ELECOMP CAPSTONE SYMPOSIUM

THURSDAY, DECEMBER 21, 2017

Celebrating 10 Years of Excellence
2008 – 2017

125
1892–2017

THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL, COMPUTER
AND BIOMEDICAL ENGINEERING

SPONSORING COMPANIES

ELECOMP Capstone 2017–2018

"WE ALL express our sincere gratitude for your support"

Thanks Very Much   Muito Obrigado   Bahut Dhanyavaad

Asante Sana   Muchas Gracias   Vielen Dank

Merci Beaucoup   Grazie Mille   Shukraan Jazilaan

Fēicháng Gǎnxiè Nǐ   Dōmo Arigatō Gozaimashita

Gratias Tibi Valde

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SCHEDULE OF EVENTS

ELECOMP Capstone Design Program SYMPOSIUM
Thursday, December 21, 2017

7:00 – 8:40 am
- Breakfast
- Registration
- Viewing of Capstone Project Posters

Location: 95 Club

9:00 – 9:15 am
Welcome
Professor Harish Sunak, Capstone Program Director
Location: Ernest Mario Auditorium, Avedisian Hall

9:15 – 10:29 am
Rocket Presentations I (8 teams)
Location: Ernest Mario Auditorium, Avedisian Hall

10:29 – 10:45 am
Break

10:45 – 12:04 pm
Rocket Presentations II (9 Teams)
Location: Ernest Mario Auditorium, Avedisian Hall

12:10 – 1:15 pm
Lunch
Location: 95 Club

1:15 – 2:00 pm
Poster Session & Demonstrations
Location: 95 Club

2:00 pm
Announcement of Top 5 Teams
Location: 95 Club

2:00 – 2:45 pm
Reception & Videos
Location: 95 Club

ROCKET PRESENTATIONS

ELECOMP Capstone Design Program
Schedule of “Rocket” Presentations
Ernest Mario Auditorium, Avedisian Hall

Rocket Presentations I

9:15 – 9:25 am	Acumentrics
9:26 – 9:34 am	AstroNova
9:35 – 9:43 am	Bay Computer
9:44 – 9:52 am	Bosch Thermotechnology
9:53 – 10:02 am	Bose Corporation
10:03 – 10:11 am	Hayward “Falcon”
10:12 – 10:21 am	Hayward “Rabbit”
10:22 – 10:29 am	Hexagon CMM

BREAK

Rocket Presentations II

10:45 – 10:52 am	Hexagon OCR
10:53 – 11:02 am	IGT Global Solutions
11:03 – 11:13 am	Infineon Technologies
11:14 – 11:21 am	Iradion Laser
11:22 – 11:29 am	ON Semiconductor
11:30 – 11:37 am	Phoenix Electric
11:38 – 11:46 am	Schneider Electric
11:47 – 11:54 am	SES America
11:55 am – 12:04 pm	TACO Comfort

WELCOME BY PROFESSOR HARISH R. D. SUNAK

ELECOMP Capstone Design Program Director

"If your actions inspire others to dream more, learn more, do more and become more, you are a leader."

– John Quincy Adams

Welcome: It gives me great pleasure to welcome you all to the Fall Symposium of the ELECOMP Capstone Design Program. This year we are celebrating 10 Years of Excellence in Capstone Design for Electrical (ELE) and Computer (COMP) engineers, at URI, in the Department of Electrical, Computer & Biomedical Engineering. Our Program partners senior-level engineering students with industry sponsors to design, build, program and test solutions to real-world problems. We are excited to present 53 seniors on 17 projects, covering a variety of problems in electrical and computer engineering. I have allocated 7-10 minutes per project for the oral "rocket" presentations, to allow more time for live/video demonstrations and poster session interactions and discussions. I hope you will have a stimulating day, and I look forward for you to come on board with a new capstone project next year The depth and breadth of work in these projects is outstanding and I hope it will inspire you to propose creative ideas for immense mutual benefits.

Capstone Bridge: The ELECOMP Capstone Bridge mirrors the well-known Wheatstone Bridge extremely well, as shown on the back cover. All facets of our Program together with our talented seniors, with diverse skills, form the two known arms of the bridge. The third known arm is the sponsoring company, their Technical Directors and the problem to be solved. Only when these three arms are in perfect balance and collaborate in excellent harmony, success is achieved in the unknown arm: The Best Outcome of the Sponsor's problem.

Together with my senior capstone designers, I would like to sincerely thank the 15 companies who became the third arms this year; they are listed on the inside of the front cover. Without their generous support, it would be impossible to execute on all the facets of the program. Special thanks to all the Technical Directors for their time and efforts in mentoring the teams.

Quote: By Bruce Parkes '96 and Raymond Leyland '93: "The students' abilities to introduce new technologies, tools, processes, designs and academic rigor should not be overlooked. Additionally, they bring a naiveté that forces questions to be answered about a company's established products, processes and protocols."

