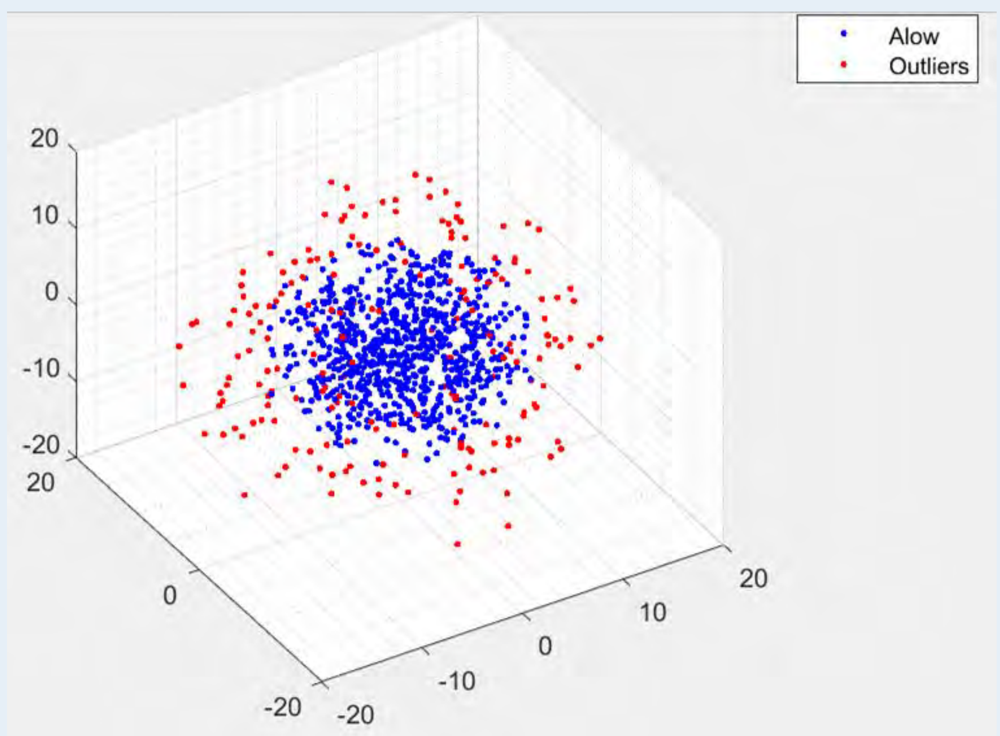

Fig. 2: Outlier Detection (PCA points in blue and Outliers in red)

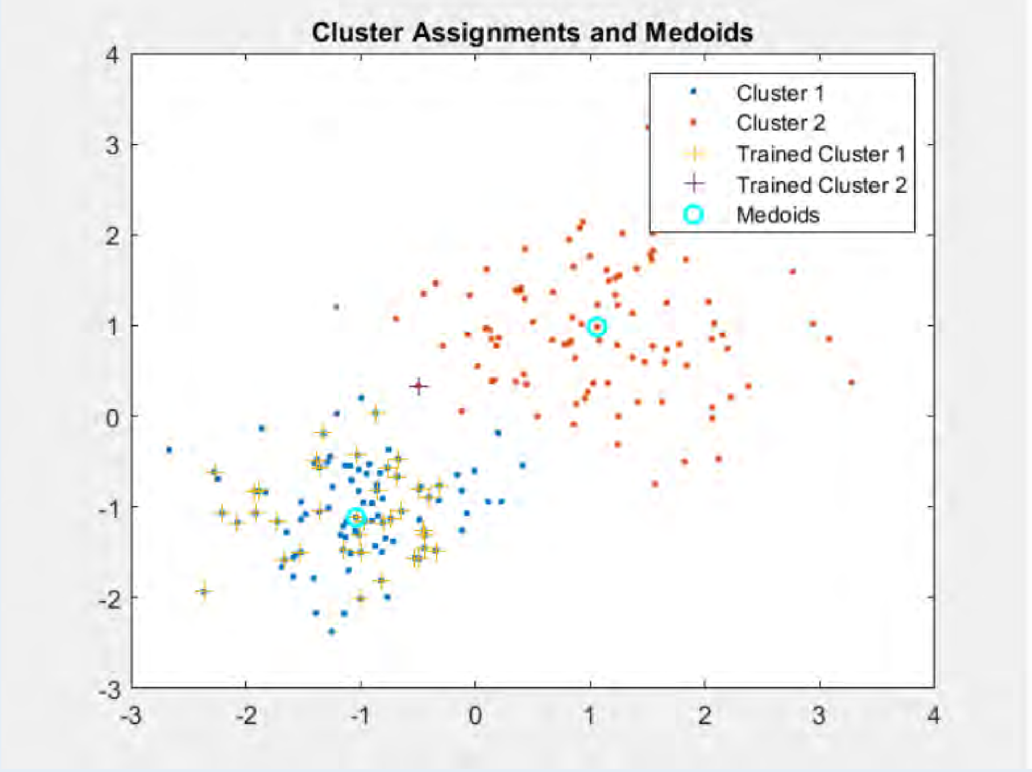

Fig. 3: K-medoids classifier (clusters) vs. Naive Bayes model (trained clusters)

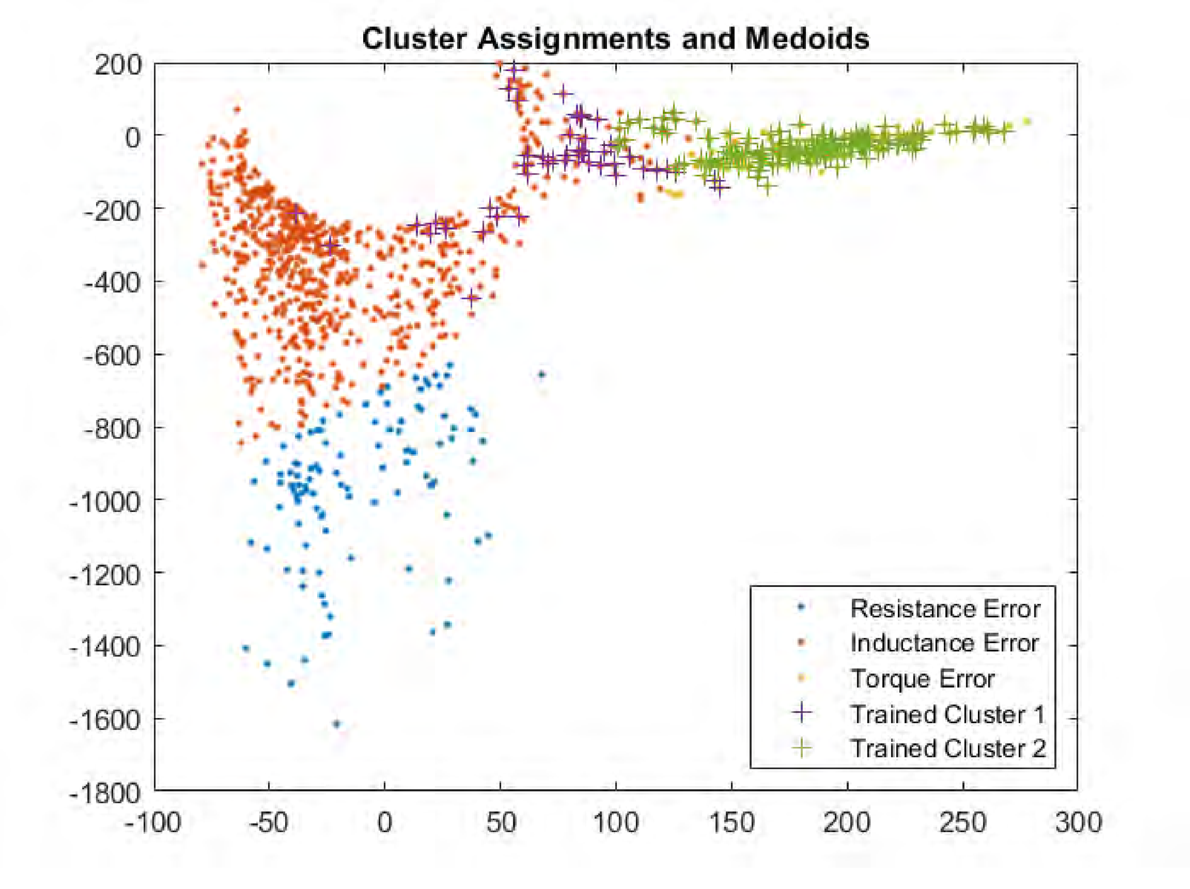

Fig. 4: Clustered data with Predicted data

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

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AM-BATS Part Deux

Investigating battery cell performance and health

EAGLEPICHER TECHNOLOGIES

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

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

Key Accomplishments

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 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.

Programmable Load Design: Designed a programmable load 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.

Test Fixture Design and Assembly: Created battery testing system fixture **(Fig 1).** that has allowed us to house 12 18650 cells and run rigorous tests on them using multiple load profiles. This Test fixture consists of a BMS, DAQ, battery cells, a load supply, multiple Power supplies, contacter, fuse and current sensor, all of which are connected through our PCB.

PCB Design: Designed a printed circuit board that houses the battery cells and all necessary circuitry required to measure the cell voltages, temperatures, and the pack current. The PCB also allows for clean wire management as all external connections are routed through headers, including all the connections needed to the DAQ and BMS.

Data Organization: As our data collecting system has yet to be fully developed and running, a Fake Battery Data Set was created to allow us to begin our Machine learning efforts. Data was organized and normalized in a way that would allow us to use Starting State of Charge and Ambient Temperature to calculate damage on battery cells through different load cycles..

Machine Learning (ML) Model Selection: Our goal is to utilize Starting State of Charge and Ambient Temperature to predict optimized values to output the least damage on battery cells. This was planned to be achieved by creating a Stochastic Gradient Descent optimization Model that will allow us to find the global minimum pointing us in the direction of the most optimized SOC and Temperature values.

ML Model Training, Calculating accurate loss and Fitting Equations: Implemented Stochastic gradient descent methods to create a model. Compiled and trained model, and the loss was calculated using mean squared error. Loss was on average with what SOC and Ambient loss is. This allowed multiple accurate fitting models to be produced **(Fig 2.).**

Orion BMS: Created a block diagram and documented all connections between the BMS, Thermistor Expansion Module(TEM), PCB and PC. Wired all connectors for the BMS and soldered the termination for the CAN bus. Configured BMS software to read and collect live data **(Fig 3.).**

National Instruments DAQ: Connected National Instruments modules to PCB Test fixtures and made sure all channels were running tests correctly. The DAQ was made up of two voltage modules one used to record cell voltages and the other to measure cell temperature and current.

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.

Project Outcome

The Anticipated Best Outcome was achieved. Our battery testing system was built and fully functional and the Machine Learning Models trained and outputting the correct outcomes. This will allow next year's team to start with collecting data and a great starting point to advance with the ML efforts.

Figures

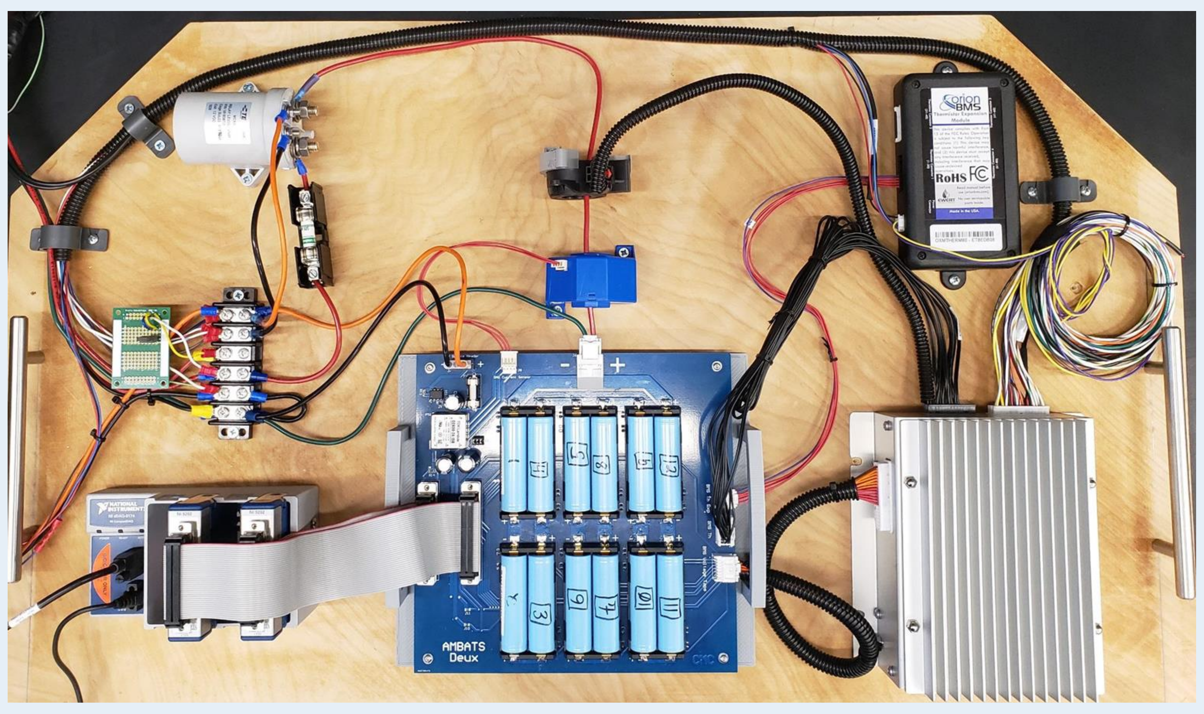

Fig 1: Battery Testing Fixture

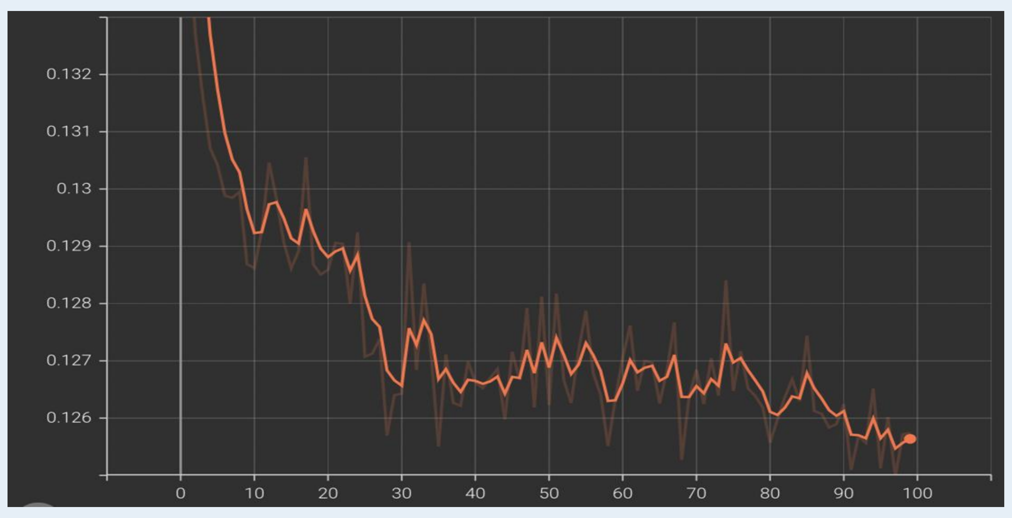

Fig 2: Trained SGD Model Improving Loss Calculations

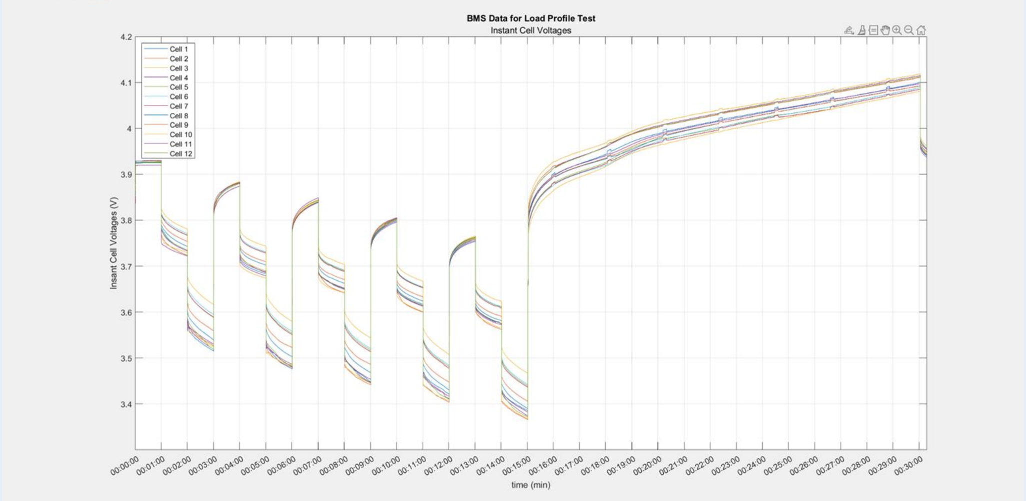

Fig 3: BMS Data Collection

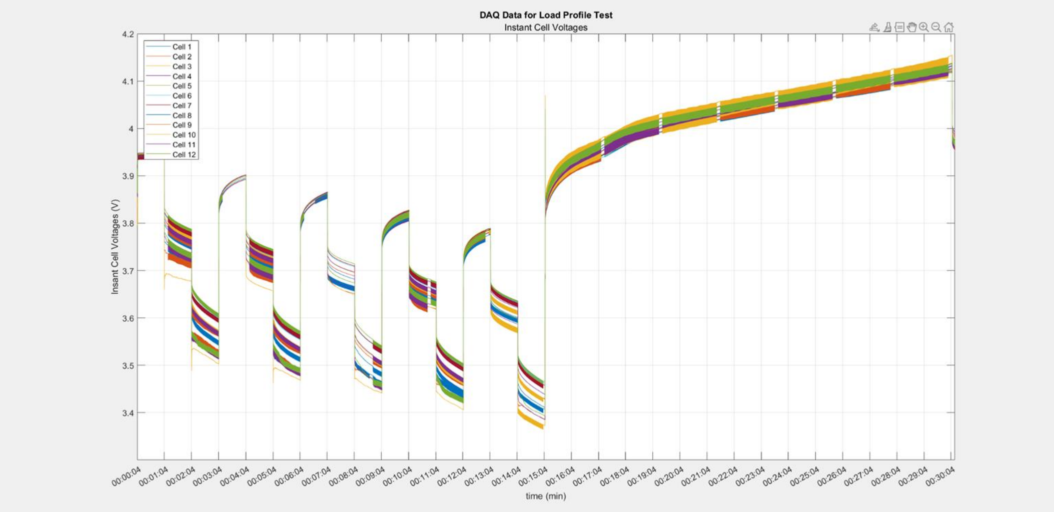

Fig 4: DAQ Data Collection

ELECOMP Capstone Program Director: Professor Harish R D Sunak

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

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GDEB - COTS

Design of a Consumer-off-the-Shelf 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 picks 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, an AFBR-S50LV85D time of flight (TOF) sensor with a range of 3m-100m to detect obstacles in front of the RC car and a camera in order to provide a live visual feed of everything in direct line of sight of the RC car for comparison against the time-of-flight data. The Raspberry Pi 4 functions 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 and assembled to accommodate all sensors and connect them to the Raspberry Pi. The first PCB Schematic operates using the SEN0140 board mounted with the GPS and power sensor. The Raspberry Pi is connected via ribbon cable and acts as the control board. The second schematic design contains the Time-of-Flight sensor which is mounted in front of the RC Car to detect obstacles in front of the vehicle utilizing a Class 1 Laser, in addition to a pair of headlights connected to the Raspberry Pi via GPIO. This board was designed with connectivity to an evaluation board in mind, the FRDM-KL46Z, due to built in compatibility to the AFBR-S50 series Explorer API from Broadcom. The last board design acts as the power distribution unit as it is connected to an additional 9.1 Volts NiMH Traxxas battery, which utilizes 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. Power Converter PCB is fully operational and supplies 5 volts to the other sensors on both PCBs.

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 and stability can greatly affect the quality of the data being collected. This step of 3D design also provided the modularity required for the team to easily mount and test the system as a whole, meeting the requirement for a secure, mobile embedded system.

Graphical User Interface using Tkinter: One of the greatest computer engineering challenges that team COTS faced was designing a graphical interface that met the Technical Director's desires for a functional program with many features. Notably, it was difficult to create an interface that allowed for the layering of icons in front of the camera feed to create a layered window effect. Attempts were made to outsource the design to other non-python platforms, but a workaround was used to layer two separate windows that acted as one unit. The python-written GUI's function is to provide analytical and visual data for the user on the status of the mobile data acquisition system. It contains features such as a gyroscope, system battery data, headlight control elements, and a customizable layout. The primary window has an element that is transparent, and within that transparent window is the RC car camera feed, layered behind the main window. The Python program also created windows of fixed position to allow this layering effect to display properly.

Live Video Feed Streaming with Python: A core requirement of this project is to allow for the user to view the current environment that the front of the RC car is experiencing. A live video feed of the front of the car using a camera was determined to be the solution to this requirement. However, readily available native packages for Python and Tkinter do not exist, so a custom package had to be used. Notably, the "imagezmq" library provided a solution that was easy to implement and provided a solution to our requirements. Each frame of the camera is sent individually and is compressed using the .jpg file type. This stream of images is displayed on a window layered behind the GUI. Furthermore, the stream quality and frame rate (how often the screen is updated) was somewhat below expectations. The stream was viewable but fell below a target frame rate of 30 frames per second. It is estimated that the true frame rate is around 15-20 frames per second.

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.

Project Outcome

Unfortunately, the Anticipated Best Outcome was not met. Even though the power convertor successfully distributes power to the other boards and sensors, the team was unable to interface with the TOF, GPS, and the Gyroscope/Accelerometer.

Figures

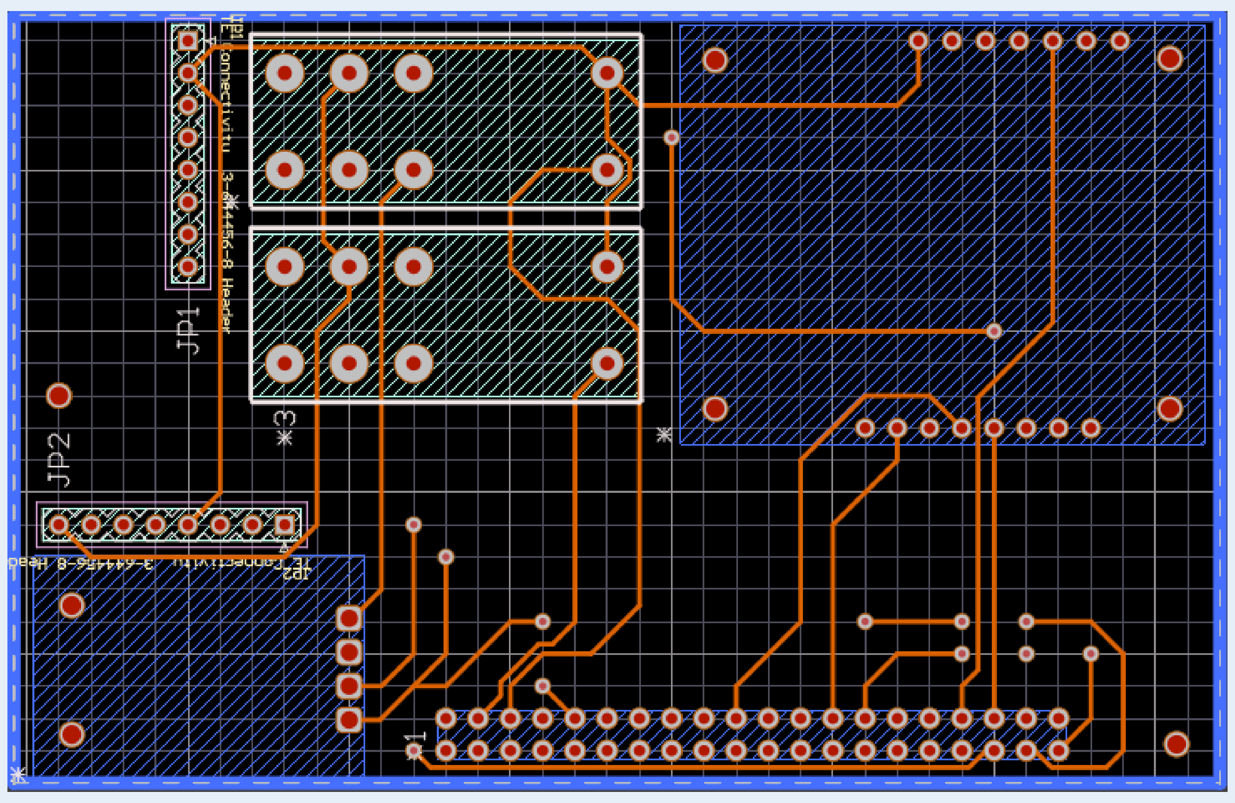

Fig.1: Digital Layout of the Main Pi PCB

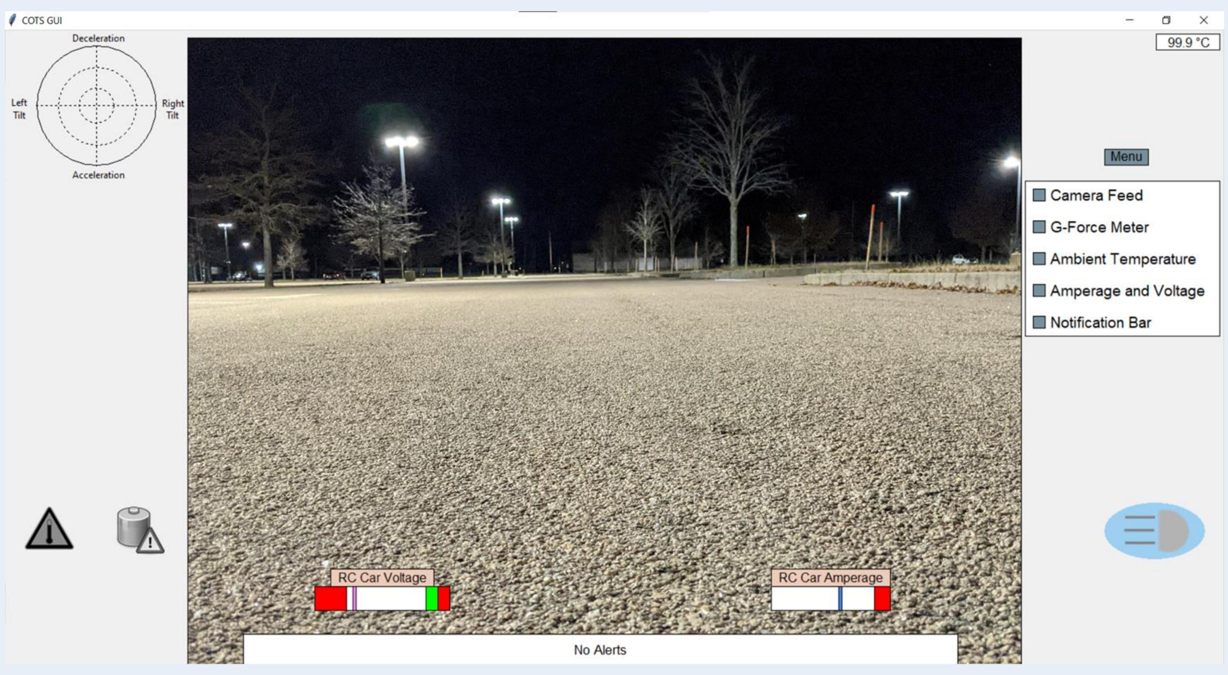

Fig.2: GUI Demonstration

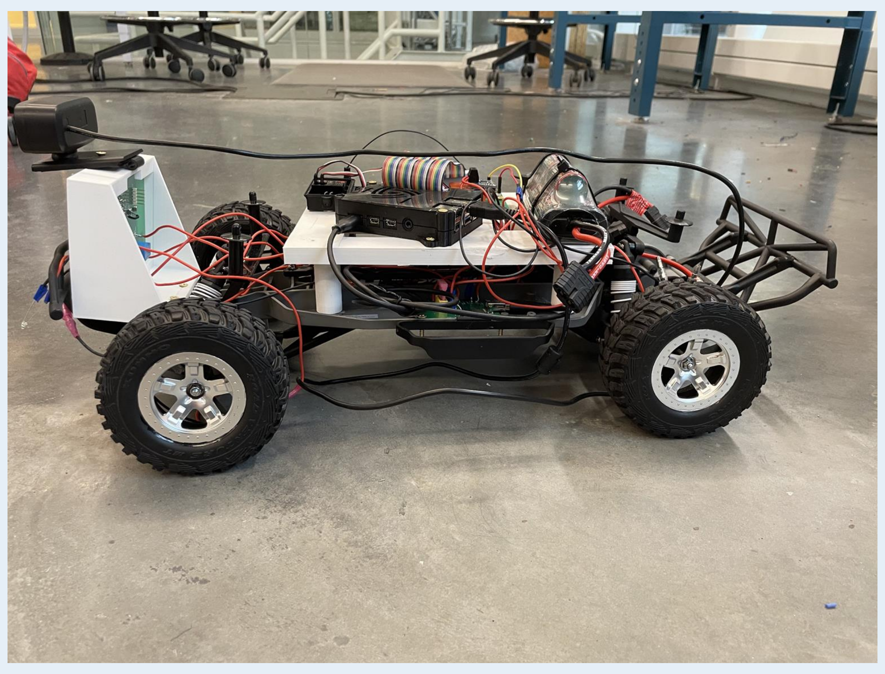

Fig.3: Implemented System

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Contactless DC Battery 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 Rob 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. This device also will enable our Navy to defend our freedom and lifestyle from tyranny. By having submarines and other Navy and military assets Russia and other countries are deterred from such hostile actions.

Key Accomplishments

Key Technical Accomplishments, Research and Findings:

- EM Induction: Inductive charging is a type of wireless power transfer that uses electromagnetic induction to provide contactless electrical power transfer to portable 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: Resonant inductive coupling is the near field wireless transmission of electrical energy between magnetically coupled coils, which is part of a resonant circuit tuned to resonate at the same frequency as the driving frequency. Power transmission efficiency is higher when the transmitter coil and the receiver coil are in close proximity to each other, and the fields are aligned.
- Inductive Wireless Power Transfer systems utilizing resonant coils enables an efficient power transfer over a large separation between a primary and a secondary, as well as allows a high degree of misalignment between coils. The high-*Q* coils are typically made of Litz wire, which exhibits lower skin and proximity effects. Another advantage of resonant systems is that autonomous underwater vehicles of different coil sizes can be charged with a single primary.

Down-selection Using Pugh Matrix Diagram: Our Pugh Matrix Downselection Diagram was used to list all of our technologies and decide which technology we will ultimately use for our project prototype. We had categories for Distance, Efficiency, Alignment, Cost, Environment Compatibility, Operating Lifespan and Feasibility and then weighed each category so we could compare the different technologies.

Project Plan: We made a Project Plan so that we could keep track of what we needed to do and when we needed to do it to get our project finished on time. It acted as a schedule for us so that we could stay on track and not fall behind. Our project plan was broken down by weeks which we put in the "dates column" and then we had our "Items to be Worked on" column with each item's number that would correspond to a list of tasks we needed to complete. Our last column was for "Anticipated Milestone Competition" which was for the biggest tasks we called milestones.

Prototype Design Using Ansys Maxwell Simulations: We used Ansys Maxwell in order to design and simulate multiple coil designs with different ferrite cores. Coils were analyzed at different separation distances and compared based on efficiency and alignment tolerance. The results of a H-field simulation using our chosen coil design are shown **(Fig. 4)**.

Prototype Proposal: The Team developed a template to document all topics required and created a google slides presentation for our Prototype Proposal. This Prototype Proposal was submitted to the Technical Directors for approval. The slides consisted of information on our project's purpose, overview and scope to establish the background information. The team mentioned the different responsibilities and their roles in completing those tasks. For the main part of the proposal, the team addressed the system description and inserted block diagrams **(Fig.1)** for visual reference. Lastly, the team added the list of materials and the building approach and testing strategy.

Produced Required Hardware to Fabricate Project Prototype (Fig. 2 + 3):

- Litz Wire: Litz wire is a type of multistrand wire used for alternating current at high frequencies. The wire is made of many thin wire strands which are insulated and woven together in a specific pattern which equalizes the proportion of the overall length over which each strand is on the outside of the conductor. This patterned winding helps to equally distribute the current throughout the wire and reduce skin effect.
- Ferrite Core: A ferrite core is a magnetic core composed of ferrite. It is used for high magnetic permeability coupled with low electrical conductivity. This will help prevent eddy current loss in our wireless power transmission system.

Anticipated Best Outcome

The 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. The Sponsor will provide guidance and operational requirements for student use in the execution of this project. To control the transfer of sensitive information, the Sponsor will utilize commercial system-based information and publicly available oceanographic conditions.

Project Outcome

We have achieved our Anticipated Best Outcome. As we have fabricated and tested a prototype that was successful in wireless power transfer in an ocean environment.

Figures

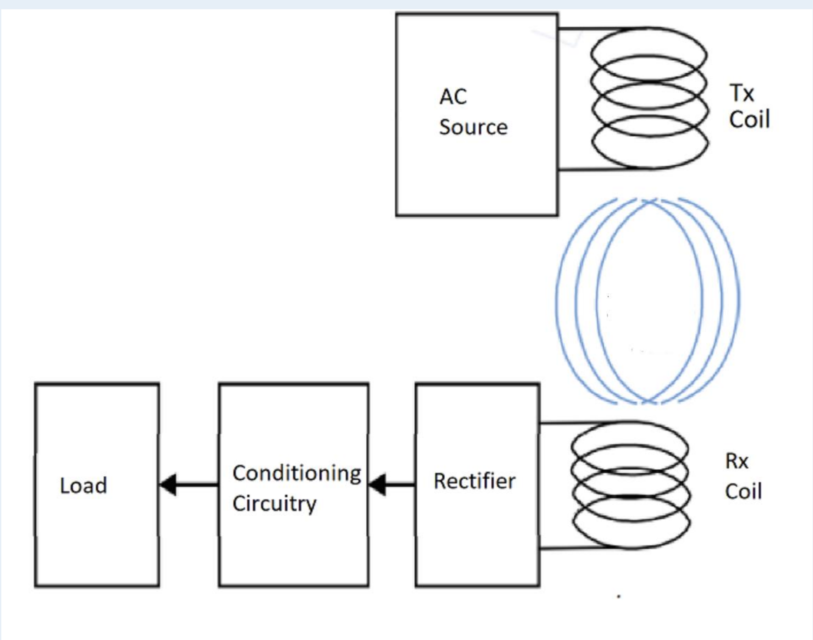

Fig. 1: System Block Diagram

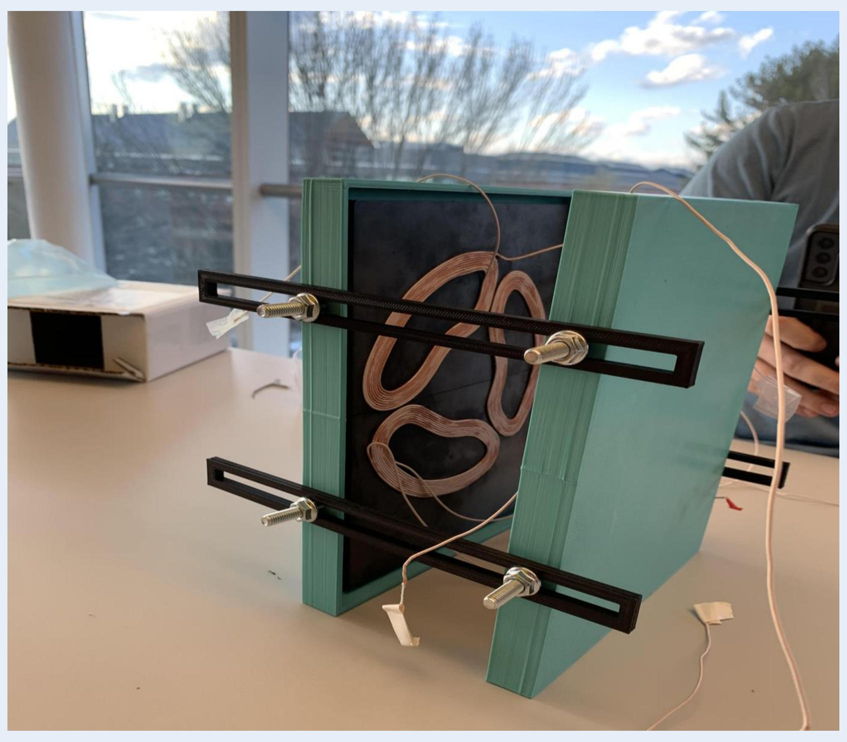

Fig. 2: Primary & Secondary Coils in Test Mount

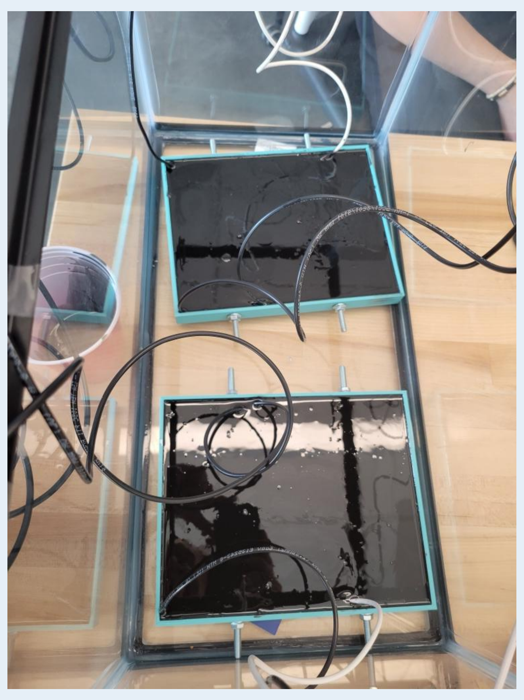

Fig. 3: Primary and secondary coils potted

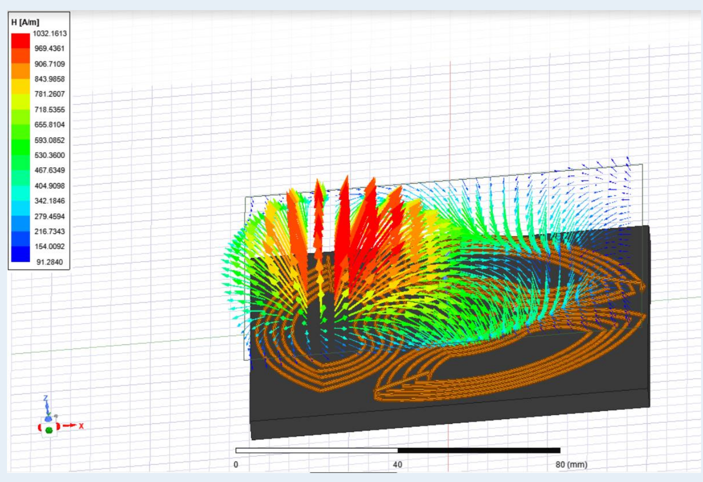

Fig. 4: H-field simulation of chosen coil design

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

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Smart Process

Smart Process Planning for Inspection

HEXAGON
MANUFACTURING INTELLIGENCE

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

Technical Directors: Zachary Cobb, Dr. Manbir Sodhi | Consulting Technical Director: Brenden Smerbeck (ELECOMP '17)

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, and other factors as well. Usually, this problem is avoided by assigning specific tools and machines to specific operators. However, Hexagon CMM's are quite an investment to manufacturers, so most companies only own a few CMMs and use them in as many ways as possible.

Being a limited asset, efficiency is key; more production, more income. Since the manager's schedule is only as good as the information known, thus there is huge potential to improve efficiency by gathering more information. 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.

Key Accomplishments

De-calibration
A Probe is randomly selected a set of rotation angle and tip angle in degrees. The rotation knuckle and the tip angle for the Probe can range from -45, 0, 45, and 90 degrees. We then choose whether to measure one, two or three planes on different axes. We divided 300-hits evenly among the number planes tested. Then we would qualify to see how much the probe's deviations have changed from the start-to-end of that test. Qualification is a process where we check the current status of the probe tip's position and standard deviation against the original calibration that we do at the beginning of the test. The tests repeat with the selected tip until all combinations of the knuckle, tip angle and the selection of planes have been all completed. This results in (12) total tests. The output of all the tests is one set of data that would show the change in X error, Y error, Z error, Probe Radial Deviation, and Standard Deviation from the qualification. Using this data, we can make more concrete decisions on what is affecting the deviations of the probe.

Job Schedule and OEE Optimization
As a team we established 3-different job routines to represent a possible test run on parts within industry. We defined within Hexagons SFx(Smart Factory asset manager) a one-hour shift to complete a random selection of each jobs per week. The number of jobs to complete is defined using linear optimization in which we maximize the amount of jobs each individual received while the total time being less than or equal to one-hour with 10 % allowance for mistakes. After data was collected, we created an optimized job list, created learning curves for each person and compared the OEE(overall equipment effectiveness) calculated with SFx to a manual calculation.

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 were responsible for creating this "master database".

Project Continuation

Future De-calibration Testing: We are going to need several more routines and experiment with similar but slightly different variables. This being an extension to the testing we already have done.

Future Learning Model: One machine learning algorithm we wanted to implement, in our program, is Decision-Trees. 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, external measurements are required. Acceleration sensors, temperature sensors, and a vibration sensors both on the granite surface and CMM movement axle bridge.

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.

Anticipated Best Outcome

The Anticipated Best Outcome was to create an algorithm to solve/give insight to one or more of these topics:

- Probe calibration intervals
- Advantages of using a tempo CMM

Project Outcome

The Anticipated Best Outcome was achieved.