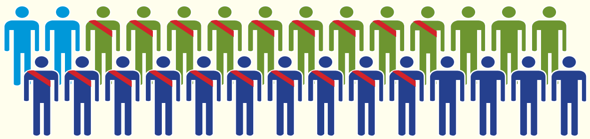
New Engineering Building: It will be very exciting to move into our new building in 2 years' time. The present freshmen class will be doing their capstone projects there. "It will be the finest Engineering Facility anywhere and will move URI to the absolute forefront of Engineering Research and Education." – URI President Dooley.

The ELECOMP Capstone Program Director with the Class of 2018 after the announcement of teams on September 19th, 2017

TECHNICAL DIRECTORS

ELECOMP Capstone Design Program
Technical Directors (TDs) 2017-2018

Overview



Total number of TDs: 28 across the 17 Projects

- 14 TDs are graduates of our ECBE Department at URI: 50%
- 2 TDs are graduates of other departments at URI: 7%
- *10 out of these 16 are TDs for the First time!*
- 12 TDs are graduates of other Universities: 43%
- *9 out of these 12 are TDs for the First time!*

Major Achievements

Particularly proud to report a major achievement for our Program: **Brenden Smerbeck** and **Denise Androzzi**, who completed Capstone Projects with Acumentrics and Bay Computer Associates last year, graduated on May 20th, 2017, and are now Technical Directors on the projects sponsored by these Companies!

Also, very proud of **Mike Caneja**, who graduated in May 2015, and championed a capstone project sponsored by Bosch Thermotechnology, one month after being appointed Product Manager. Thanks Mike!

TDs from our Department of Electrical, Computer and Biomedical Engineering

Brenden Smerbeck (2017) *ELECOMP Capstone Graduate 2017*
Denise J Andreozzi (2017) *ELECOMP Capstone Graduate 2017*
Mike Caneja (2015) *ELECOMP Capstone Graduate 2015*
Mark Rodrigues (2010)
Sandro Silva (2002) *2nd Year TD*
Mike Guerra (2002) *2nd Year TD*
Mike Smith (2001) *2nd Year TD & Consulting TD on 4 Projects*
Robert Davis (1997)
Bruce Parkes (1996) *2nd Year TD*
David Kortick (1990)
Chris Tate (1989)
Denis Galipeau (1988)
Jamie Murdock (1984) *2nd Year TD*
Frank Kolanko (1981)

TD from our Department of Mechanical Engineering

Jonathan O'Hare (1994) *2nd Year TD*

TD from the College of Business Administration

Christopher Kyes (2016) *MBA*

TDs from other Universities

Peter Upczak *2nd Year TD*
David Durfee *2nd Year TD*
Joe Gundel *2nd Year TD*
Jeff August
David Connolly
Jerry Huson
Daniel Jaquez
Phillip Manning
Stephen McDonald
Frank Metayer
Robert Milkowski
Luka Petrovic

SAVE THE DATE!

ELECOMP CAPSTONE
SUMMIT
FRIDAY, MAY 11, 2018

Acumentrics
Trusted Power Innovations

Network Managed Power Distribution Unit for Military Application

acumentrics.com

TECHNICAL DIRECTORS:

Brendan Smerbeck
Peter Upczak

TEAM MEMBERS: (L to R)

Brenden Smerbeck
Nathan Mensah (E & C
Michael Majdalani (C)
Jonathan Travelyn (E
Jeremy Peacock (C & CS)
John King (E)

PROJECT MOTIVATION:

Power Distribution Units (PDU) are an integral component in providing power to a number of electrical appliances, which many entities rely on. With the explosion in interest of Internet of Things (IoT) devices utilizing embedded systems, companies are realizing the demand for these networked devices. With networking capabilities, products can have remote monitoring and management ensuring a higher amount of fault detection, safety tracking, and statistics accumulation to further develop better products and give notice for possible system failures. Currently, Power Distribution Units have seen some integration with networking capabilities in commercial markets. With regards to the market for Power Distribution Units that adhere to military quality and safety standards, there is a gap that is seeking to be filled. Having the capability to remotely monitor device statistics and manage the devices that provide power to their appliances can bring much needed security and safety to the military. This gap and need for safety is the project motivation for Acumentrics.

ANTICIPATED BEST OUTCOME:

The best outcome is to have a fully functioning Smart PDU prototype that can be presented and painlessly handed off to the Acumentrics engineering team. The prototype will provide sufficient power to connected appliances and will meet military quality and safety standards. Users will have the ability to remotely control the device via a web application's GUI, to switch outlets on and off; monitor statistics such as current, voltage, wattage, temperature and humidity; receive notifications when something goes wrong: overheating; view logs of monitored statistics; and generate reports from said logs.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

With the Internet of Technology bubble growing fast, networked technologies are becoming a norm today, and it is up to companies such as Acumentrics to provide products that allow management and monitoring of devices in a protected and practical form, for both industry and military. A large implication is the usability and ease of use of said technology to guarantee a pleasant and stress-free user experience. To remain an industry leader, Acumentrics must take this into account when building its products. This will help expand Acumentrics' market offerings to satisfy growing customer demands for ruggedized network-capable PDUs.