Figures

Figure 1: Coordinate Measure Machine

Figure 2: ::A-45B90:: Rotation 90°,Tip Angle -45°

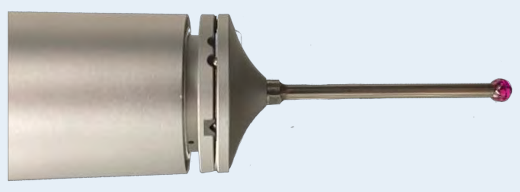

Figure 3: Stylus Tip used by the CMM

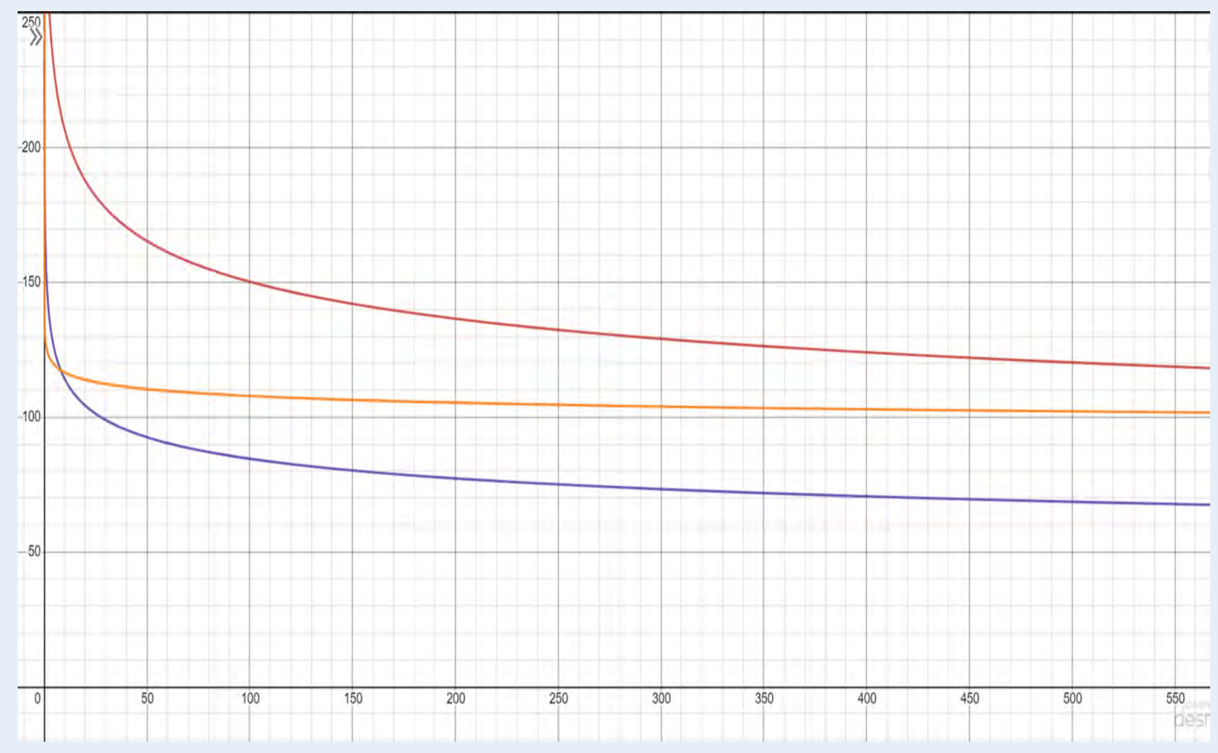

Figure 4: Gasket Learning Curves: Red= Juan (153 seconds= 90 variations), Purple: Pat (87 seconds= 90 variations), Orange: James (109 seconds= 90 variations)

	PR_Error	Styli width (In)	datetime	tip ID	x ABS	yABS	zABS	Probe ID
SD_Error	0.2594	0.3378294	0.293626	0.3205810	0.1728007	0.2086039	0.117342	0.5416525
PR_Error		0.2413396	0.290745	0.1450256	0.4537059	0.9407869	0.286044	0.4682956
Styli width (In)			0.882732	0.8653378	0.1869164	0.2129521	0.194025	0.11138021
datetime				0.5343180	0.0937102	0.2992758	0.084590	0.1802073
tip ID					0.2284091	0.0875808	0.270533	0.0038302
x ABS						0.1542403	0.736172	0.3163962
yABS							0.016648	0.3857442
zABS								0.1929335

Figure 5: Probe Test Correlation Graph – cells outlined in red are considered to be important

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

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UATR Tool

User Acceptance Test Report Tool

iXblue

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

Technical Directors: Daniel Nugent, Patrick Moran, Patrick Lieffering

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

Data Parser For Repeater Data: A data parser was created to read in data exported to a log file from the INS system that records relevant data including commands sent that need to be tested. The text parser searches the log file for important headers and splits the data by each comma or special character found in the line, and prepares the numbers as floats to be graphed in the test report PDF, as well as finding when the zupt mode has been turned off to begin compiling data to be tested.

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 been updated to send commands to the INS. A second GUI was created to deal with the command and logging side of the project. Currently on the GUI, there are buttons to receive a data stream from the INS, restart the unit, create a logging file and other small functions that manipulate INS and read in data such as an indicator light for certain stages of the test. **(Fig. 2)**

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 **(Fig. 3)** can be sent through the python code. Progress was made sending proper commands to the INS and adjusting system functionality.

Threading for Processes: To properly use the Tkinter GUI in conjunction with concurrently running processes such as data stream acquisition, the team had to implement threads in the code so that the GUI would not freeze up and crash when a function was called to interact with the INS. Now that threading has been implemented, working within the GUI itself is fast and responsive and every system function we need can be built on top of this.

Condition tests: Condition tests are one of the main components for the project as a whole. The condition tests are upper and lower limits calculated by summing and averaging all points recorded after the test begins, when the zupt status has been indicated as off **(Fig. 3)**. For the duration of the test values fluctuate, so the data before the change in zupt status will cause false flags of the condition tests. Hence why the upper and lower limits must be fixed and compared with each value recorded in the log file. This is the main feature of the 'test report tool'

Pdf Report Document: A test report document has been created for the user to easily see whether or not the device being tested is within working parameters. When the log file is digested into the program a report including the heading, roll, pitch and position graphs will be created. This pdf report will show all data points in the test, and whether or not they cross the fail thresholds. **(Fig. 4)** The report also contains the Fog and accelerometer biases, which must be accurate to pass the test.

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.

Project Outcome

The Anticipated Best Outcome was not met. The team was very close to the ABO, however we fell short due to time constraints. The final deliverable product was very close to completion, but not refined enough to be called complete.

Figures

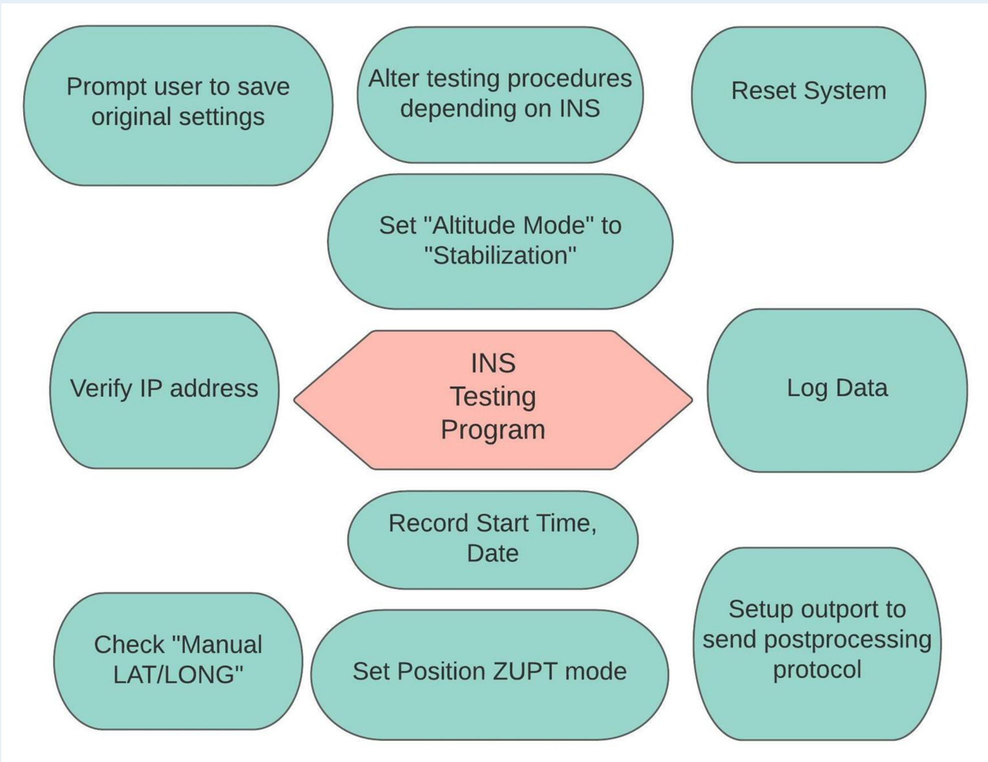

Fig. 1: UATR Program main functions implemented

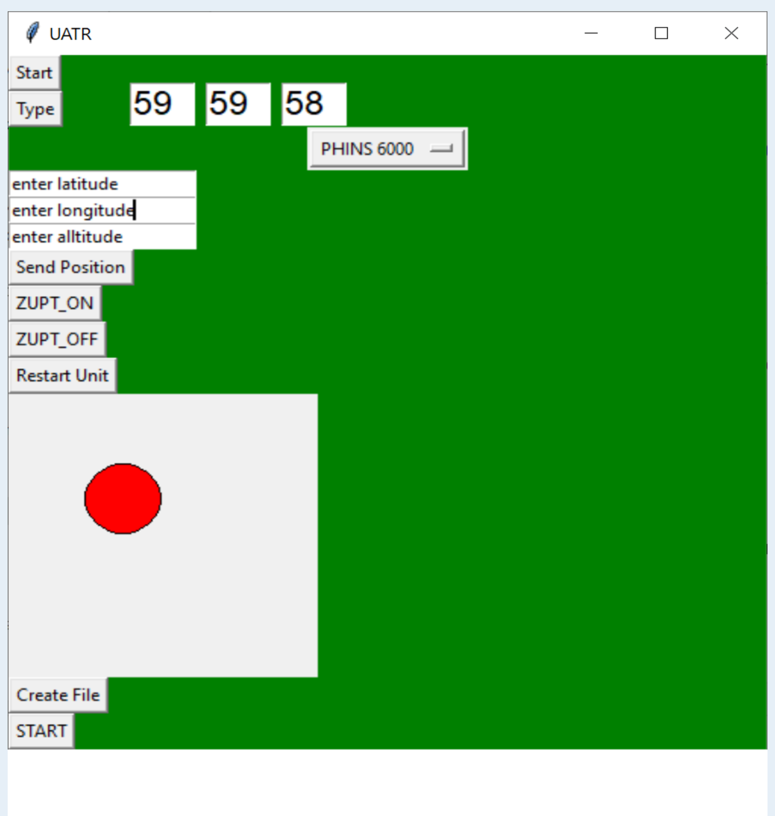

Fig. 2: GUI showcasing functions being used

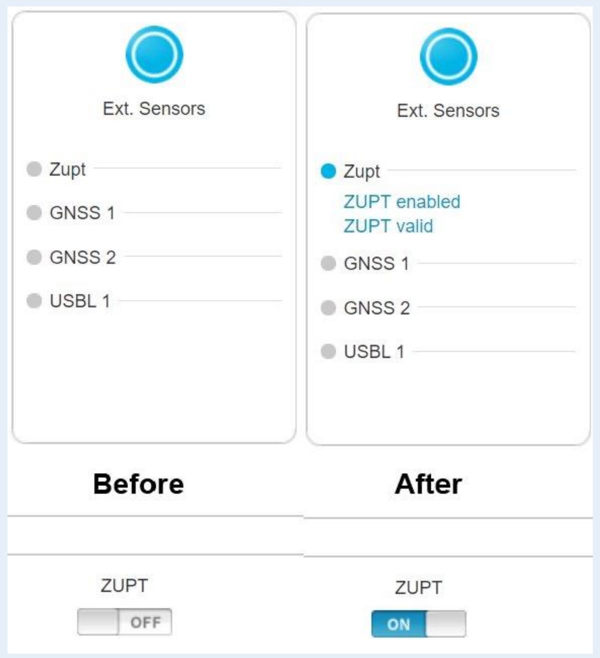

Fig. 3: Demonstration of successfully sent command to alter system functionality (Zupt Status)

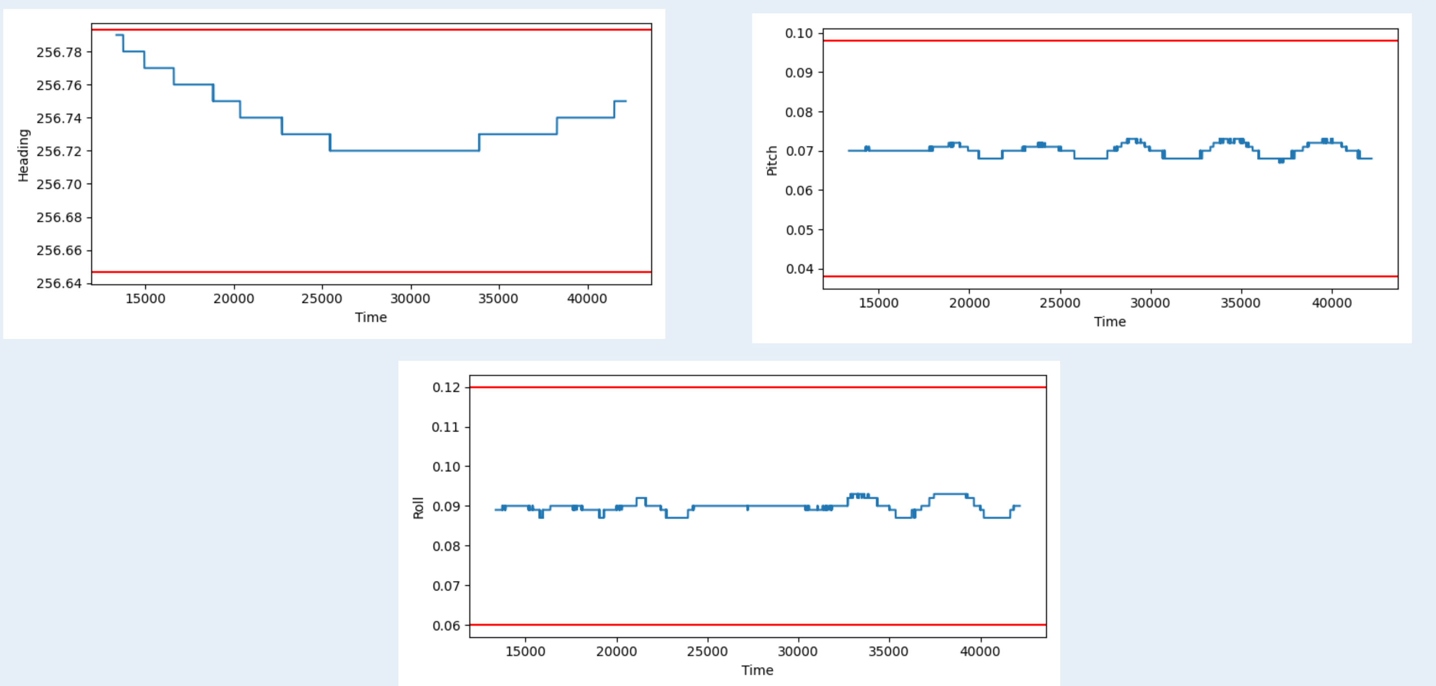

Fig. 4: Upper and Lower bounded graphs from test report

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

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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

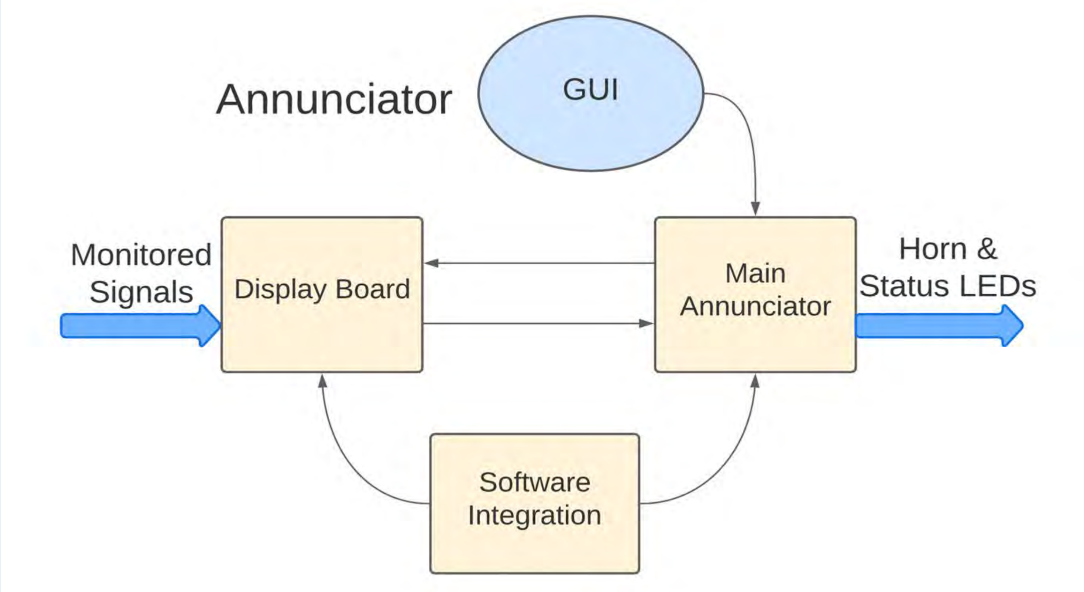
Phoenix Electric Corporation designs custom solutions for the power industry. One product which Phoenix Electric Corporation produces is a control box. It houses an annunciator that is connected to control circuitry and to a circuit breaker. Currently Phoenix Electric corporation relies upon third party annunciators to monitor their control circuitry. These annunciators are not tailored to meet the company's needs nor are they cost effective. To remedy these issues Phoenix Electric Corporation partnered with URI's Capstone program to design a custom annunciator. This annunciator will meet the hardware and software requirements that Phoenix Electric Corporation has. The annunciator will be integrable with the company's control boxes since its chassis is built to fit the company's equipment. Lastly this product will decrease Phoenix Electric Corporations expenses of buying expansive third-party annunciators. Phoenix Electric Corporation will increase their profit by selling their annunciators to their customers.

Anticipated Best Outcome

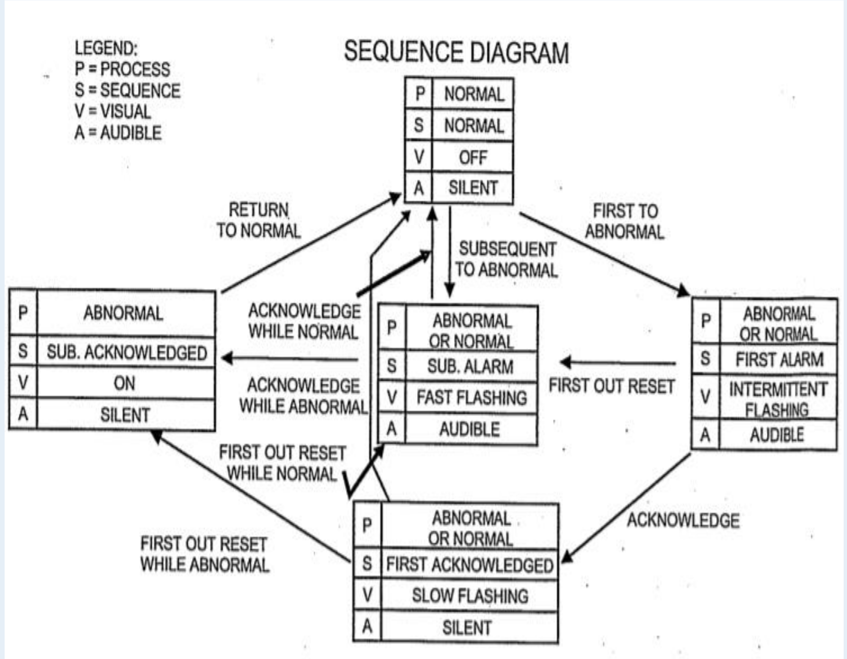
The anticipated best outcome of this project is to present a functional prototype of the annunciator. This annunciator will be expandable, monitoring from 12 to 48 signals. It will have remote access through RS485 or Fiber communication. It will contain visual and auditory displays to alert of fault conditions. All alarms can be reset and acknowledged remotely or manually. The annunciator will store data pertaining to dates and times of faults and will track which signals failed. The annunciator will also be programmable through a GUI, to change alarm sequences, alarm delays, and the status of the monitored circuits.

Key Accomplishments

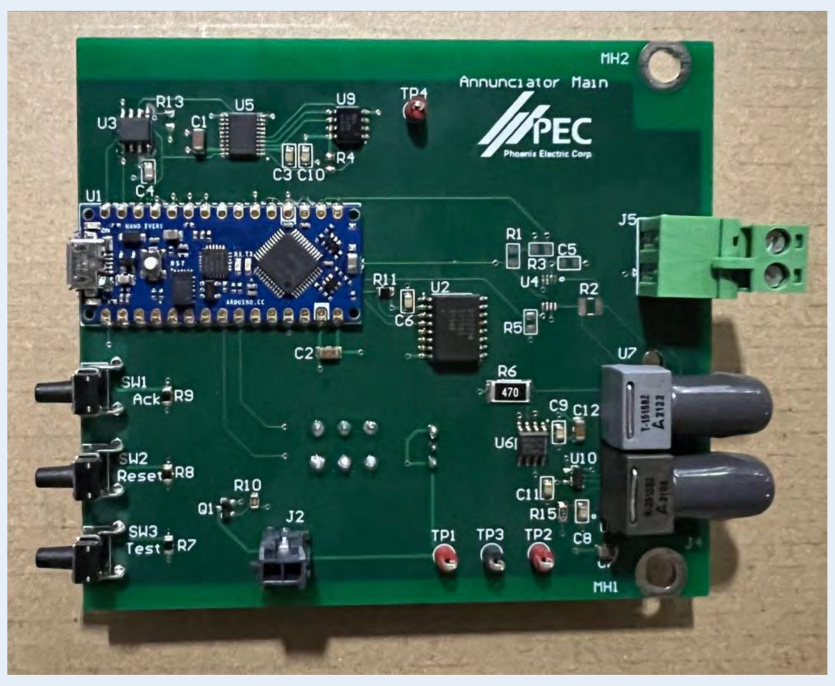
- **Alarm sequences A, M, F1A, F3A:** The annunciator was requested to contain these four alarm sequences as described in the ISA-18.1-1970(R2004), Annunciator Sequences and Specifications. Each of these sequences follows a different set of logic which required individual designing, implementation, and troubleshooting. For an example of alarm sequence see **Fig#6** which shows alarm F3A.
- **GUI:** The GUI was designed to allow users to change the configuration of the annunciator board (**Fig#1**). The settings include the NC/NO channels, the time delays, and the horn selection. The GUI also changes the virtual pushbuttons, the alarm sequences and the size of the annunciator board. The GUI can also retrieve previous settings and show previous errors in the system.
- **Reconfigurable settings:** The program allows the user to change certain parameters of the annunciator. This includes whether a channel is normally open or not, its time delay, and if the horn will be used. Other settings that can be changed are the sequence the system is using, and the system's time. The latter of which is important to prevent the need of reloading the program, during a system power down.
- **Memory map:** During the course of this project a total of two memory maps were made. The first of which was specifically made for working with the 12-channel evaluation board. A second memory map was created for the 48-channel annunciator, and includes time delays, horn usage, serial number, channel configuration, and a data log.
- **Data Logging:** A requested feature was a form of system logging when events of interest occurred. This was handled with careful consideration to ensure a balance of space, efficiency, and simplicity was achieved. The system can record when an error occurs, when an error is cleared, and when the reset or acknowledgement buttons are pressed. Some considerations that went into this are, redundant entry prevention for buttons, rewriting oldest entries when the log is completely full, and a memory saved pointer to next entry write.
- **Compatibility update for new hardware:** With the introduction of the newly designed hardware came a wave of new software considerations. One of the most important things to implement into the program became the expandability of the system from 12 channels to 48 channels. Other changes to the program included pin updating, conditional changes, function redesigns, and memory addresses.
- **First annunciator design:** The project started with hardware consisting of breakout boards for each of the main components. The first redesign parsed the breakout boards for the FRAM, IO expanders, and the RTC. The system had a main board and a display board, in which the biggest constraints were in the IO expanders, since we were using 4 per 12 channels.
- **Second annunciator design:** The second design changed the system drastically, where the display boards would contain the channel inputs and outputs along with the IO expanders and the annunciator board would have everything else. The schematics were also changed to help give the board more utility. Jumper connectors were added to the display board to configure the IO expanders to specific addresses. Using these jumpers gave the board the capability to support up to 48 channels or 4 display boards. On the display board inverters were used to control the bi-colored LEDs. This gave the board the capability to show specifically which channel on the board failed.
- **Final annunciator design:** The final annunciator design was focused on fixing the issues with the first annunciator boards. For this design, four variants were made of the main board to support fiber optic (**Fig#5**) or RS485/422 (**Fig#2**) communication and two types of FRAMs. The two memory options were added due to part shortage. The display board was also also updated in the new design. This update only fixed bugs on the display board.