ACCOMPLISHMENTS TO DATE:

Prototype Circuit: From functional specifications, designed and built a prototype circuit capable of controlling eight NEMA outlets while measuring metrics including input voltage, power consumption (of each outlet), and temperature/humidity.

Component Selection: Researched and performed a cost-benefit analysis to select viable components. Components were required to meet "rugged" requirements including temperature, isolation (Hall Effect sensors), and performance (analog-to-digital converters).

Formal Schematic: Following testing, constructed a formal schematic from the prototype circuit to be sent for pcb layout and fabrication over winter break.

Analog Signal Measurement: The prototype circuit measures input voltage and current at each outlet by passing analog signals through an analog-to-digital converter; transmitting digital signals to a Raspberry Pi through a SPI interface. AC input voltage is measured via step-down and full-bridge rectification.

Web User Interface: Designed and constructed login, system overview, and notification pages accessible through a user-friendly and intuitive graphical user interface hosted by an internal web server.

Data Logging and Visualization in Real Time: Historical data retrieved from the sensors is logged and accessible from within the web application. Users can either view historical data in a table format or real-time data from sensors in a customizable real-time chart; controlling which sensors are visible and over what time span.

User Interaction: From the System Overview page, the user can select which sensor data is displayed on the real-time chart and the time range of the x-axis as well as toggling outlets on and off. Users can also configure threshold values for current, power, voltage and temperature; triggering notifications and/or outlet behavior.

Notifications: In the event that a sensor's measured value falls outside a user-defined threshold, the system shall automatically send an email to a preconfigured list of recipients and display a popup window detailing the event.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Programmable LCD Screen: The system shall have a programmable LCD screen on the front of the case which allows the user to navigate through menus displaying metrics: power consumption at each outlet, and the overall system, system temperature, etc.

Fabrication: The PCB fabrication, once complete, shall be integrated into the formal prototype of the PDU. Once this PCB is integrated, it will need to be fully tested for functionality and effectiveness. If it is not functional, the design will need to be redone, and tested again.

Ruggedized Case: This shall be suitably designed to meet industry and military standards for environmental metrics: rain, dust, heat, electromagnetic interference, etc.

Error Handling: The application shall have to have sufficient error handling to ensure that the system has adequate fault tolerance to maximize reliability and prevent the failure of the system. Errors shall also have to be logged and viewable by the user.

System Security: The application shall have to have more security, such as input validation and sanitization, to maximize vulnerability avoidance and ensure the confidentiality and integrity of the system's data.

continued on next page

Network Managed Power Distribution Unit for Military Application

acumentrics.com

REMAINING TECHNICAL CHALLENGES - CONTINUED

Mobile Friendly Version: The application currently loses some functionality and user-friendliness on mobile platforms. The application shall have to detect whether the user's hardware is mobile or not and redirect to a mobile version of the application in that event.

Documentation: Acumentrics shall be continuing development upon the completion of the Capstone program. The project will have to have sufficient documentation to facilitate a stress-free hand off.

UPS Communication: The system should be able to communicate with an Uninterruptible Power Supply (UPS) that is is connected to via the Simple Network Management Protocol (SNMP). If the UPS conveys that it is currently on battery power, the system will have to allow the user to choose which outlets remain on via a priority selection.

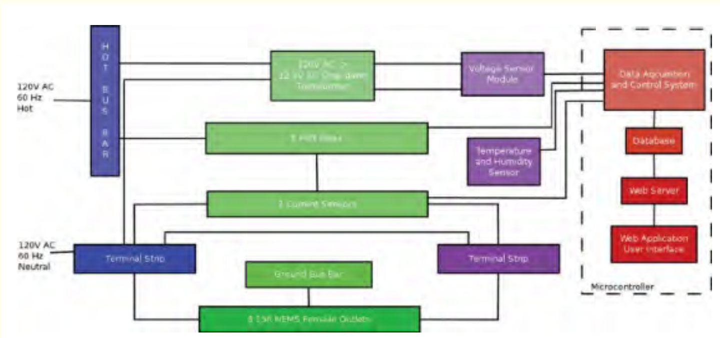


Fig. 1. General Block Diagram of the system

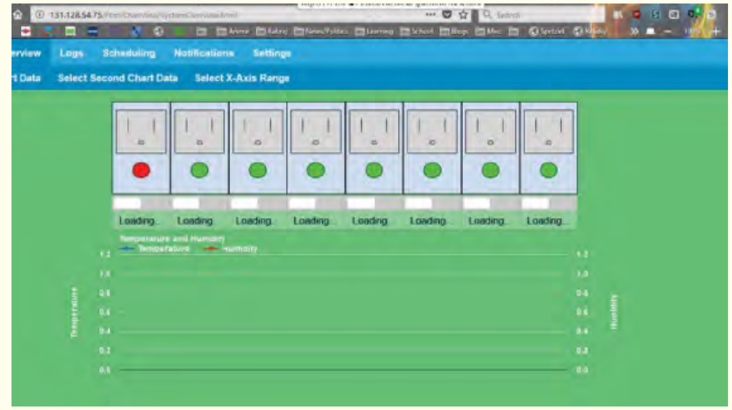


Fig. 2. System Overview Page: gives user control over outlets & displays real-time data.