Fig#4: Block diagram of the Annunciator



Fig#6: Example of alarm sequence F3A

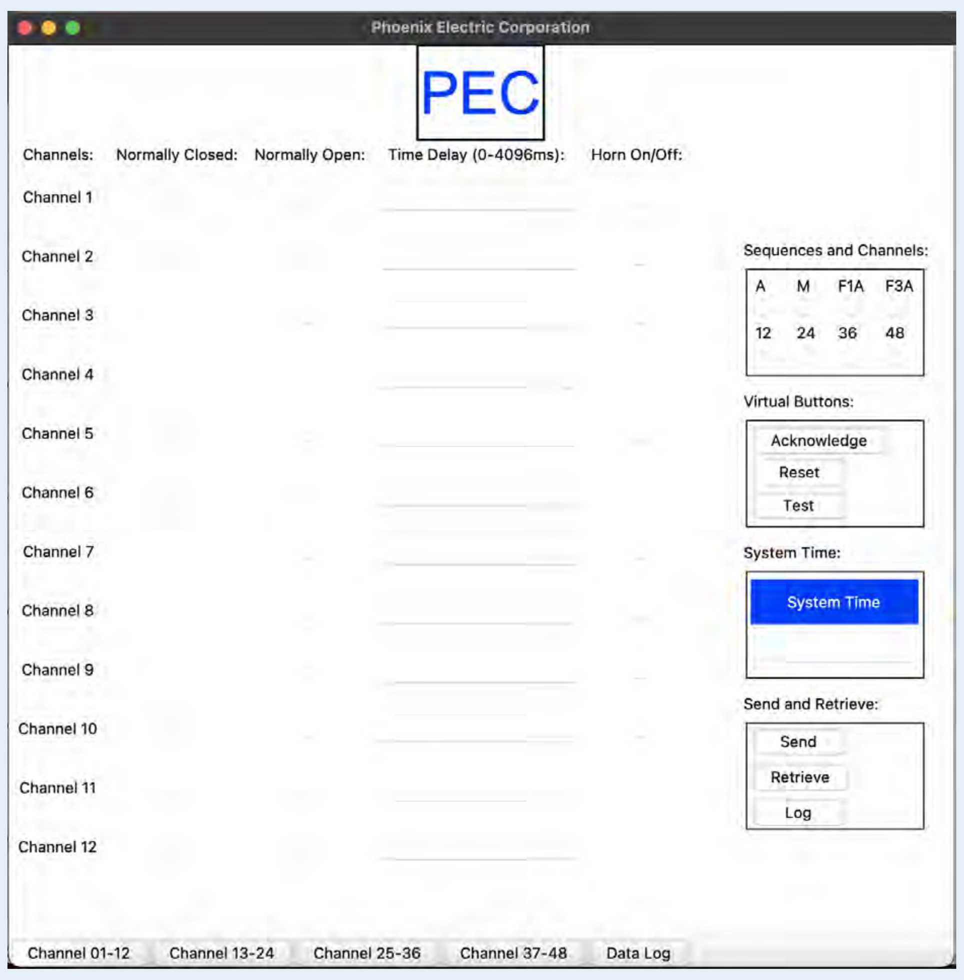


Fig#5: Annunciator Main Board (Fiber)

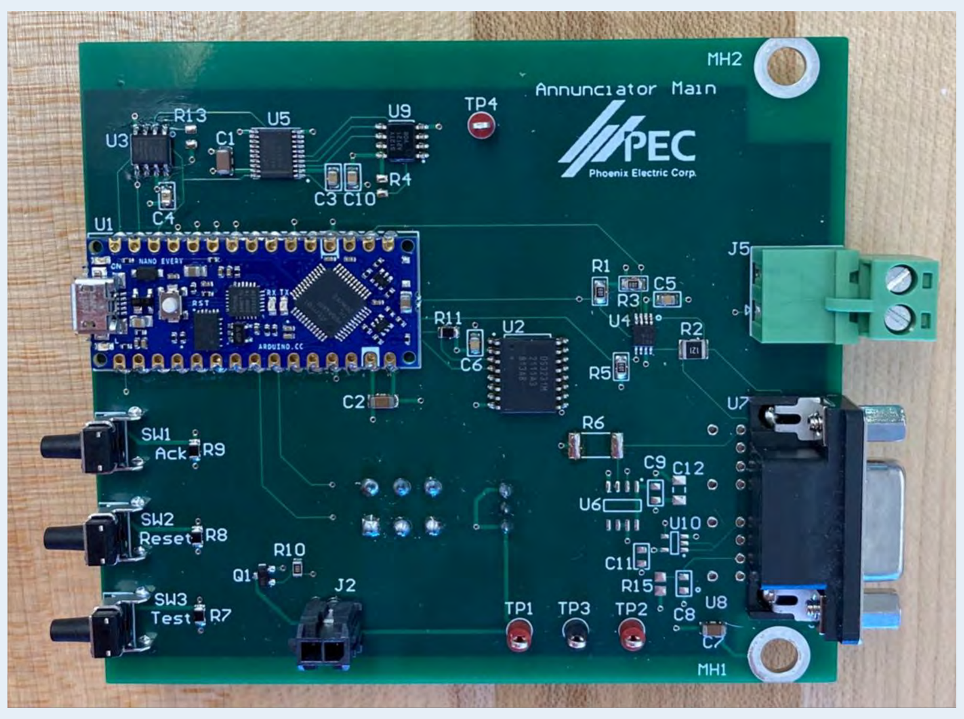
Project Outcome

The Anticipated Best Outcome of the project was achieved. The annunciator prototype monitors the normally open and normally closed signals.

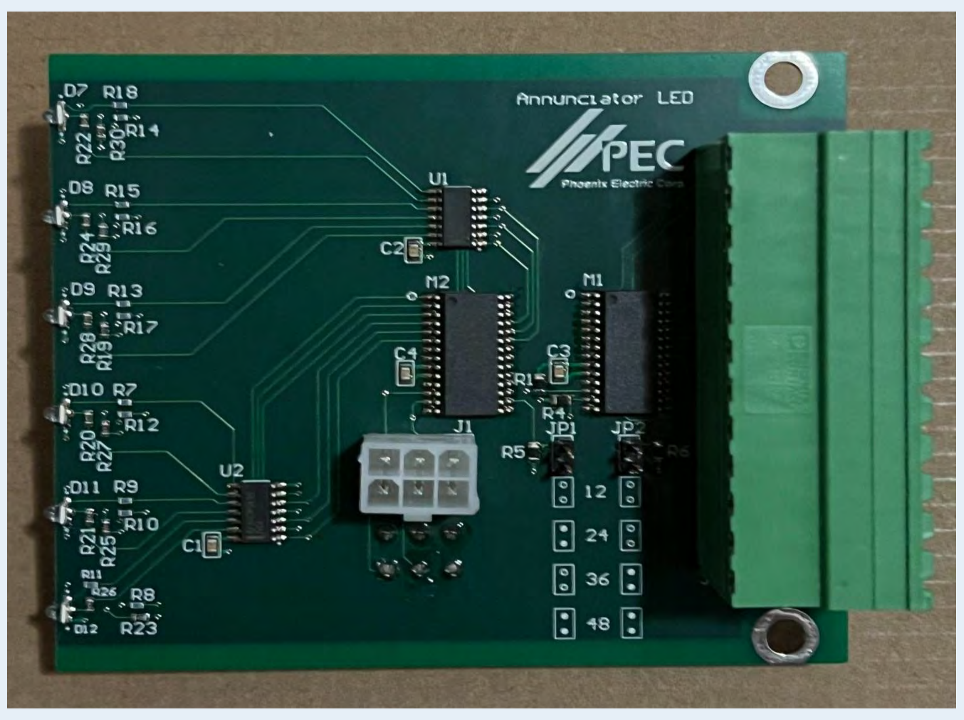
Figures



Fig#1: GUI use to configure the Annunciator



Fig#2: Annunciator Main Board (RS485)



Fig#3: Annunciator Display Board

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

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Hand Gesture Classification

Data Labeling of Gesture Based Biosignals

PISON

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

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

Generated Key Points to use for Validation:
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.

DTW Onset detection on all Sessions:
Dynamic Time Warping is an algorithm that was used for onset detection in this project. This algorithm is very dependent on how accurate the thresholds are for the gestures in this project. Since this was a small dataset to work off of, the thresholds should be adjusted in the future. After implementation of this algorithm, it was clear that better thresholding data is needed for this algorithm to be successful in the future.

KWL Onset Detection on all Sessions:
KWL onset detection was used to aid in better defining the true onsets and offsets. After implementing KWL, it was easy to see that the threshold values were hypersensitive . More adjustments will need to be made for a more accurate result from KWL. The KWL algorithm seems the most promising and will be used in the future.

Bio-Signals and Hodges onset detection on all sessions:
This was another algorithm that was solely signal based instead of being a video-based detection. This implementation was extremely accurate and showed impressive results in terms of the onset and offset bounds of accuracy. **Fig. 1**

Metrics Implementation:
A script was written solely to test the accuracy and ability of the algorithms used to detect onsets and offsets. The onsets and offsets were given from the true onset and offset script and KWL, DTW, and Bio-signals were all tested to see how they did against each other. Overall, bio-signals and KWL performed the best, and some parameters were tweaked to yield even better results. The use of another script was crucial for giving new test values for the thresholds and inputs for the KWL and bio-signals onset detections. The algorithms were then run again and ran through the metrics to see any differences between the different parameters used.

Onset Detection Visualization:
In order to visualize the onset detection algorithms, and how efficient each of them were, a script was generated to plot the square waves from each onset detection algorithm against the initial EMG data. This would then allow a better understanding of how accurate the algorithms were. **Fig. 2**

Roboflow Implementation:
During the course of this project, Roboflow was integrated into the model to speed up the development process. Roboflow is an outside company, in which Pison is using their software to help aid in labeling images split images from the initial video files. A large amount of images were then uploaded to Roboflow via API call, which were then manually labeled to test and train a model. The more images and more variety that is uploaded the more accurate and robust the model gets. **Fig. 3**

Split reps Manual Labeling True Onsets:
Through the use of a GUI, each session was split into blocks, which would then show the EMG data in a visual setting. From then on, a true onset and offset was taken for multiple high confidence sessions. These onsets and offsets were stored in an array of 0s and 1s, 0s being nothing is happening and 1s being a gesture is occurring. **Fig. 4**

Anticipated Best Outcome

The anticipated best outcome of this project has been changed since the initial start of this project. The new ABO consists of having a fully constructed semi-automated pipeline that can accurately label the necessary hand gestures for this project. This project also now consists of a new Roboflow aspect which is now going to be used as an alternate form of processing images against a machine learning model. 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), but in terms of the contractual deliverable, this is not strictly necessary.

Project Outcome

The Anticipated Best Outcome of the project was achieved.

Figures

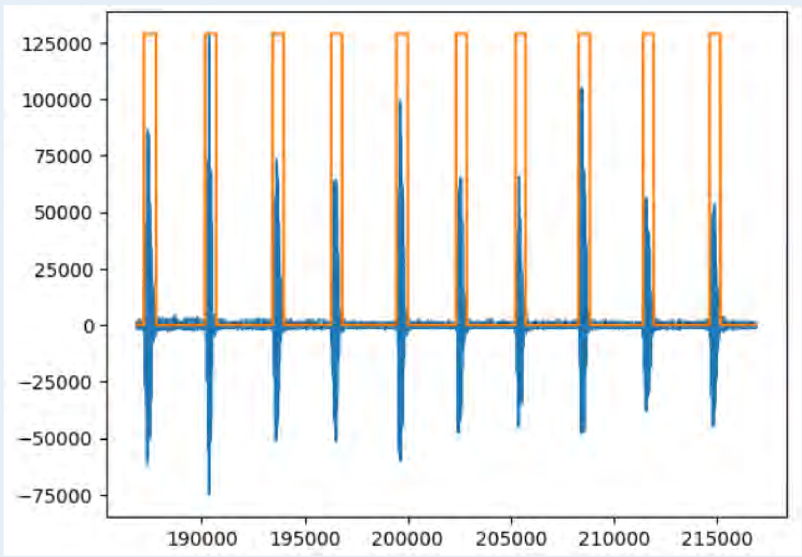

Fig 1: Biosignals Onset Detection

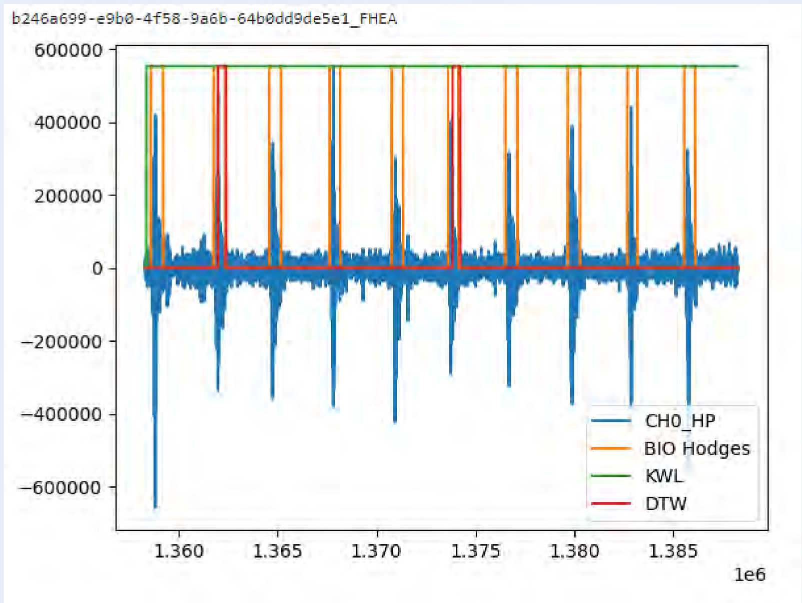

Fig 2: Onset Detection Visualization

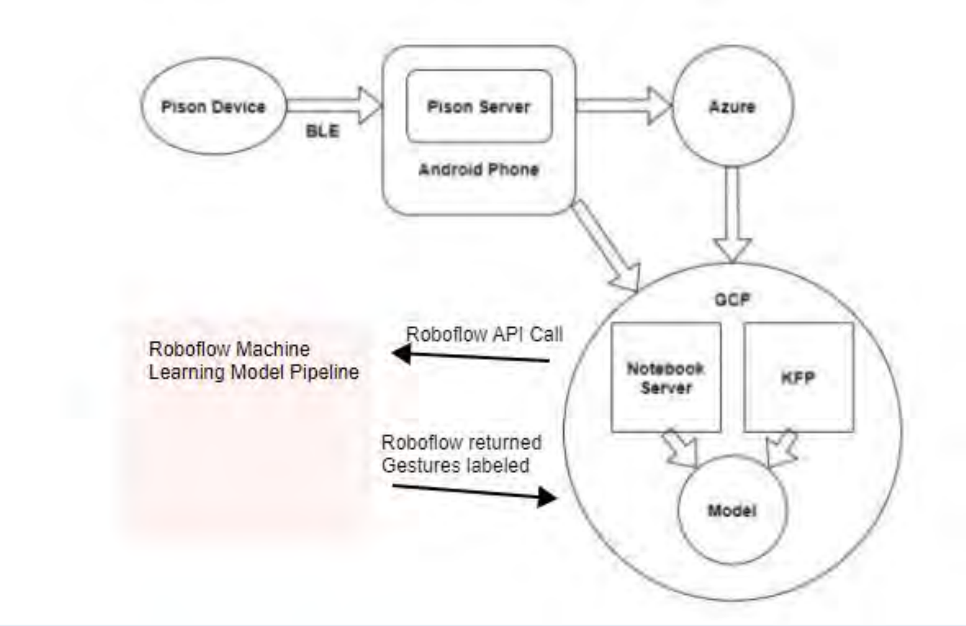

Fig 3: Development Block Diagram Including Roboflow

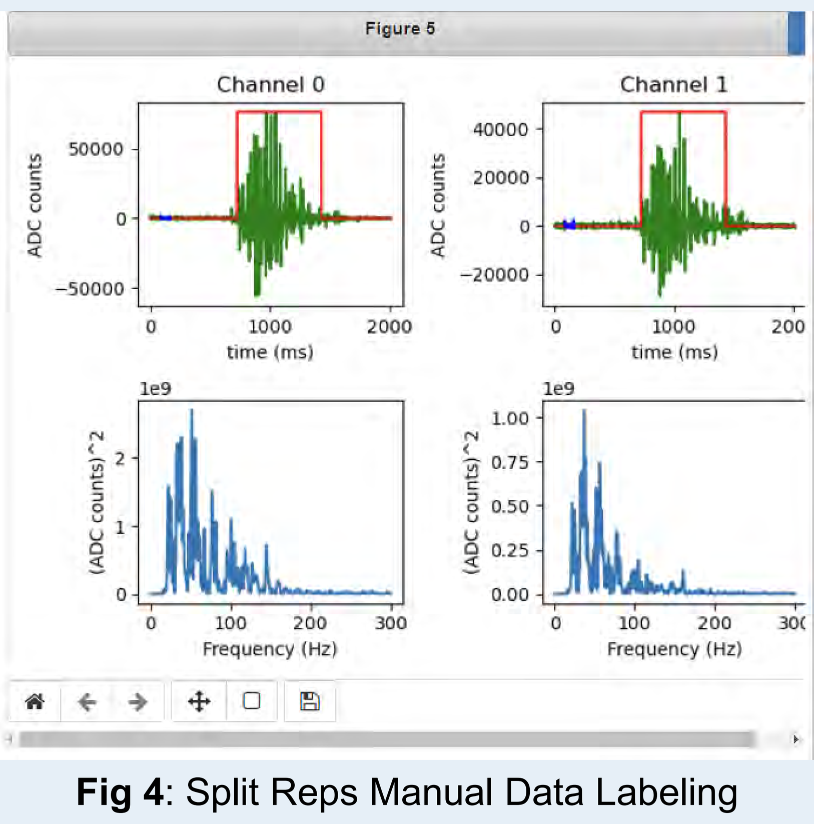

Fig 4: Split Reps Manual Data Labeling

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

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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.
- **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. Movement is input by the evaluator in the evaluator GUI and is modeled off of simulated acceleration tests and tactical diameter measurements.
- **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 a real time map to show the location of own ship in relation to geography and secondary contacts, along with the ability to customize, create, and set the movement of secondary contacts for the operator to interact with, and ability to set ship movement orders received from operator.
- **Evaluator GUI Sprites:** Used Affinity Photo to create 2D image sprites for secondary contacts, merchants, own ship, buoys, submarines, warships, and planes. Sprites will appear on the evaluator GUI map to represent the location of its corresponding vehicle/buoy in relation to the own ship. Took overhead images of Rhode Island geography in Blender to create a geography sprite to represent land on the evaluator GUI map.
- **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.
- **Rhode Island Geography Models:** Used TouchTerrain to create a geography model of RI with elevation data, and purchased a separate model from cgtrader.com containing building assets. Combined both models, resulting in one model with accurate elevation data and buildings/port features to provide an accurate representation of the Rhode Island coast **(Fig 3)**.
- **Ship & Buoy Models:** Downloaded free ship models for secondary contacts and own ship. Secondary contact ships include a merchant (cargo ship), sailboat, trawler, and small craft. The ownship's model is a Virginia class submarine. Created buoy models in Blender, as there were no free buoys models available online.
- **Weather:** Rain and snow effects were implemented using the Unity Engine's particle system component. Fog effects are created using the scene lighting settings. Particle effects are created in a large radius around the operator to maintain performance while reducing the operator's visibility. Evaluator can enable or disable weather effects during active simulation via the Evaluator GUI.