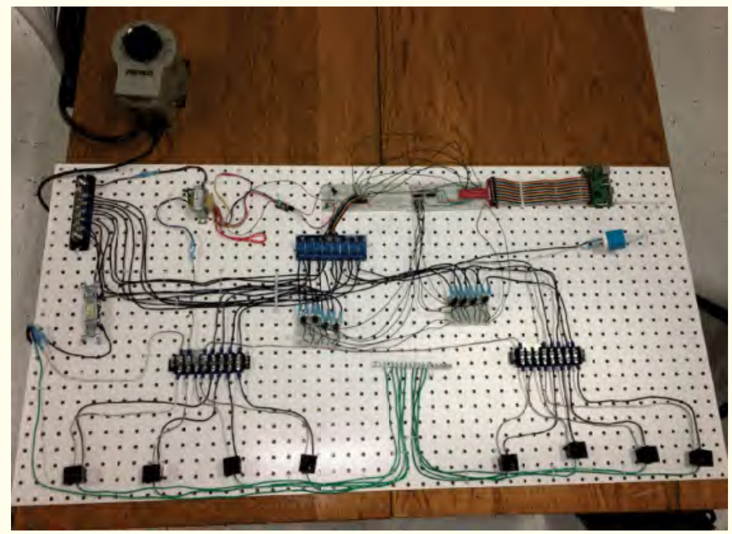


Fig. 3. Top-down view of the fully functioning prototype PDU.

AstroNova®

Portable Waveform Generator

astronovainc.com

TECHNICAL DIRECTORS:

David Kortick
Chris Tate

TEAM MEMBERS: (L to R)

Noah Johnson (C)
Nickolas Morello (E)
Thomas Mauldin (E)

PROJECT MOTIVATION:

AstroNova is committed to supplying their clients with the most innovative test and measurement equipment on the market. To demonstrate the capability of such equipment, a handheld Waveform Generator was created; however recently the design has become obsolete due to rapid growth in the capabilities of these systems. Since there is no similar device on the market, AstroNova commissioned a Portable Waveform Generator to be designed as a replacement for the current design. This waveform generator will be able to demonstrate the full capability of the data acquisition systems that are manufactured by AstroNova. In addition, there is the possibility that this product will be of interest to future stakeholders due to its uniqueness. This has been kept in mind during the design process to ease the transition from an in-house product, to a product sold on the market. This new product will allow AstroNova to demonstrate the powerful capabilities of its data acquisition products.

ANTICIPATED BEST OUTCOME:

Team AstroNova will develop a new portable waveform generator that can be used as a direct replacement for the older model. The last waveform generator was updated eleven years ago. Our new and improved WaveGen will feature a sleek updated design along with an easy to operate user interface. We plan to have a PC application that will allow the user to program arbitrary waveforms into onboard memory to be recalled later. In addition, the PC application will provide more control over the WaveGen. The updates and improvements to the product will offer new capabilities that will make it even more useful than the last.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

The portable waveform generator will allow AstroNova to showcase their test and measurement equipment at trade shows in a way that was not previously envisioned. The key feature of the product is the ability to generate, store and output custom waveforms. This feature allows AstroNova associates to tailor the waveform output to suit the intended audience, maximizing relevancy and boosting sales potential. It is this versatility, as well as a low unit price that set the waveform generator apart as a possible innovative market product after some refinement. Furthermore, WaveGen will serve as a powerful hardware troubleshooting instrument for field technicians and engineering personnel alike due to its frequency range and resolution.

ACCOMPLISHMENTS TO DATE:

- **Main Controller Selection:** After research was conducted by the team, it was found thata Xilinx Artix Series 7 FPGA would be the best choice for our needs.
- **Main Component Selection:** Many components were researched and analyzed to select the most suitable components for the design.
- **Power Distribution:** The team was able to design a power distribution system that exceeds the runtime specification.
- **Reviewed Schematic:** The WaveGen schematic was reviewed and is being used to fabricate Revision A of the Printed Circuit Board.
- **User Interface:** A 20 character by 4 character LCD user interface has been designed, and software has been written to allow the operator to navigate through menus and adjust the outputs.
- **Internal Design and Implementation:** Using Vivado Tools, the internal architecture and all low level parameters are being implemented. This includes all I/O, power control and user interaction interpretation.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Creating the Waveforms:** Waveform generation relies on a complete hardware solution, which is currently in production.
- **Controlling the Waveforms:** The waveforms that are generated will need to be controlled both locally by push buttons and by the PC application. This includes frequency and amplitude adjustment.
- **Output Verification:** The waveforms that are generated will be analyzed for signal quality, frequency resolution, and consistency.
- **PC Application:** A PC application will be developed to setup and program the WaveGen via USB. This application will allow granular control of each channel based on client needs.
- **Validation:** Numerous tests will be performed and revisions will be implemented in order to produce the best quality product.

AstroNova®

Portable Waveform Generator

astronovainc.com

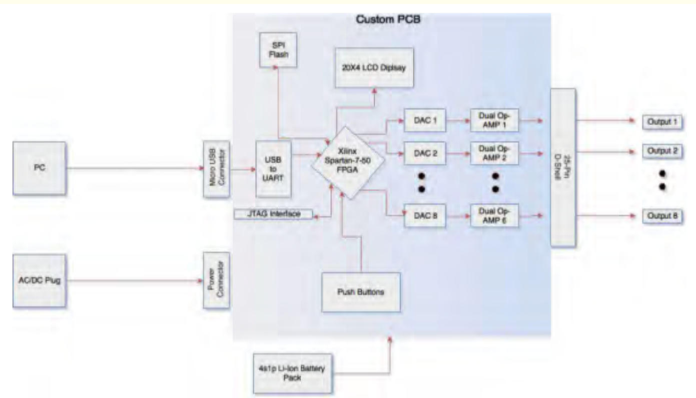


Fig.1: System block diagram of WaveGen project: Major components of our design.

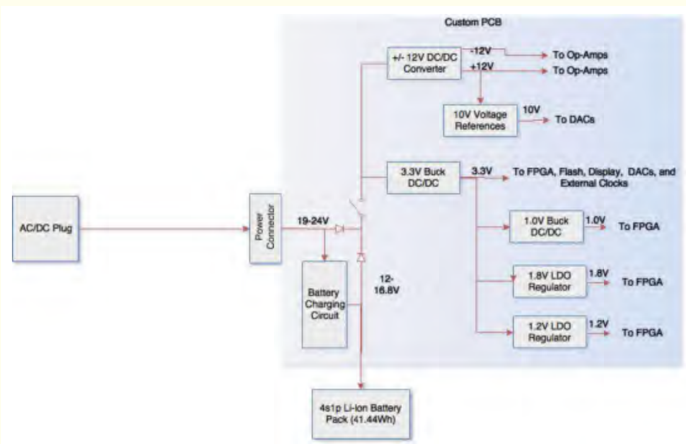


Fig.2: Block diagram for the power distribution network of the waveform generator.

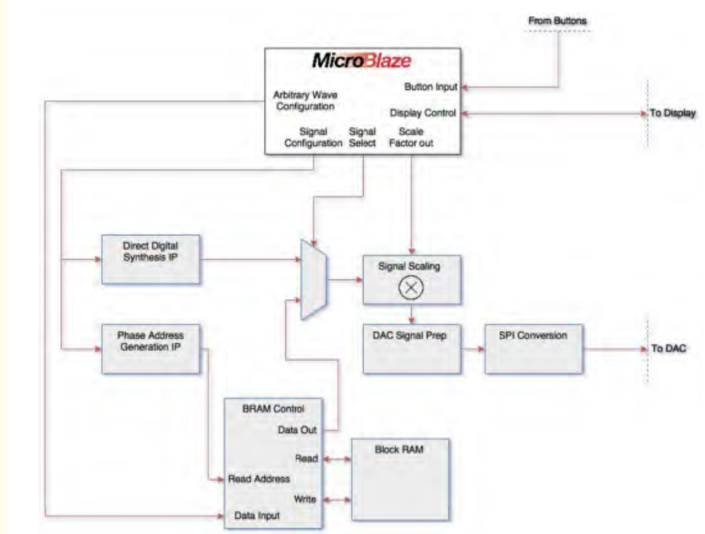


Fig.3: A block diagram of the FPGA fabric that deals with user interactions. The MicroBlaze is essential to the design as it is integrated into the FPGA fabric.

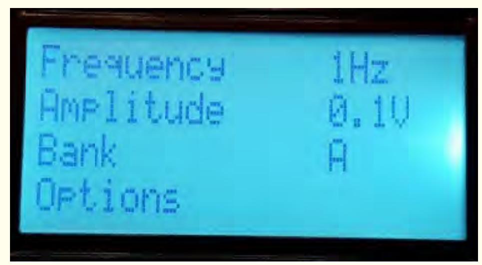


Fig.4: Main menu of the user interface.