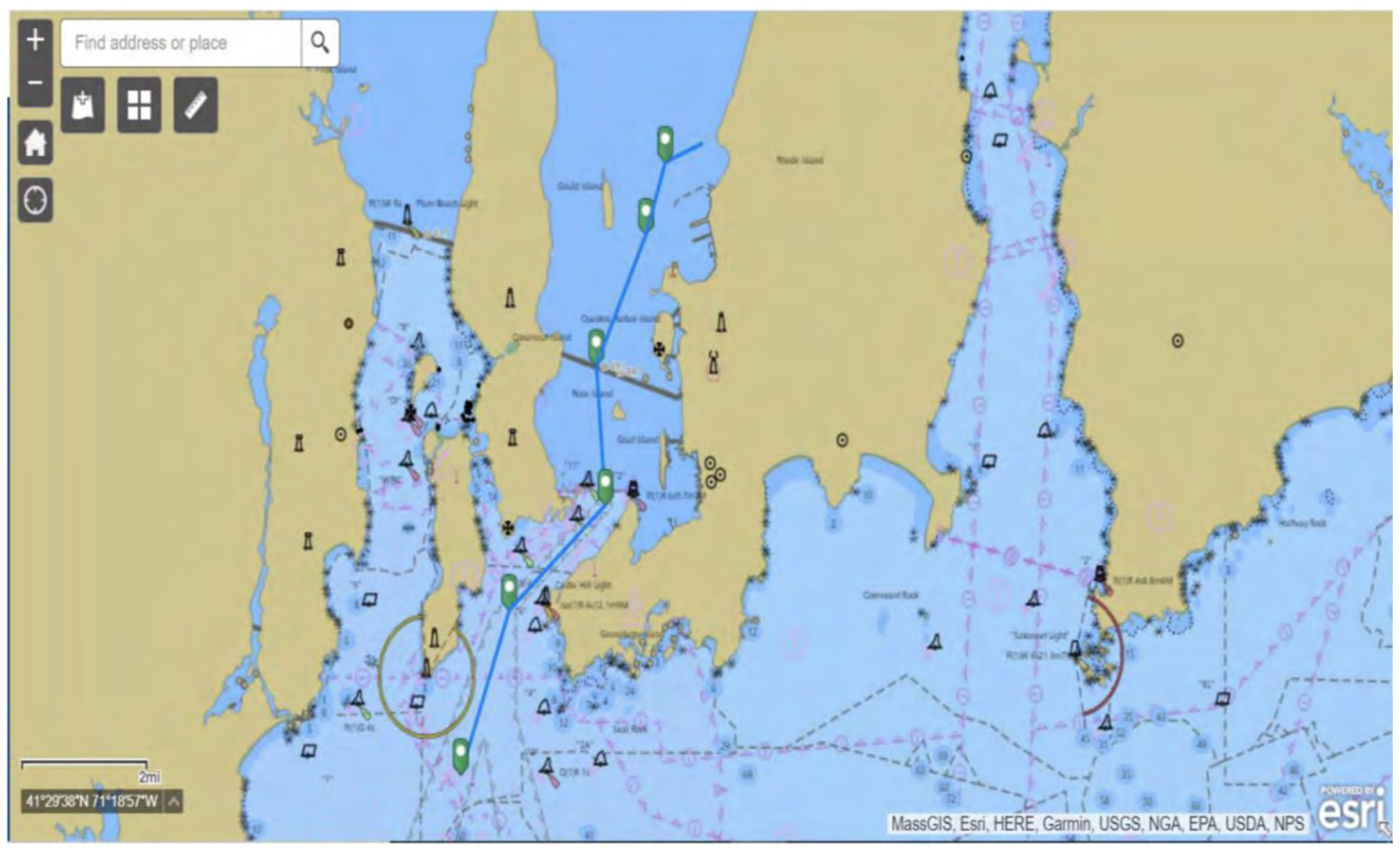

Fig. 4: Example Newport Approach

Anticipated Best Outcome

The best outcome anticipated to be delivered by 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.

Project Outcome

The Anticipated Best Outcome was achieved. At the beginning of the year, we promised a realistic and immersive Virtual Reality training program with the ability to effectively train maritime operators how to handle and navigate their ship under various conditions to include abnormal weather, high contact density, and visual-only navigation through Rhode Island's Narragansett Bay. After 6 months of hard work, we are pleased to declare this outcome a reality.

Figures

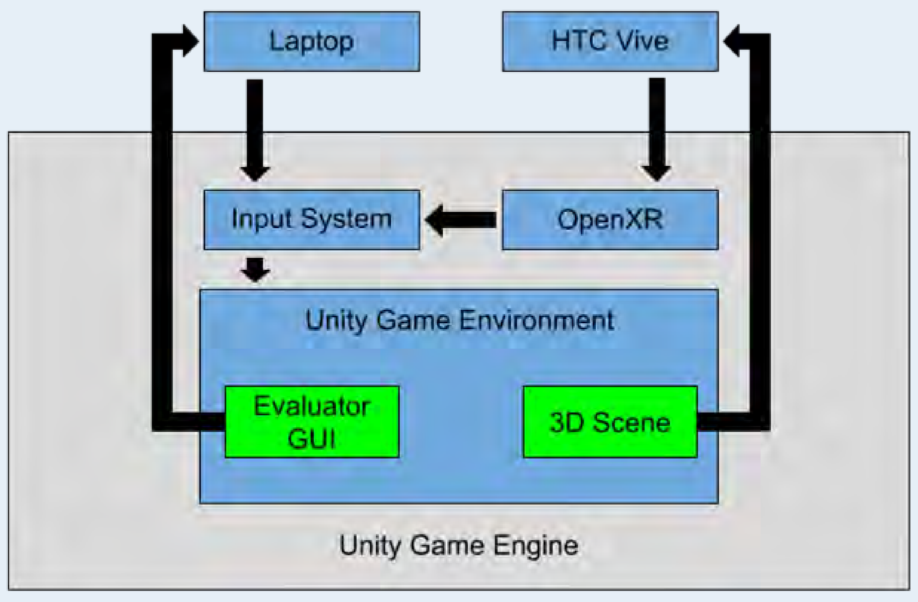

Fig. 1: The functional block diagram

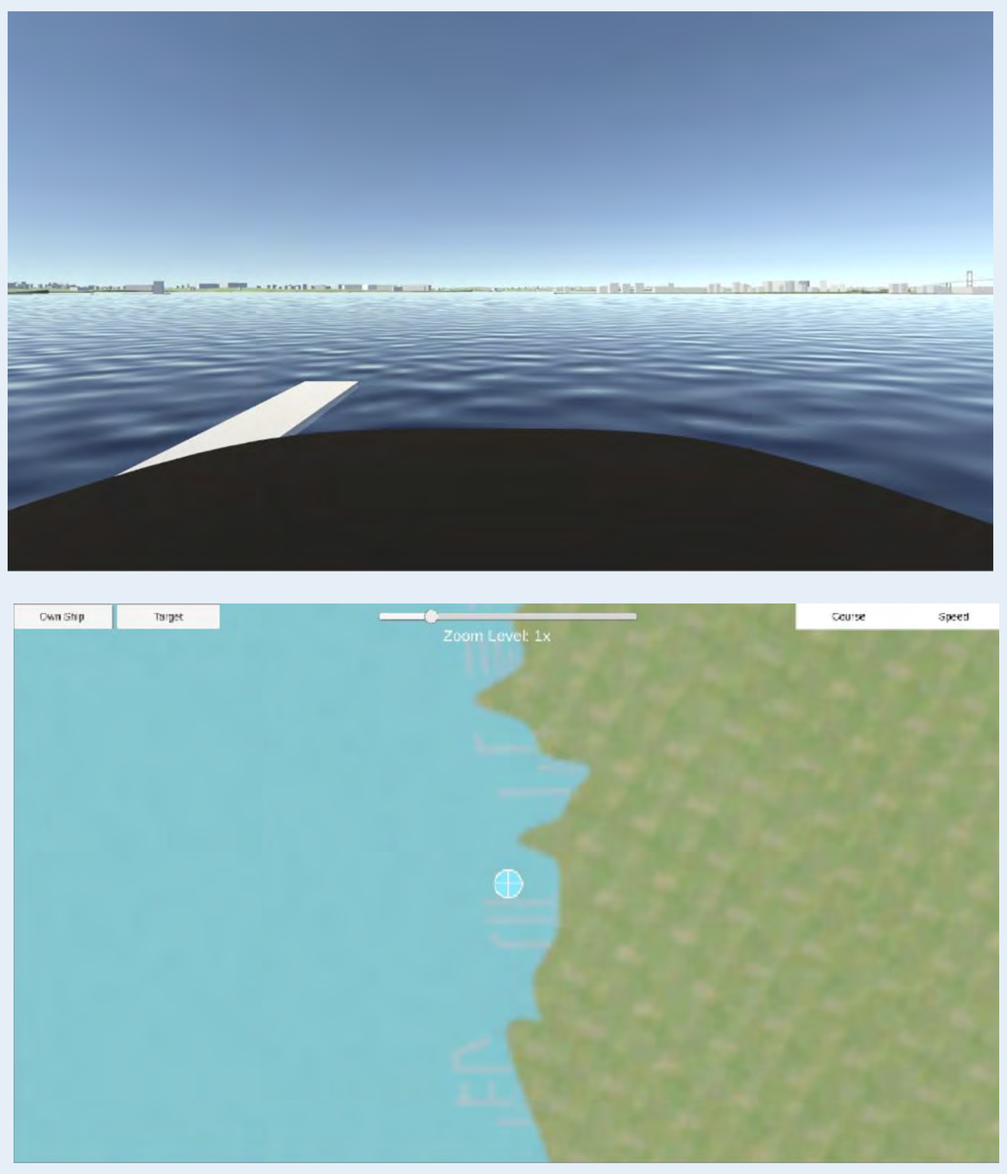

Fig. 2: Unity Project in Editor application (Top: Scene View w/ placeholder boat & water, Bottom: Evaluator GUI with real time map)

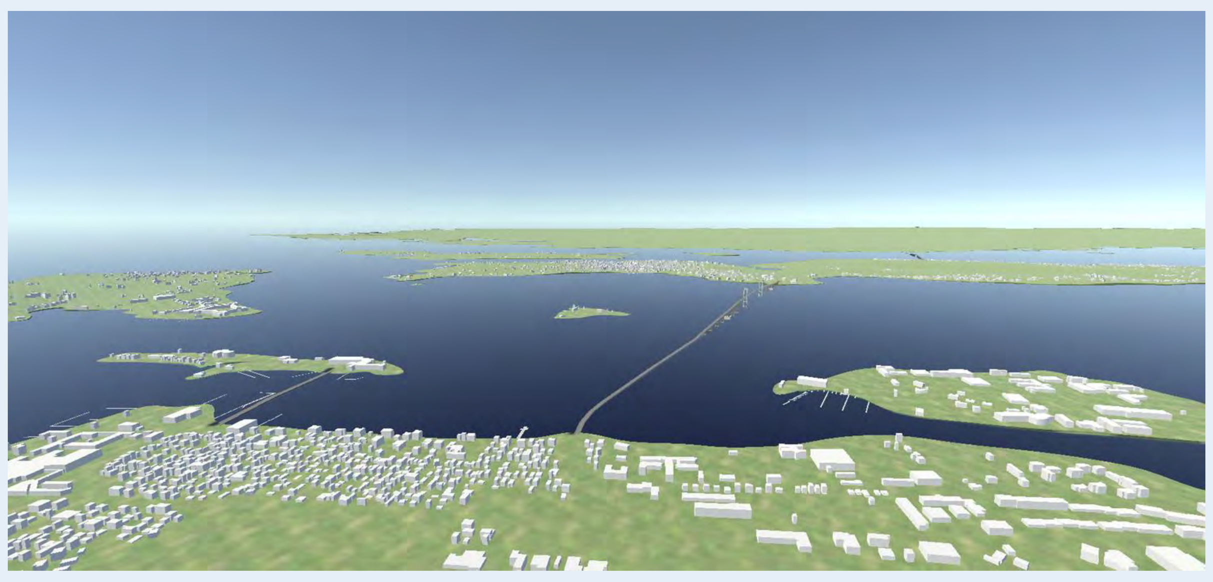

Fig. 3: Rhode Island 3D Model (Newport pictured)

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

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SPBBTR

SmartPlug Bluetooth Button Transmitter and Receiver

Taco Comfort Solutions® A Taco Family Company

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

Technical Directors: Phillip Manning, Robert Kellicker, Nicholas Costello | Consulting Technical Director: Mike Smith ('01)

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 circulate 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.

Key Accomplishments

Prototype Button Board: One of the largest roadblocks our team has had to overcome has been mounting the MDBT50 module onto the Button Board. We have tried many different methods to get the module secured and functioning, but none have been successful. TACO Comfort themselves had to get it soldered on and even they themselves are not sure it's done correctly. All that is left is to finish populating and test Arduino code on the module in hopes that everything is functional.

Hardware Testing For SmartPlug: Preliminary Testing for the SmartPlug circuitry which included testing of the LED MODE, POWER and ERROR circuitry, MODE-BUTTON circuitry as well as the EXTERNAL_SENSOR circuitry. In addition I cut out a hole in the casing of the SmartPlug in order to do safe on-board testing because of the dangers the high voltage side of the board presents. In addition, I had to write simple code to allow successful testing.

Completion of New Rev for Schematics: Received comments and suggestions from technical directors about making corrections to schematics on PADS for SmartPlug. Based on what was suggested, I installed PADS software and made necessary changes to the schematics in order to be able to implement the MDBT50 module onto the SmartPlug. This would set us up towards the final product which should be able to communicate with the Prototype Button Board final product. **(Fig. 1)**

SmartPlug Layout New Rev: Made corrections to layout of the SmartPlug based on corrections made to SmartPlug schematics with the goal of having both completed so that the design with the MDBT50 module can implemented into the SmartPlug and a new board can be ordered and fabricated in the future. **(Fig. 1)**

Mobile Application: Creating a mobile application using Flutter as the platform. Successfully have a physical Android Device connected to Flutter. Currently the Flutter Demo Home Page is available that displays the amount of times a user presses a button. The goal is to have the mobile application act as a button using Bluetooth Low Energy that will communicate with the Smartplug. Along with sending messages to the user the history of the times it was pressed and when it was last pressed and a message that says recently pressed, try later. Downloaded an example of Bluetooth Low Energy (for flutter) from github with errors that need to be debugged, along with creating widgets such as the button and side bars. (**Fig. 4**)

Timeout Errors: Developed code that records when the connection from the button to the SmartPlug takes too long. It is not ideal to allow the devices to attempt connecting forever. Once the time limit is reached, a timeout occurs and the error is recorded. **(Fig. 3)**

24-Hour Idle: Developed code that will transmit a message from the button to the SmartPlug, if the button has not been pressed in a period of 24 hours. This is so the SmartPlug knows the button is still operational and just hasn't been used. The message is to transmit the amount of timeout errors, the remaining battery power, and the bluetooth signal strength. **(Fig. 3)**

Button-Press Time Limit: Developed code that will ignore a button press if the button press occurs within 15 minutes of the last, successfully transmitted button press. Once water in the home is recirculated and heated up, it will remain hot for some time. As such, it would be redundant and a waste of energy to heat up the water if it is already hot. **(Fig. 3)**

Low Power Mode: Developed framework for a power management system that will allow the button to hibernate, thus conserving energy and extending the life of the product. **(Fig. 3)**

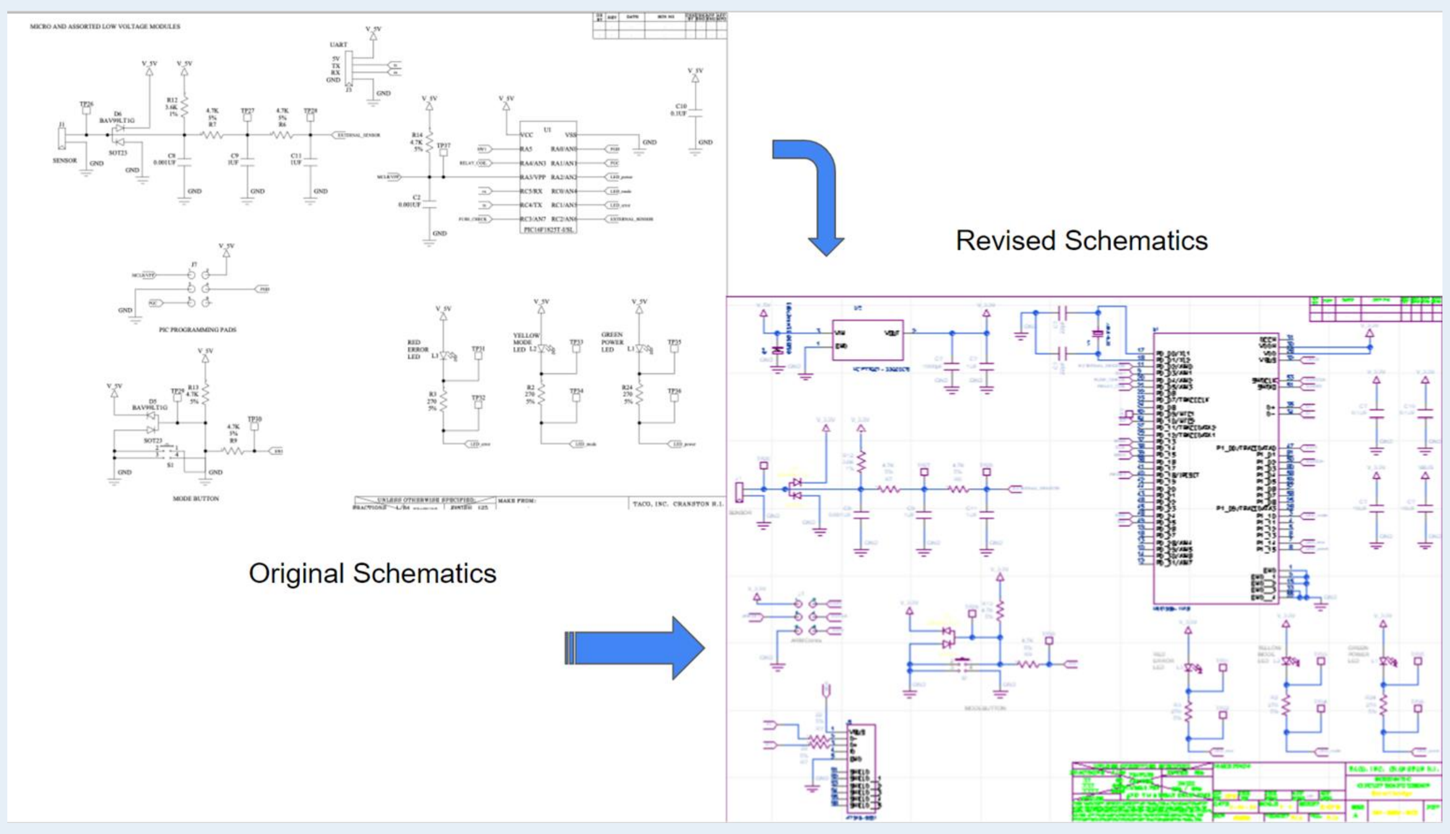

Fig. 1: Schematic Revisions and Corrections Comparison to Original

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.

Project Outcome

The Anticipated Best Outcome was not achieved.