Three Phase Motor Controller

baycomp.com

TECHNICAL DIRECTORS:

David Durfee
Denise Andreozzi

TEAM MEMBERS: (L to R)

Brandon Lian (C & E)
Daniel Finan (E)
Evan Magno (E)

PROJECT MOTIVATION:

Originally, this project started as a motor controller for an electric wheelchair. This controller was later augmented for the operation of an electric bicycle, and is currently being redesigned for medical technologies that would require our motor controller. Many new design decisions have been made with the transition into the newest implementation, most notably, the control system in place for the position control algorithm; which left us with a lot of room for improvement. Second is the implementation of a parallel transistor setup that will allow higher current output while keeping the parasitic capacitance of the transistor configuration low. The goal of this project is to continue overcoming the obstacles that have yet to be solved and to further our designs. In the end we would like to have a motor controller that drives a larger range of currents, redesign the controller's board in order to maximize the use of space, and a more robust implementation of the position control.

ANTICIPATED BEST OUTCOME:

The best outcome of the project would be to have a completed market ready product with all updated and redesigned features that the current design does not have. These features include a redesigned MOSFET layout that can produce higher output currents, updated power supplies that can handle an increased range of input voltages, reliable current sensing, and the development of a robust position control algorithm. The outcome of this project will yield a product that is capable of controlling higher powered motors than the ones seen in previous designs, and can control the motor of a large scale medical device.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

Reaching the project's best outcome would mean the product is very close to market readiness. When this product is released into the market it would mean a higher level of precision and safety for current motor controllers found in the medical industry. The product can be applied to an even wider range of technologies that need a reliable motor controller that may or may not even take advantage of our position control algorithm, like a human operated electric vehicle or appliance. With our best outcomes met we would be bringing a robust motor controller to a wide variety of markets.

ACCOMPLISHMENTS TO DATE:

- Research of fixed point notation calculations. This was a notation we were not familiar with, since the kinds of programs we have written are typically for CPU's that have hardware capable of completing floating point calculations. This is a very common technique in DSP for saving time and performing calculations faster without the need for additional hardware.
- Implementation of Radians per second to RPM wrapper function. This function is useful for our product, since setting speed in radian per second is non-intuitive to a user when performing tests and was good for helping our understanding of performing fixed point calculations.
- Researched motor control theory and H-Bridge MOSFET implementation. The current design of the motor controller uses the H-Bridge design to output about 20 Amperes to the motor. To increase current output, we designed an H-Bridge with parallel MOSFETS.
- Updated 3.3V power supply. The improvements made to the controller will require a 12-60V input voltage that the current 3.3V regulator is not equipt to handle. I used TI Webench to find a regulator that with a 12-60V input voltage, 750mA output current, and a 3.3V output voltage. The part I decided to use is the TPS54160. This chip is rated to be able to have an input voltage of 3.5-60V. I used the data sheet to calculate the configuration to achieve a 12-60V input, rather than 3.5-60V.
- Researched current sensing techniques and current sensing amplifiers to amplify the voltage across two sense resistors and output that voltage to the DSP chip. Additional research on low pass filtering, inverting op-amp design, and digital to analog conversion. Simulated basic current sense amplifier on Ltspice. Began to implement a second sense resistor and second op-amp to the existing design to get two different sensing levels.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- Proof of position control concept. We are currently working on a matlab script as a proof of concept for our position control algorithm. Before jumping into adding the algorithm to our firmware, it is important to prove our concept by simulating our velocity curve. This approach will help us work out any bugs before integrating our algorithm.
- Implementation and integration of the position control algorithm. This is a key feature in our product and we have found that the implementation from last year's team could be simplified further. In order to simplify the algorithm we are using the information available from the controller instead of using LaGrange polynomials to model and extrapolate our future position.
- Finish research on current sensing techniques and current sensing amplifiers. Continue to understand how the output of each amplifier will interact with the DSP chip and what the DSP chip will do if the current levels are too high. Find different sense resistor values and see which is best. Add second resistor and op amp to each motor leg to get two different current sensing levels. Set the gains of each op amp correctly to achieve this.
- Update the schematic on Dx Designer. The new 3.3V supply needs to be added, the 5V supply needs to be removed, a CAN and RS-232 serial interface needs to be added, the updated current sensing circuits need to be added, the new H-Bridge MOSFET design needs to be added, and the rest of the old schematic needs to be copied over to the new schematic.
- Once the schematic is complete, we can start putting together the layout of the board in the Pads software and we can move onto the production of the newly designed board.

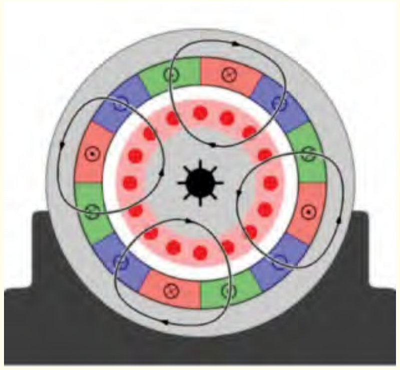


Fig. 1. Three Phase motor with twelve poles for spinning using the electromagnetic induction from the electric field we generate

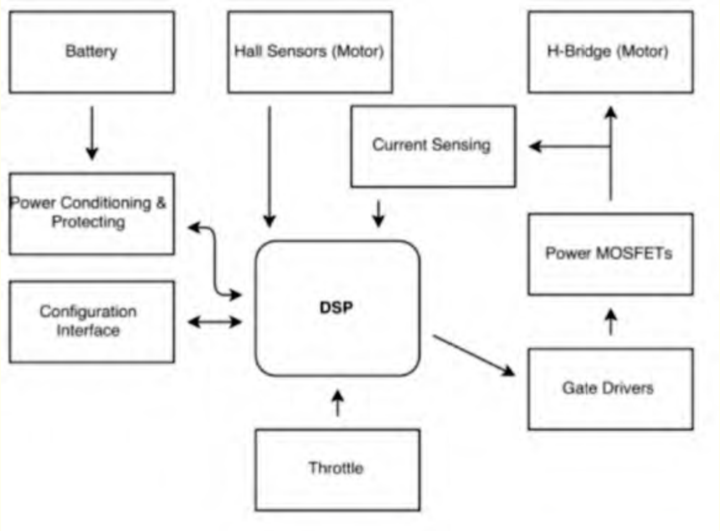


Fig. 2. Block Diagram of the components in our Three Phase motor controller, describing which components communicate between each other

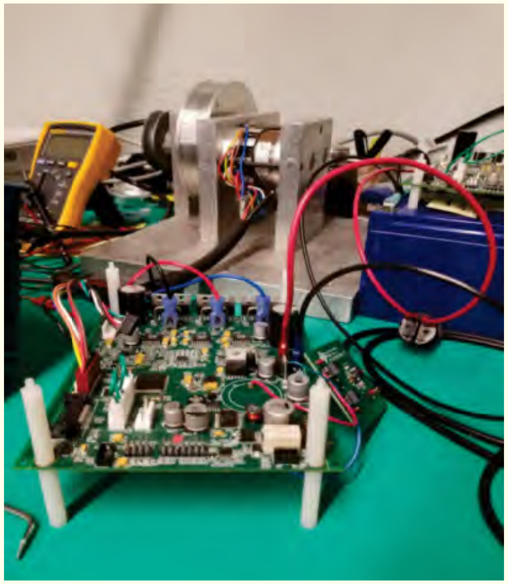


Fig. 3. Our testing area including a motor and our motor controller

Fig. 4. The previous application of our Three Phase motor controller as an electrically assisted wheelchair

BOSCH Thermotechnology

HVAC Equipment Failure Modes and Potential Solutions

bosch-climate.us

TECHNICAL DIRECTORS:

Jerry Hudson
Mike Caneja
Mike Smith

TEAM MEMBERS: (L to R)

Cole Wright (E)
Victoria Eno (E)
Alex DePetrillo (C)
Mike Smith

PROJECT MOTIVATION:

The brand Bosch, **Invented for Life**; is committed to producing the highest quality products, Consumers buy their products and services because they offer quality and reliability. In the HVAC industry, Bosch offers comfort solutions in the form of Air Source Inverter Ducted Split Heat Pumps and Water Source Geothermal Heat Pumps. Beyond the mechanical components these systems require for good heat transfer, the systems have evolved to include more electrical and software based components. A result of increased components is an increase in vulnerability to failure. To maintain the company's reputation of quality and reliability during the manufacturing of these systems, Bosch utilizes low failure-rate components. The focus of this project is to help ensure such an equally satisfying result. Team Bosch is tasked with identifying component failures, and proposing solutions to extend the life of the components. The team devised a means of measuring component operation through both software and circuit design to monitor how various aspects of heating/cooling systems affect unit operation.

ANTICIPATED BEST OUTCOME:

Ideally, our group will build a hardware and software system which will be capable of field failure data for multiple types of HVAC system. This system will extract meaningful input such as temperature, run time, voltage, and current for various mechanisms within the unit. This data will be interpreted using a micro-controller to better understand failures of individual components in HVAC systems. The final deliverable will be a prototype which will incorporate these hardware and software systems.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

The successful completion of this project will provide Bosch with a deeper understanding of how HVAC systems fail in the field. Moreover, this system will allow Bosch to see which components have higher failure rates, when components begin to fail, and how to improve their HVAC systems so that there are less failures and less warranty claims. This will help Bosch to cut both the costs and time taken to resolve claims, helping the industry to address issues faster and more effectively. Ultimately, the resulting information will aid Bosch to further develop higher quality products.