Figures

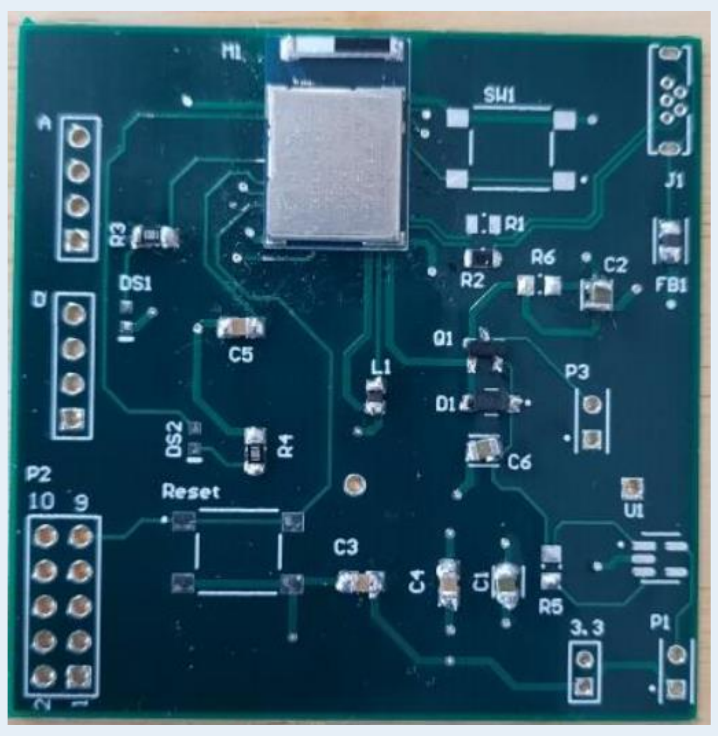

Fig. 2: Prototype Button Board Being Repopulated for Testing

```
void IdleTimer() {
  if (millis() - LastTimeConnected >= 86400000) {
    Serial.println("Button idle for 24 Hours. Sending report to SmartPlug.");
    Bluefruit.requestPairing
    if (Bluefruit.connected()) {
      Serial.println("Bluetooth Signal Strength: " + BLE.rssi() + ble_gap_evt_adv_report_t->rssi ())
      Serial.println("Battery Level: ")
      Serial.println("Errors: " + TimeoutErrors)
void LowPowerMode() {// delay()
  // nrf_pwr_mgmt_init()
  // nrf_pwr_mgmt_run()
  // nrf_pwr_mgmt_config_standby_timeout_enabled
  // RTC1 app_timer for internal interrupt - https://devzone.nordicsemi.com/guides/short-range-guides/b/software
}

bool CheckNotRecentButtonPress() {
  if (true == ButtonPressed && LastTimeConnected <= TimeBetweenButtonPress) { // 900000 millis = 15 minutes
    minutes_ago = LastTimeConnected / 60000;
    minutes_left = TimeBetweenButtonPress - LastTimeConnected;
    Serial.println("Button was pressed: " + minutes_ago + " minutes ago. Please wait " + minutes_left + " more m
  }
   else {
     // send button press and initiate
     // use boolean true/false to call this and use true/false to button-press
  }
}
void Timeout_Error_Func() {
  if (true == ButtonPressed && RadioState = RADIO_STATE_IDLE) {
    Bluefruit.Scanner.start(0);
    PressTime = millis();
    // RadioState == RADIO_STATE_SEARCHING;
    Serial.println("Button pressed. Attempting to connect.");
    else if RadioState == RADIO_STATE_SEARCHING || RadioState == RADIO_STATE_CONNECTING;
      if (millis() - PressTime >= 10000) {
        Bluefruit.Scanner.stop;
        Serial.println("Connection Timed Out. Try again.");
        TimeoutErrors += 1;
        RadioState == RADIO_STATE_IDLE;
        Serial.println("Radio State changed to IDLE");
      }
```

Fig. 3: Prototype code for timeout error, 24-hour idle timer, button time limit, low power mode

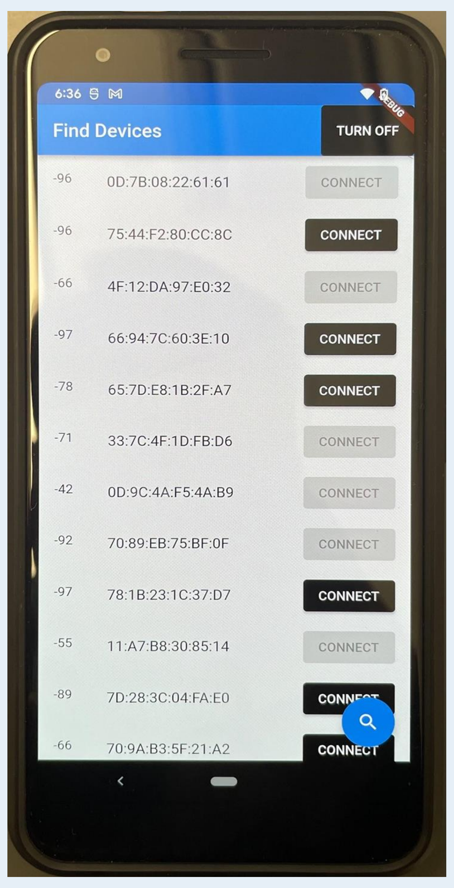

Fig. 4: Application Development using Bluetooth Low Energy for PBB and SmartPlug design

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VICOR

Probe Interface Hardware Checker

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

Technical Directors: Al Binder, Nathan Shake, Daniel Hartnett

Project Motivation

The purpose of a hardware checker is that it immediately tells the test engineer that either a passive component value is incorrect, a component doesn't have a good connection, or a relay is backwards or non-functioning. Having a working hardware checker available gives the ability to quickly debug the hardware and find out the problem. Without one it'd be unspecified if the hardware is dejected, which wouldn't inspire confidence in the board. This ensures that before VICOR sends out the board overseas, the hardware sent is precise and done properly, guaranteeing customer satisfaction. Having the hardware checker at our disposal saves money on company travel, where traditionally it would require an engineer to fly out to the CM to solve the issues. This would allow for the company to save time that would've been lost from having to mail hardware that could potentially run into shipping delay, and money that it would cost to ship out.

Key Accomplishments

P012/P014 Probe Card: There were many technical responsibilities our team had for VICOR's hardware checkers. To begin, for the first couple weeks, our responsibilities included reviewing code for the P012, and the P014. We received code along with the schematics that matched between the two. Our task was to review the code, see what on the schematics the code was testing, and highlight it. This ensured that we could read code and actually see what it was doing and how it was able to test a specific path. We then were given a P012 bump and trim schematic, along with the code only for the trim file. Using what we had, we had to relate the two bump and trim schematics and build a P012 bump code that tests everything in the bump schematic.

P052 Probe Card: The P052 hardware checker was completed by team member Giuliano Biondi. This newly updated schematic of the P052 probe card involved a new timing page, along with a brand-new main page, since the newer P052 differed in pins. In this hardware checker code, it consisted of code written for each APU, every path that could be tested that had a resource, resistor tests, and capacitor tests. The second page of the schematic involved the timing page. To test this page, I had to switch relays and follow the paths from the main page onto the timing page.

Eagle Test Program: After putting time into understanding the eagle test program, our team is now able to understand how to compile, test, and work on the code inside the eagle test program. This is beneficial because in eagle, there are many different buttons that assist you in writing and editing code. Programs such as raide and other tools proved to be helpful in debugging code. You are able to compile, run the code, and actually see where you get errors, and go to that line and step through each line to see where there is an error in the code, which can save a lot of time for projects.

P069 Probe Card: The P069 hardchecker was completed by the team member Boston Le. The P069 was similar to the first probe card received; the P014. However, there were minor differences that made a tremendous impact with pins and apu's being in different locations or having mat's that will provide different readings. Like most other hardware checkers this had a schematic that had to be contact traced following different paths to see what was occurring. Simultaneously these paths would allow the designer to construct code following the paths and in this scenario from left to right. The code is created to verify the pins by forcing current/voltage to either measure voltage/current. If the range falls within the proper limits, then the code works correctly. With relays being closed and opened to the APU's you can expect 0 uA if the relay does not open to the APU, however if it opens to the APU without any other resources such as resistors you can expect the certain amount of voltage/current forced to make it to the pin.

P040 Probe Card: The P040 hardware checker was completed by the team member Boston Le. In this spring semester a new assignment to create a hardware checker was tasked . This hardchecker is the P040's and it was an all-new checker with new schematics. The main page, timing, and driver page were all fresh and it would be my first time viewing it. In the beginning we verify a path has been tested by highlighting contact traces to see which pins went to certain APU's or resources.

100 Pin Needle Checker: The 100 Pin Needle Checker was completed by the team member Giuliano Biondi. After the completion of the P052 Hardware Checker, the next task was to create a program that tests if each pin on a needle work. To do this, a program was created by testing the resistivity of the pin being tested and its surrounding pins while there was an open connection, and again while there was a short connection. After that was created, two new sets of tests needed to be created, testing the capacitance of the pin being tested and its neighboring pins again, while having a open connection and a short connection. After all these tests, we can conclude if the pins are correctly working or not.

Anticipated Best Outcome

The best anticipated outcome of the project by April 15th, 2022 would be that the designers create as many hardware checkers as possible, and with that, gain a good understanding of how the code works. The hardware checkers will be able to test the probe cards to confirm the hardware's functionality. These hardware checkers will be fully functional for every probe card created under the same specifications as the code written.

Project Outcome

The Anticipated Best Outcome was achieved**.**

Figures

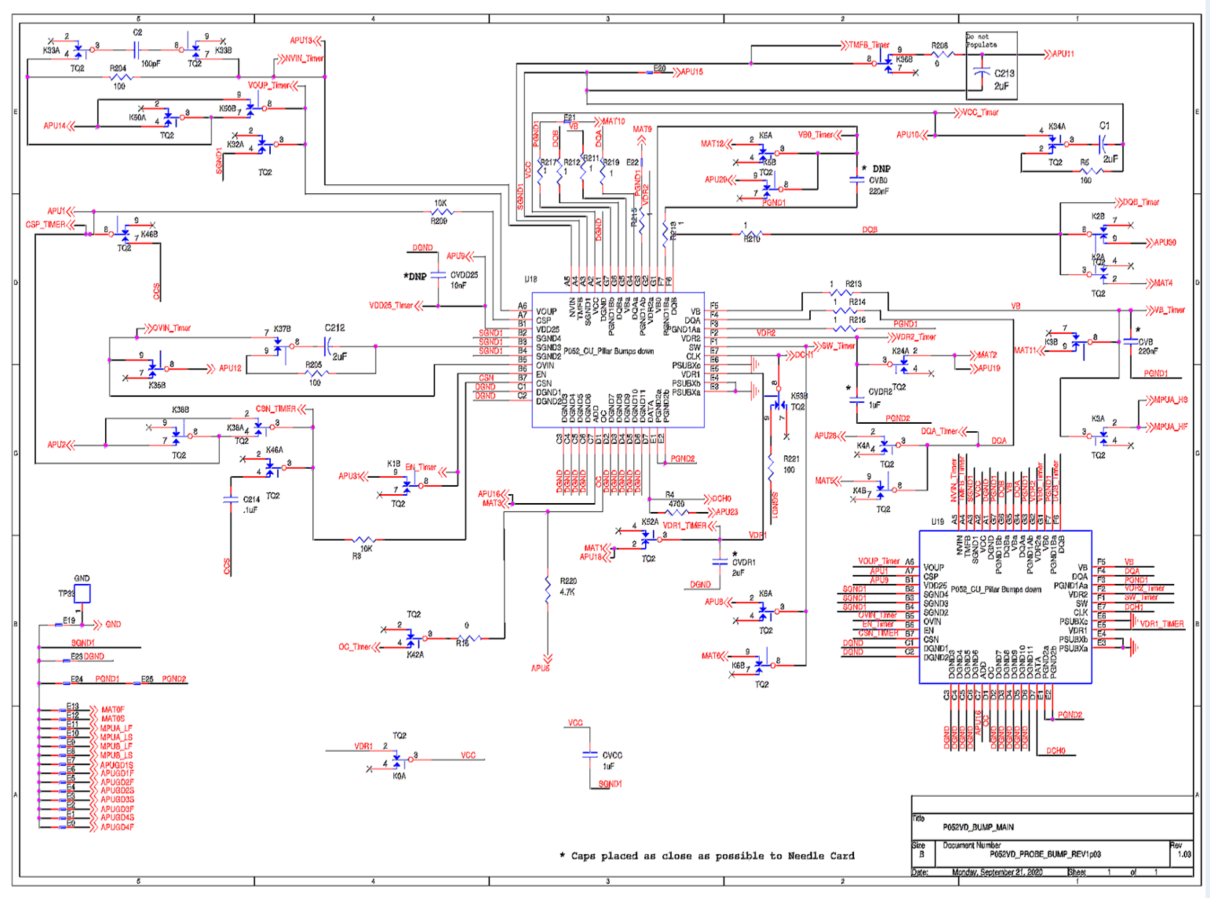

Figure 1: *P052 Main Page*

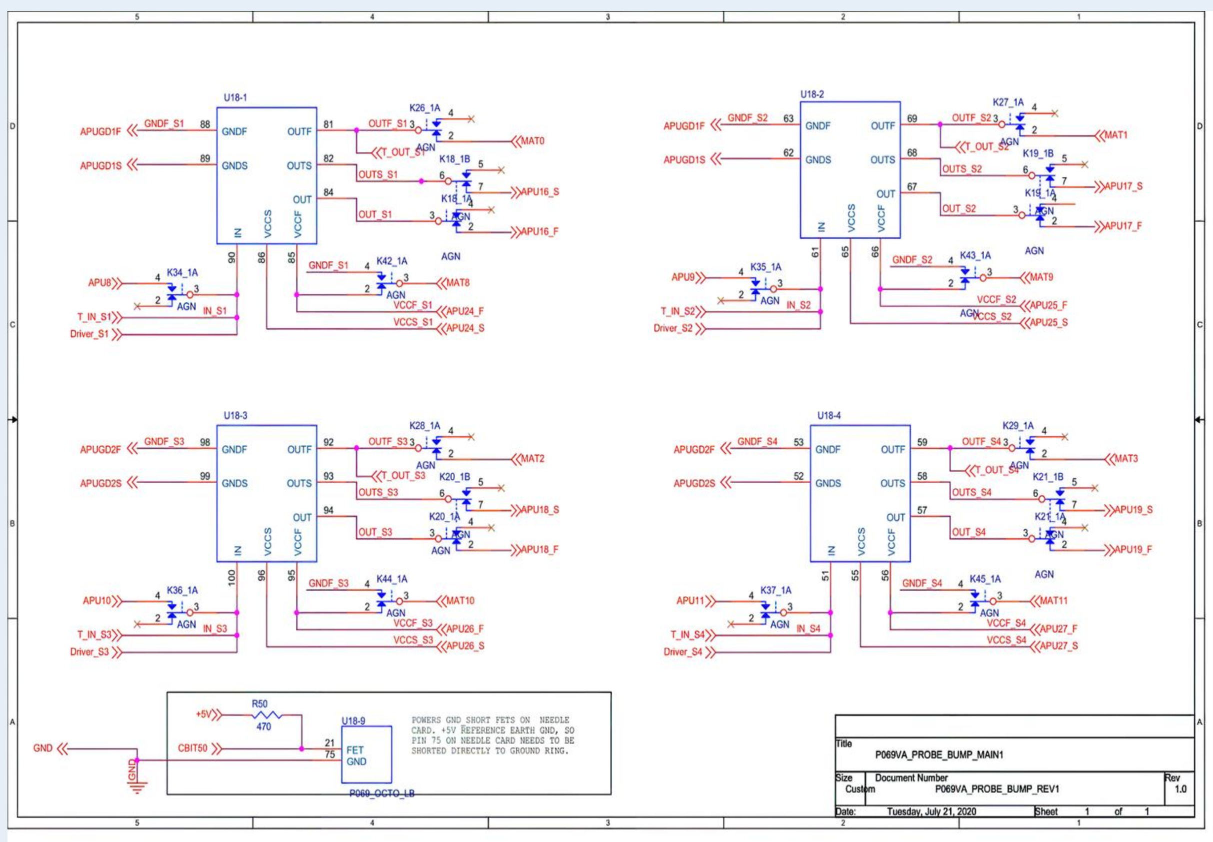

Figure 2: *P069 Main Page*

```
// PIN 71
    apuset( PIN_71 , APU_FV, 1.0, APU_10V, APU_1MA, PIN_TO_VI );  //turn PIN71 ON
    lwait( 10000 );



//Pin 71 to 70
    apuset( PIN_70 , APU_FV, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait( 1000 );
    pin71_70_o=apumi( PIN_71, 10, 10 );
    pin71_70_o*=1e3;

    apuset( PIN_70 , APU_VIOFF, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait(1000);



//Pin 71 to 71

    pin71_71_o=apumi( PIN_71, 10, 10 );
    pin71_71_o*=1e3;


//Pin 71 to 72
    apuset( PIN_72 , APU_FV, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait( 1000 );
    pin71_72_o=apumi( PIN_71, 10, 10 );
    pin71_72_o*=1e3;

    apuset( PIN_72 , APU_VIOFF, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait(1000);


//Pin 71 to 73
    apuset( PIN_73 , APU_FV, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait( 1000 );
    pin71_73_o=apumi( PIN_71, 10, 10 );
    pin71_73_o*=1e3;

    apuset( PIN_73 , APU_VIOFF, 0.0, APU_10V, APU_1MA, PIN_TO_VI );
    lwait(1000);
```

Figure 3: *Needle Checker Resistance Test for pin 71*

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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 to obtain the status codes which is a time consuming and tedious process. 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. The sensor system will be capable of quickly detecting and deciphering the status LEDs to determine if the product is properly functioning in real time.

Key Accomplishments

Sensor Characterization
Over 18 varying types of sensors were tested creating different light profiles to compare the characteristics of each before selecting Kingbright's APS5130PD7C-P22 all in one photodiode sensor due to its distinct results across the measured conditions making the algorithm development easier as well as the physical design advantages offered by having the RGB sensors in the same package.

PCB design and fabrication
The 2.2" x 2.5" six layer double-sided PCB shown in **Fig. 2** possesses six APS5130PD7C-P22 sensors feeding into a voltage divider between a resistor to ground and an operating amplifier. The sensor signals are sent into the multiplexers (NX3L4051PW,118) which are then sent into the microcontroller (dsPIC33CK256MP508). The microcontroller controls the switching of the multiplexers and uses temperature sensors (TMP236AQDBZRQ1) to monitor the overall prototype. The PCB contains a 5V layer, a 3.3V layer, and a ground layer since the Kingbright sensors use 5V while the microcontroller uses 3.3V. The different voltages are obtained by using two DC/DC converters (Max1626). A transceiver (MAX3227CDBR) creates a serial connection between the microcontroller and the computer. A DB9 serial port is located on the PCB which connects the transceiver and the computer. The PCB was fabricated by JLCPCB and was populated in the Capstone Lab.

Enclosure and Mounting Solution Design
A 3D printed enclosure was designed and assembled to encase the PCB along with a mounting solution attaching it to the TX550 card creating a "dark channel" isolating the status LEDs from the ambient light shown in **Fig. 2**. The enclosure has a viewing slot built into the cover facing the TX550 so that the sensors can detect the LEDs.

Microcontroller Configuration
The microcontroller uses its ADC module to monitor the signal from the photodiodes and the temperature sensors. Offering several ADC resolutions, a 12-bit resolution was selected to represent 4,096 unique values. Remappable I/O pins are used to control the switching of the multiplexers. A JTAG is used to program the microcontroller.

Algorithm Development
With the completion of the sensor characterization, several trends were observed proving useful in the development of the LED/Color Detection algorithm. To differentiate if an LED is on, the three colored channels were totaled and the result would be compared to the threshold being 0.5V. If the result was greater than 0.5V, the logic displayed in **Fig. 3** would be checked.

Communication
Established and tested serial communication between the microcontroller and the user's computer, by using the microcontrollers UART transmitter(TX) pin to stream data to the user interface and receiver(RX) pin to receive commands back from the user interface. Putty was also implemented as a debugging tool for this process.

Graphical User Interface
The GUI created allows the user to establish a communication connection once the COM port setting have been specified. Under "LED Status"(**Fig. 4**) the user can view the state of each color LED. Under "Sensor Array" (**Fig. 4**),
six cells were added to represent the sensor array, giving the user a visualization of what the sensor array is viewing. Once fully implemented, each corresponding cell will change to the color of the LED that has been detected.

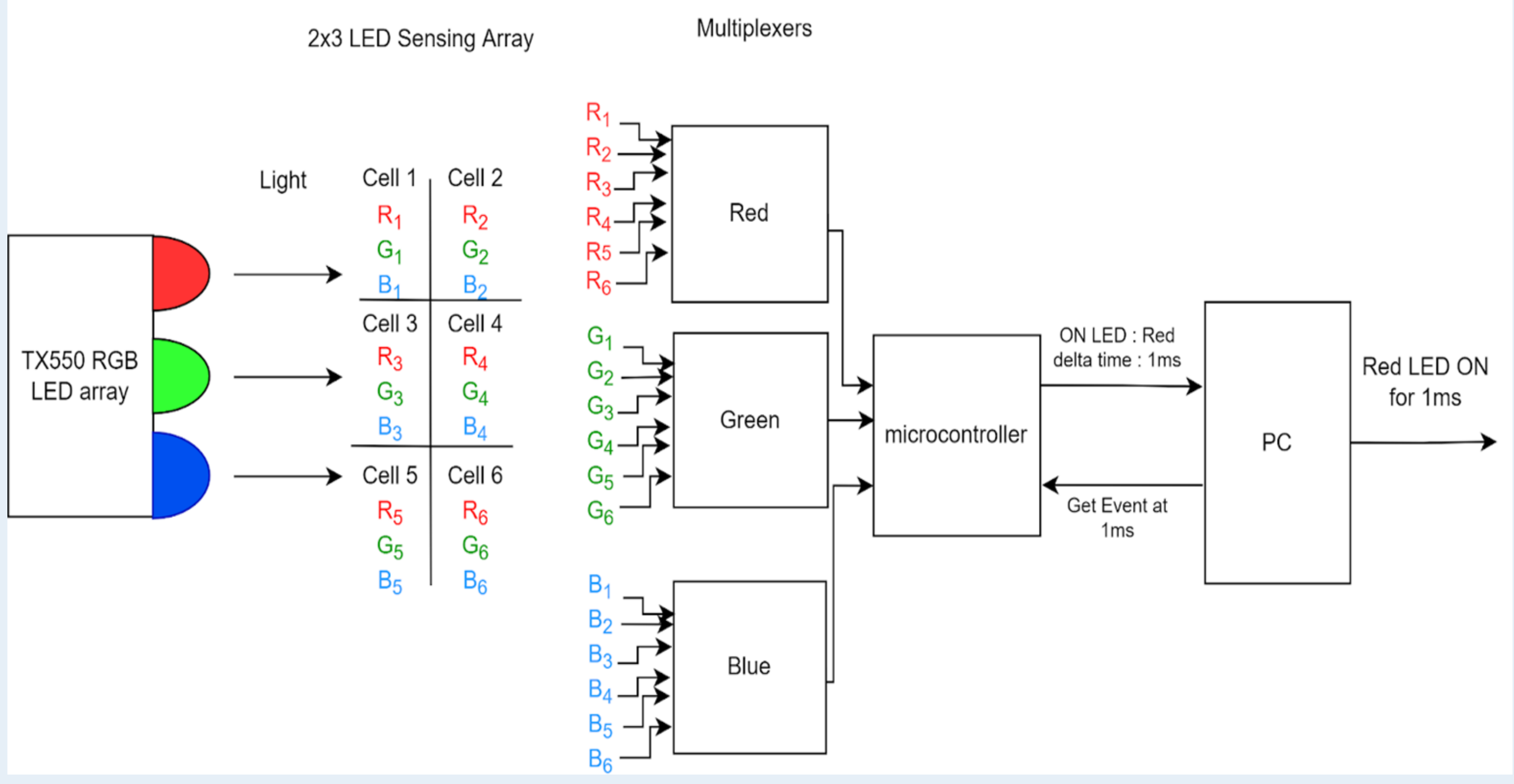

Fig. 1 : Overall System Block Diagram

Anticipated Best Outcome

The ABO of the project is to deliver an automated mountable prototype capable of viewing RGB colored status LEDs incorporated in VoltServer's TX550 product, record the blink sequence and durations of the LED blinks, decipher the received information and display the status code to the viewer simultaneously. A user manual w/ complete bill of materials will be submitted, describing in detail the components and parts used for the completion of the project. Circuit schematics will be provided, defining the layout, assembly and fabrication of the PCB. Alongside these files, well described source codes for the software and firmware development will be included.

Project Outcome

The ABO has not been fully met. Completion of sensor characterization led to the successful implementation of the LED/Color Detection Algorithms. Implementation of the algorithms has led to the development the GUI. A new revision for the board is needed as the JTAG was unable to connect to the microcontroller and the footprints for the DC/DC converters were incorrect.

Figures

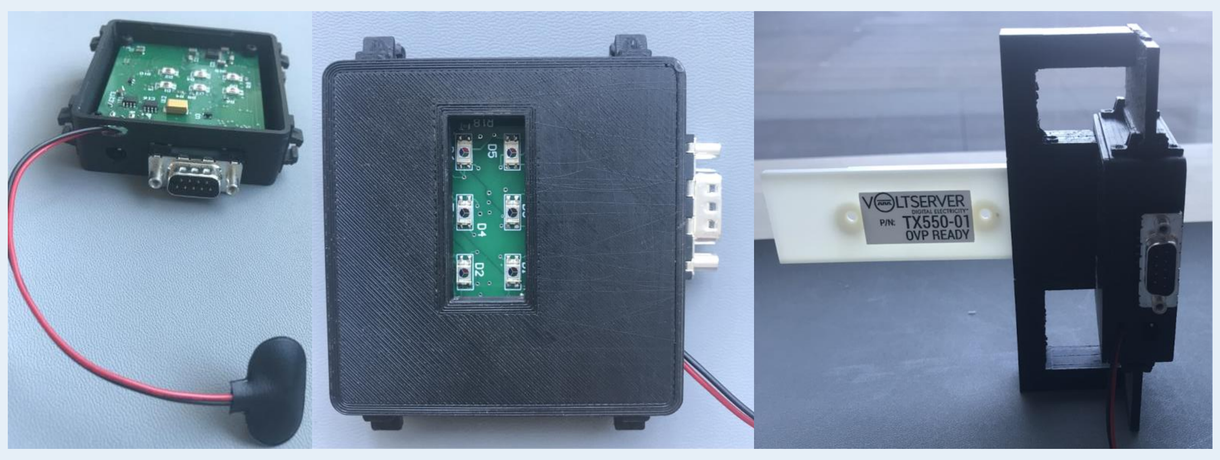

Fig. 2: Prototype Hardware with Enclosure and Mounting Solution

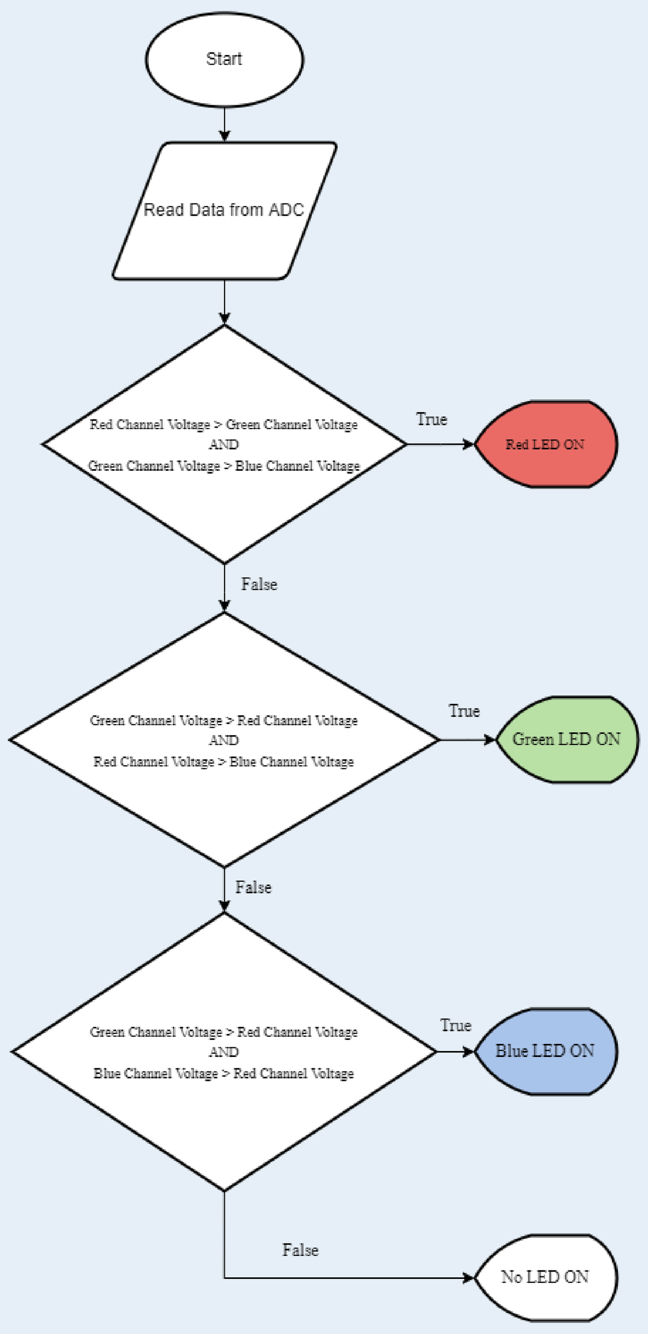

Fig. 3 : Color Algorithm Flow Chart

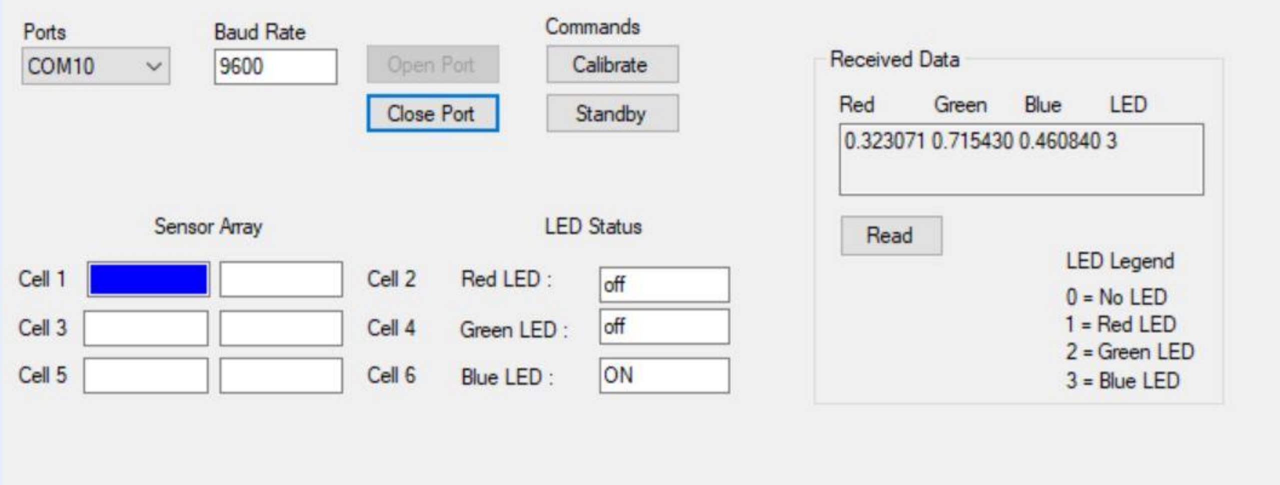

Fig. 4 : Graphical User Interface

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

ELECOMP CAPSTONE
VIRTUAL SUMMIT
TUESDAY, MAY 10, 2022

THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Volvo 240 Modernization

Updating the Volvo 240 with a Controller Area Network

VOLVO 240 ELECOMP

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

Consulting Technical Directors: Brenden Smerbeck (ELECOMP '17), Mike Smith ('01)

Project Motivation

Volvo's 200 series vehicles are some of the most iconic road cars ever produced. They were in production from 1974 to 1993, during which over 2.8 million vehicles were manufactured. Many of these vehicles are still on the road today. However, quality replacement parts are becoming scarce and vehicle owners have to resort to expensive used or aftermarket options. The instrument clusters are difficult to source and working instrument clusters are almost impossible to obtain. Designing a modern replacement with inexpensive and abundant components would be a needed lifeline for a lot of 200 series owners. Producing a digital instrument cluster that uses a Controller Area Network (CAN) would fill gaps in the market for 200 series replacement parts. It will also aid in keeping many of these wonderful vehicles on the road for years to come. This project will also provide ample learning opportunity to the contributing team members.

Key Accomplishments

Lighting: Designed circuits to operate all vehicle lighting using h-bridges, relays and current sensing circuits. These circuits provide the capability to switch the high current exterior lighting from an isolated micro controller. It will also sense when a bulb has failed and send a corresponding message to the Digital Display

Speedometer & Tachometer: Designed circuits to convert the frequency outputs from the Vehicle Speed Sensor (VSS) and the Ignition Coil into voltages. Each voltage can then be referenced by a Teensy and represented as a corresponding vehicle speed or engine RPM.

Fuel and Coolant Temperature: Designed circuits to convert a variable resistance value from the Engine Coolant Temperature Sensor and the Fuel Level Sender into a corresponding voltage to determine their respective values.

Vehicle Circuit Redesign: Redesigned all required circuits in the vehicle to remove any components made redundant from our design. As well as ensuring that we do not provide an incorrect voltage or current to the sensitive controllers installed on each node **Fig 3**.

Printed Circuit Boards: Designed and ordered two custom circuits boards. The Digital Display Node is unique and functions as a computationally powerful central node. The Front and Rear Nodes are very similar, so the design incorporates both designs on to one board to reduce complexity and cost. There are 2 different boards that dependent of the installed components will become the Digital Display, Front and Rear Nodes **Fig 1, Fig 2**.

CAN Programming: After ordering a list of each possible signal in our design by importance and severity from high to low. We have assigned each signal a value from 0-2047 and programmed each node to receive and send the associated data with the priority we established.

Digital Dashboard Display: Designed and implemented a Digital Dashboard Display using SDL, a 2D graphics library. Using a Raspberry Pi and a 7" display to visualize vehicle data **Fig 4**.

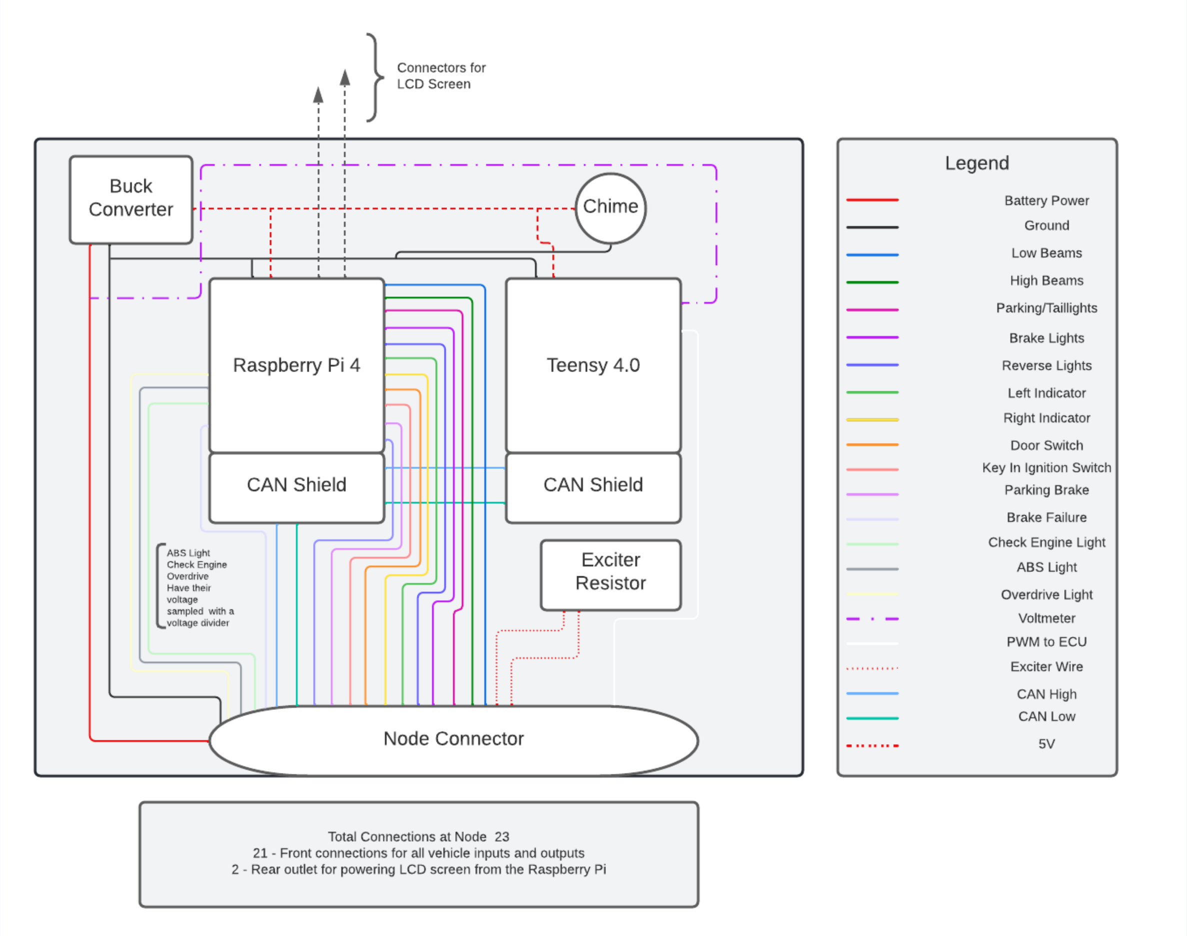

Fig. 3 Vehicle Node Redesign Block Diagram

Anticipated Best Outcome

Produce a functional prototype Digital Dashboard Display using a Controller Area Network (CAN) to communicate data across multiple vehicle sensing nodes. The Digital Display will be able to display the vehicle speed, engine RPM (Revolutions Per Minute), coolant temperature and fuel quantity. This data will be collected, analyzed and sent to the digital dashboard from two nodes controlling the front and rear vehicle sensors, signals and lighting. The prototype will be tested on a test bench using circuits designed to mimic current vehicle sensors and signals. If the prototype works on the test bench, then it will be tested in a Volvo 240.

Project Outcome

We achieved our ABO, despite setting ourselves an ambitious goal. The reason for our success was the impressive individual contributions and consistent teamwork.

Figures

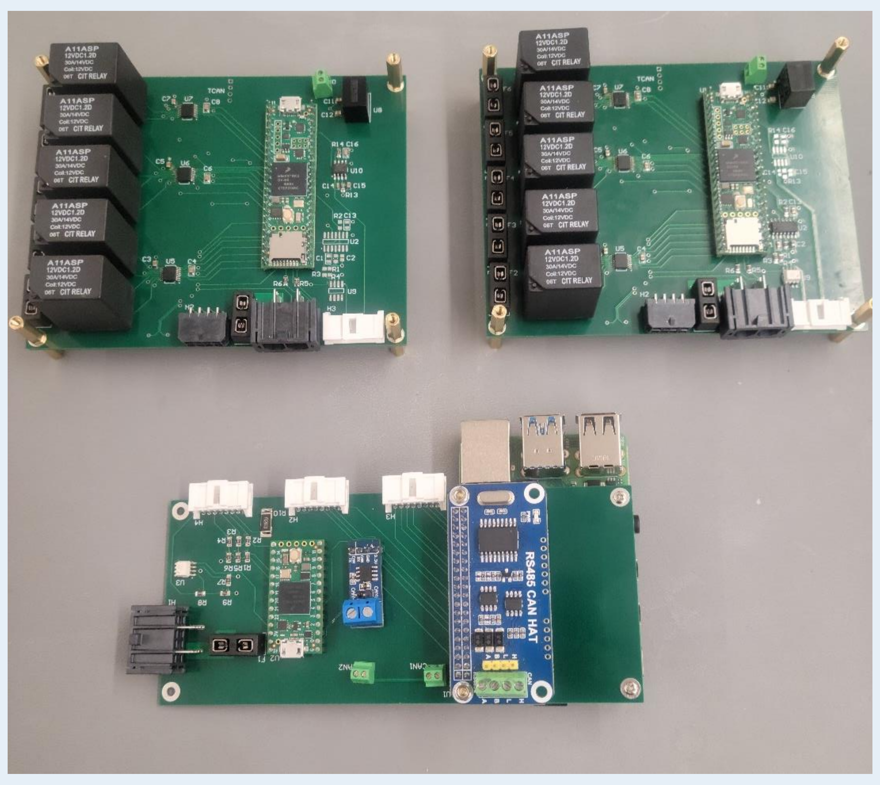

Fig. 1 Final Printed Circuit Boards

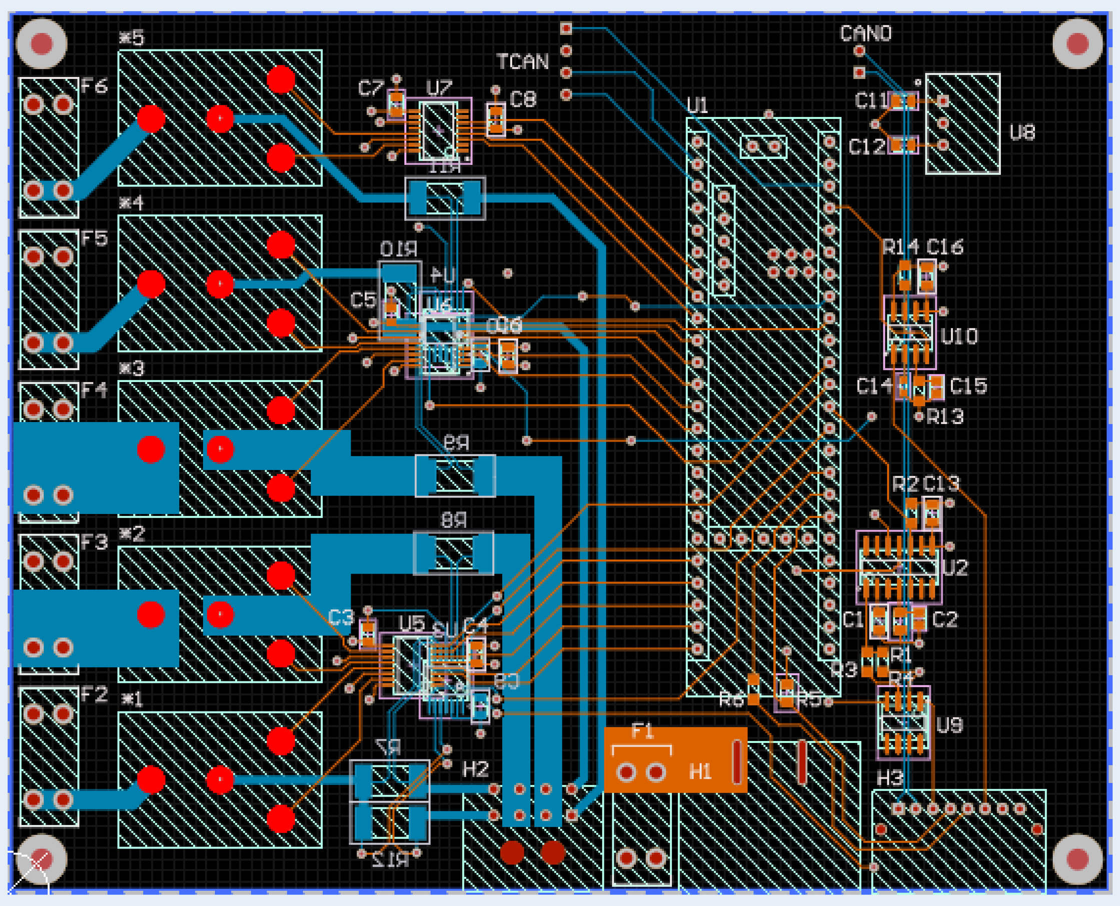

Fig.2 Front and Rear Node Schematics

Fig. 4 Digital Display Running a Systems Check

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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.

Microphone to TCP audio stream:
Using some of the example code provided by the xcore-sdk, a FreeRTOS task was built to send audio data to a preprogrammed network socket via TCP.

TCP audio stream to DAC:
Created a collection of tasks that takes in an audio stream and outputs it to the DAC to be later transmitted through the speakers. Similar to the microphone audio stream implementation, multiple tasks needed to be created to pass data around between tiles to have access to the proper hardware. Since the DAC on our development board was not functioning, testing for the correct output of data has not been conducted.

Machine Learning Model:
Created machine learning sequential model that takes a spectrogram as an input using TensorFlow. The model is able to predict if baby is crying or not

Audio CODEC & Power Supply 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.

PCB Design and Component Population:
Implementation of the WM8960 audio CODEC with the power supply. Components were selected based on availability and component size (we selected 0805 for our component size).

Daughterboard Testing and Troubleshooting:
Troubleshooted power supply (including the USB-C and buck converter chip), and temperature sensor which were verified by an onboard LED. Confirmed power delivery to temperature sensor and CODEC, however power delivery from USB-C and buck converter were non-functional

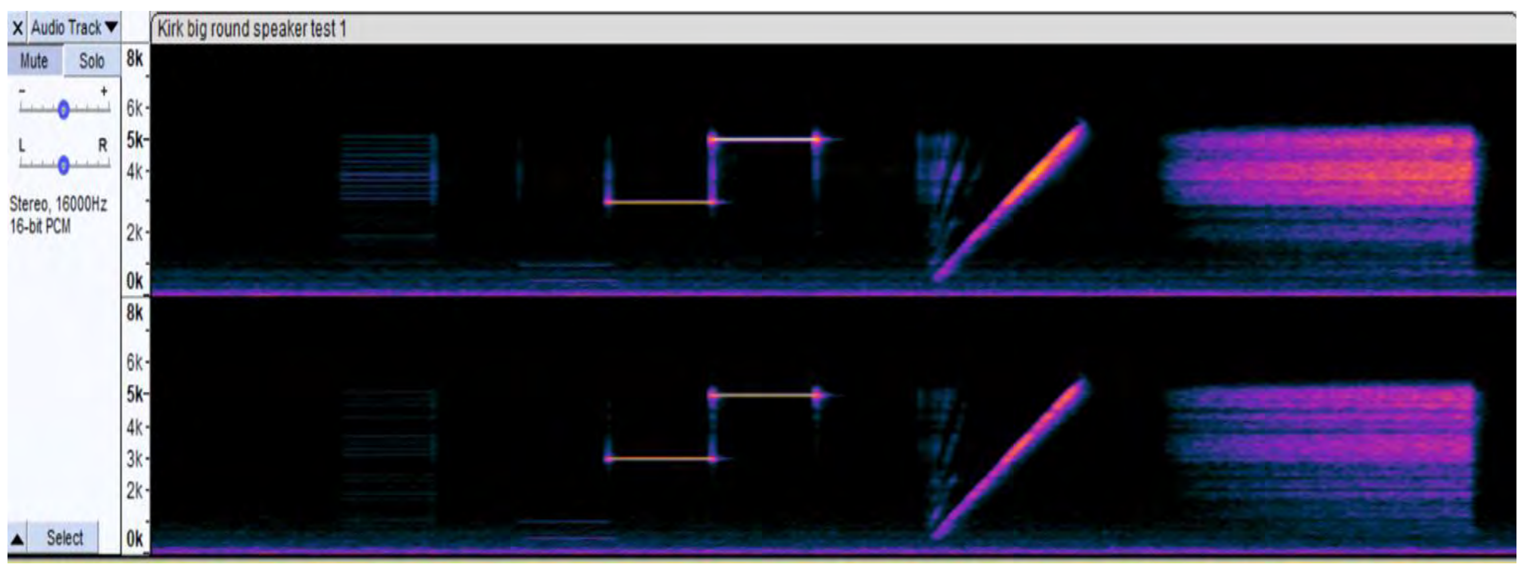

Figure 4. SP-3606 Speaker Spectrogram Waveform

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.

Project Outcome

Unfortunately, the Anticipated Best Outcome was not achieved. The XMOS team was able to create most of the individual components necessary to complete the project but combining it into one complete product was not possible.

Figures

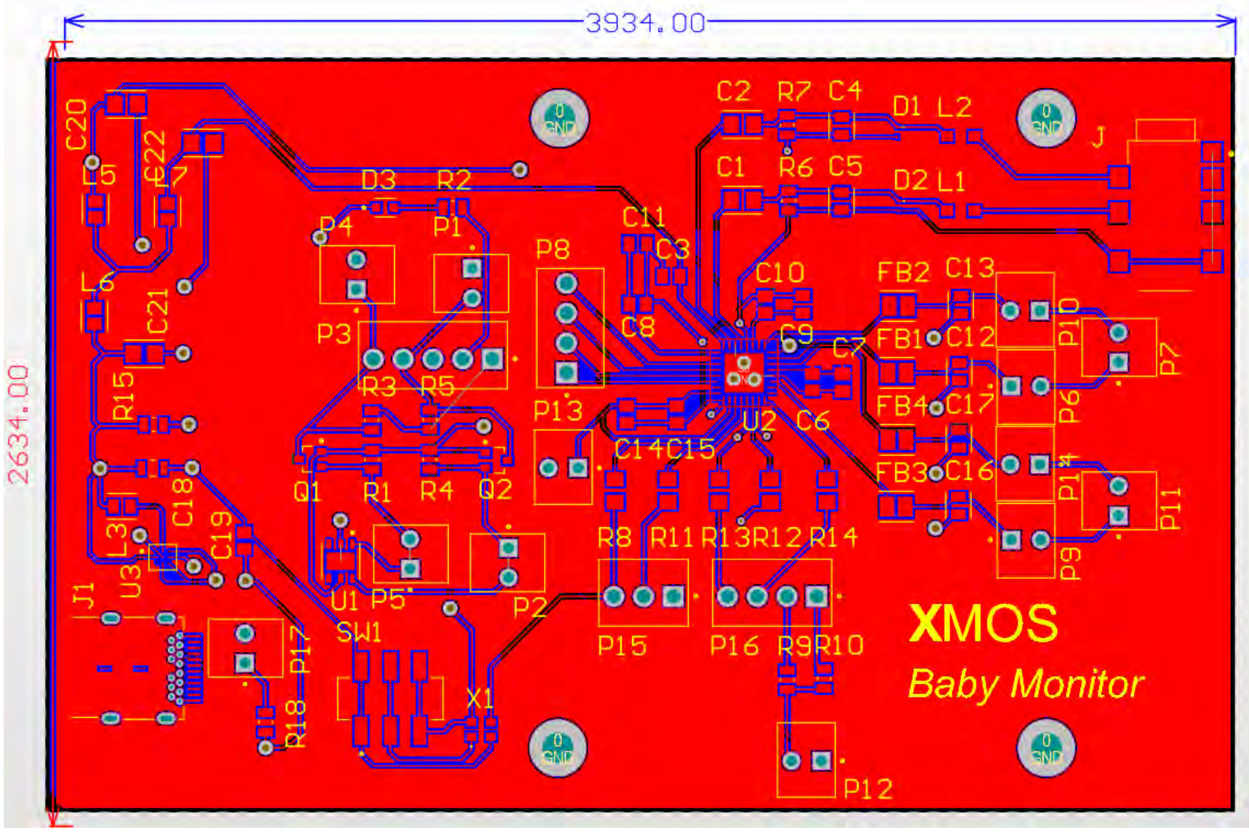

Figure 1. XMOS Daughterboard PCB Layout

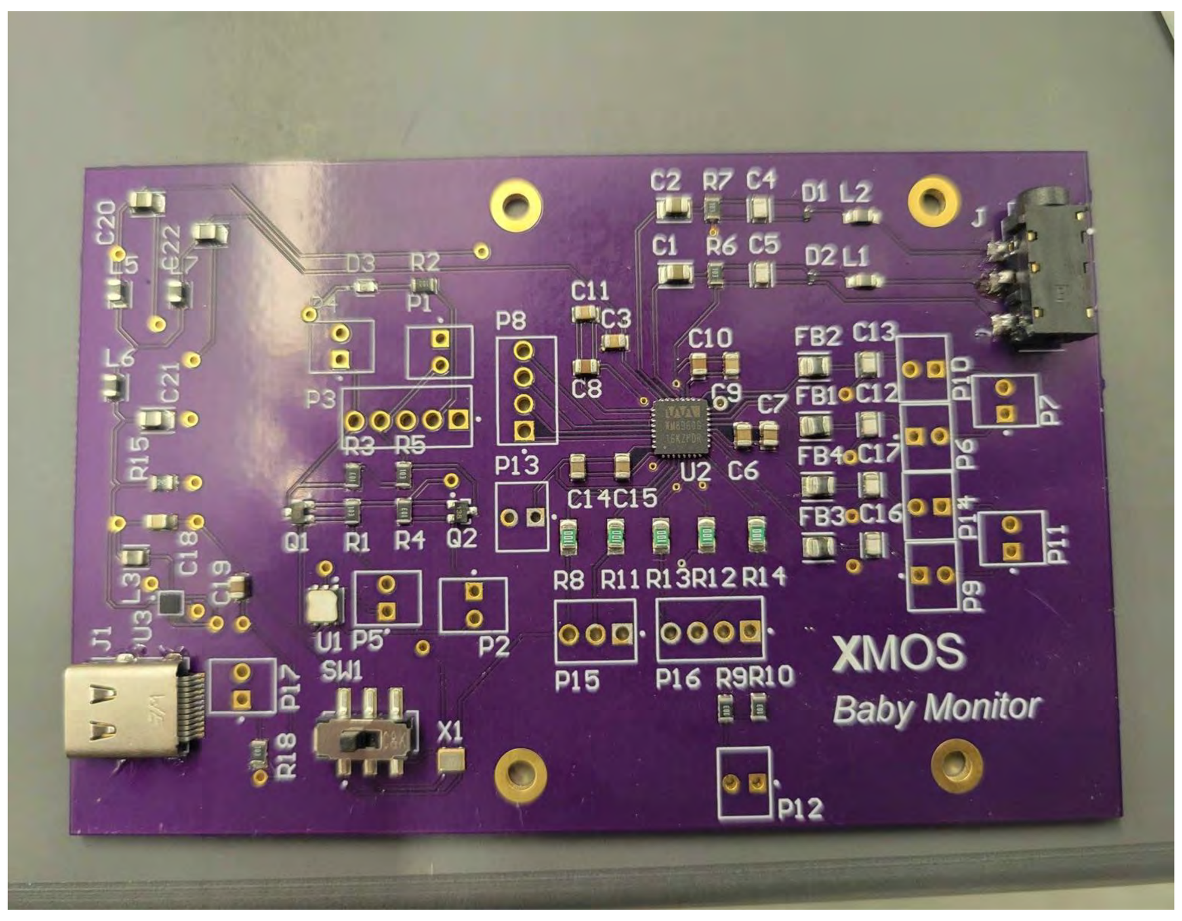

Figure 2. Populated Daughterboard without pin headers

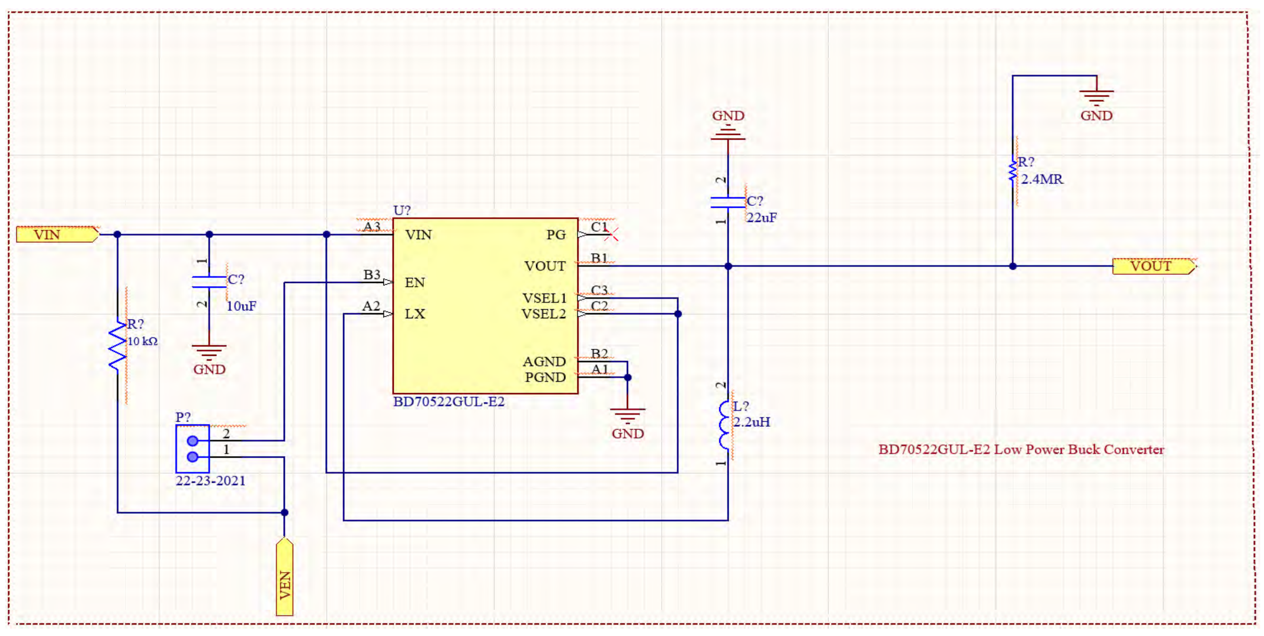

Figure 3. BD70522GUL-E2 Buck Converter Schematic

ELECOMP Capstone Program Director: Professor Harish R D Sunak

email: sunak@ele.uri.edu telephone: 401-874-5859

ELECOMP Website: https://uri.edu/elecomp-capstone

Torque Measurement

Printer Realtime Torque Measurement

ZEBRA

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

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

Project Motivation

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

Key Accomplishments

GUI Development: The current GUI was made using python and its built-in GUI development package, 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, buttons, logos, and entry boxes for appropriate data points. In addition to that, there is a button that outputs a graph in a pop-up window. This graph has the torque reading printed on the Label as shown in **Fig 2**.

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. We had many issues with data transfer like buffer resets, buffer overwrites, data type conversions, variable multiplexing, delay time, transferring using an interrupt, transferring using DMA, and more but we managed to overcome most of them.

Dev-Bench Interfacing: The current Dev-Bench originally came with code made by 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. Throughout the project's lifespan, we had to bring the fixture back to Zebra for troubleshooting to find out that the printer itself was the problem. That has now been fixed and the team has enough knowledge to assemble/disassemble the fixture thanks to good documentation. The current fixture can be seen in **Fig 1**.

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. However, due to coding problems, we haven't been able to integrate the Transducer, but we got it to a point where we could add it to the fixture

Analog-to-Digital Conversion: In order to get data from the transducer, a separate function had to be set up to grab analog voltage data and convert it to a digital signal(**Fig 4**) to be sent to the GUI. This was done using PuTTY, and the current method is to place it in a log file for easy manipulation. This functional setup works both with signals coming in from a function generator, and signals coming from the transducer itself, and the voltage tolerance and resolution can be adjusted with a voltage divider.

Filter Assembly: In order to get consistent and clear readings from the transducer, a filter that operates like in **Fig 3** has to be assembled. After some discussion, it has been determined that a low-pass filter is needed to accommodate the transducer output. After working closely with our TD's we managed to complete the filter and build it on a PCB so that it is ready to be used with the Transducer.

Anticipated Best Outcome

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

Project Outcome

We did not meet the Anticipated Best Outcome, but we managed to get very close. All that needs to be done right now is to overcome all the coding issues we have with the Nucleo Board and then interface the GUI and serial comms code with the general hardware code.

Figures

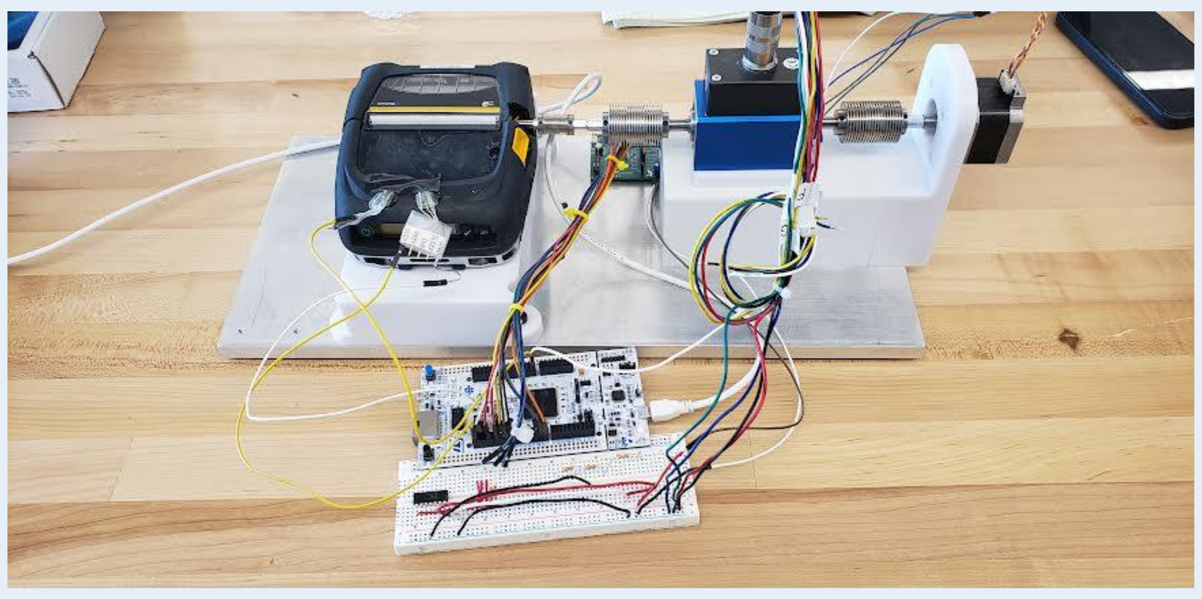

Fig 1: Current torque measurement fixture

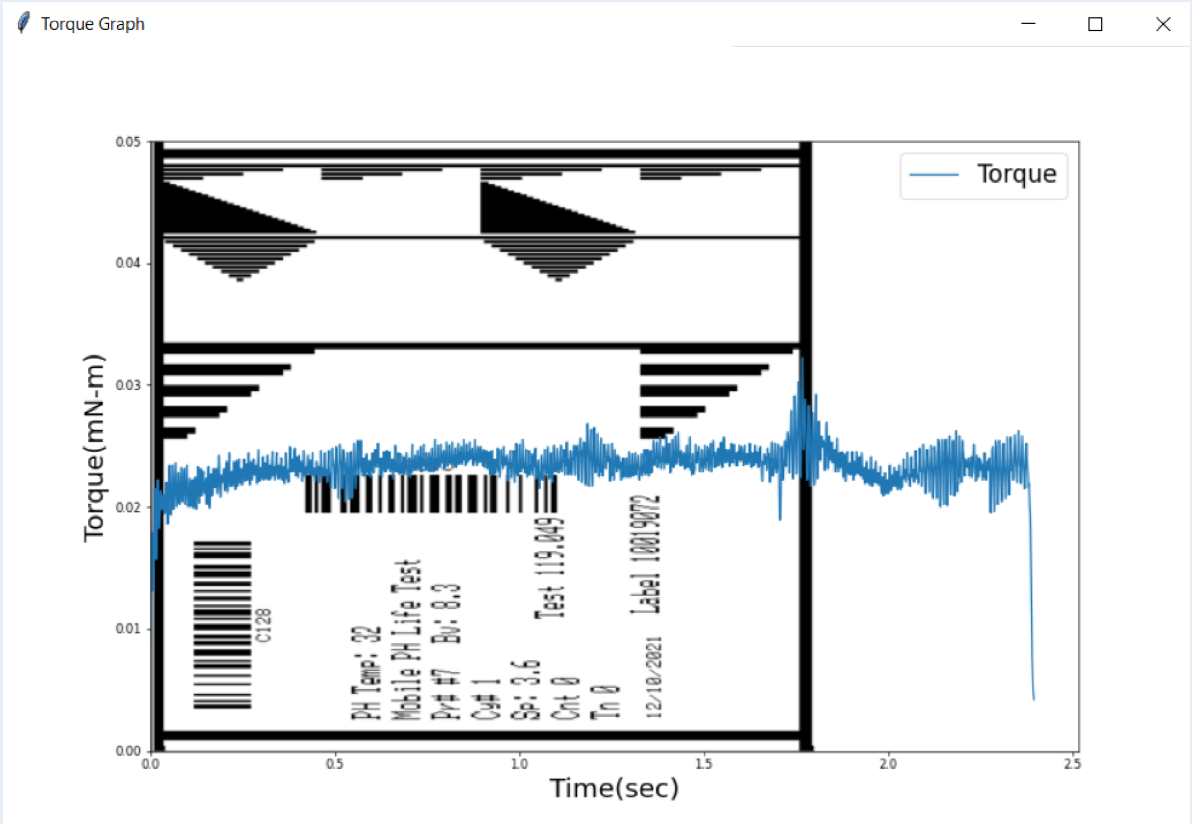

Fig 2: GUI Graph output of Label with Torque reading

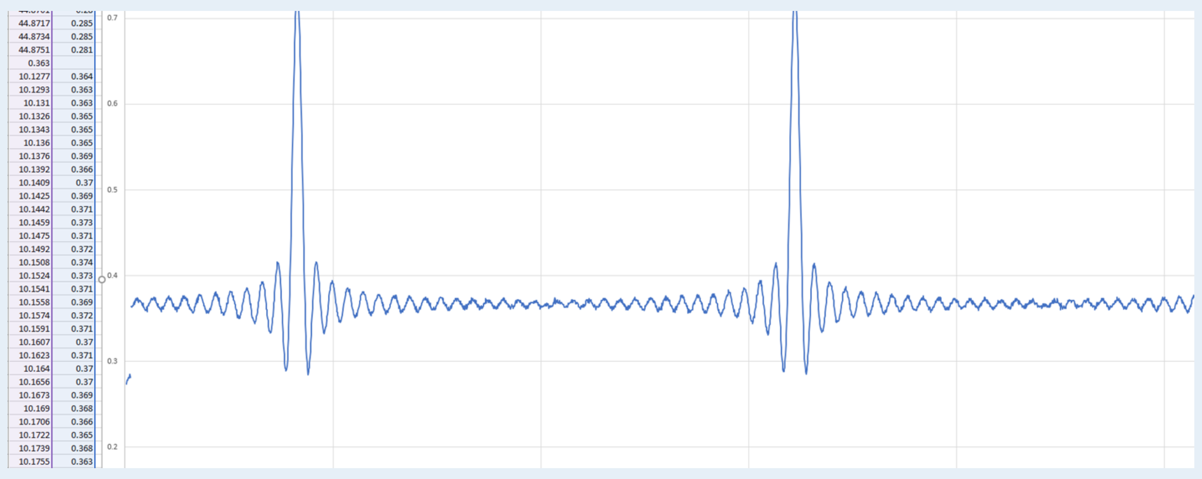

Fig 3: ADC Sampling Graph