ACCOMPLISHMENTS TO DATE:

- **Research of HVAC Systems:** Our research of the different types of HVAC systems was very important to begin our project. In our research we were able to gain a deep understanding of how HVAC systems operate which allowed us to have a better understanding of which components will be monitored and how to monitor these components.
- **Sensors for Monitoring Equipment:** Our research of different types of sensors helped us to gain an understanding of the types of sensors that are available on the market. Our research also helped us learn about making design decisions based on factors such as price, size, and accuracy.
- **Sensor Implementation:** Researching different sensor implementations has helped us to understand some of the limitations and challenges we will be facing when building our system. Sensor implementation is a crucial step in our project because proper implementation of sensors is mandatory for extracting data precisely and as effectively as possible.
- **Data Logging:** Logging data and viewing data in an effective manner is a very important step because data must be kept in a useful format so that data can be read and understood by those without much HVAC experience. Developing a system which is able to show data in a useful way is one of the main goals of this project and a very important step in the project.
- **Hardware Specification, Software Specification, Bill of Materials:** The hardware specification, software specification, and bill of materials are our main deliverables for this semester. To be able to provide these documents we needed to know our system inside and out. Writing accurate and exhaustive documents we needed to have a deep understanding of what we will be building in the future and how we plan to meet our best possible outcome provided to us by Bosch.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Build HW System: Construct a HW/SW system which will be capable of acquiring field failure data for multiple types of HVAC system. This system will extract information such as temperature, run time, voltage, and current for various mechanisms within the unit. Furthermore, this system must be capable of logging and recording the received data for future software analysis. This system will contain an infrastructure of sensory devices that were determined during this past semester to be beneficial to our project.

Test Cases: Test cases will be devised for hardware verification by individually testing the specific components within the two specific heat pump system considered for this project. These cases will be considered measured faults that we will utilize as a controlled variable when similar components fail.

Code Arduino: An Arduino-based infrastructure must be coded to record and display the received data. This structure must be capable of handling all the incoming data from the sensory components, and then log the information within an SD Card. Afterwards, a LCD Touch Screen Display unit will be configured for the Arduino Leo to display recorded data from a user friendly interface.

Analyze Received Data: After a series of controlled fault testing, the computer engineer will program the Arduino so that it will analyze the data to view failures and allow engineers to gain a better understanding of why components fail.

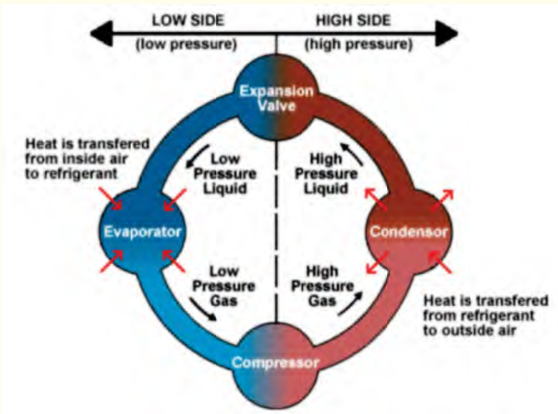


Fig. 1: Model representing how heat pumps utilize the refrigeration cycle to move heat to a desired location.

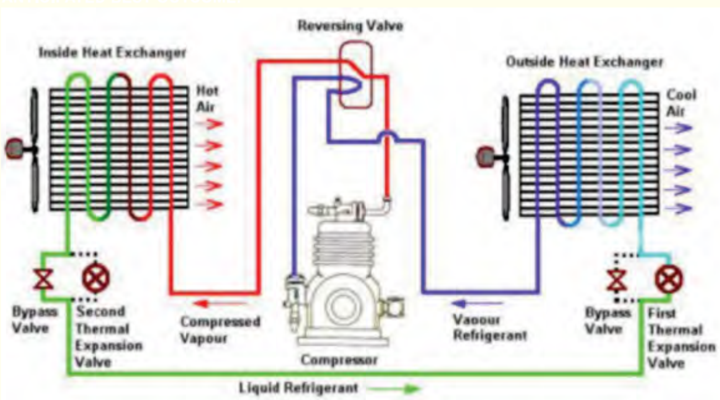


Fig. 2: Diagram of the basic operations of an HVAC system.

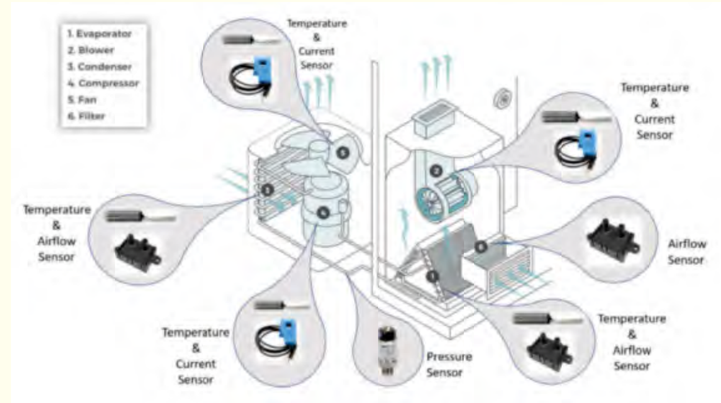


Fig. 3: Comprehensive schematic of how the HVAC unit will be monitored using various forms of sensor technology.

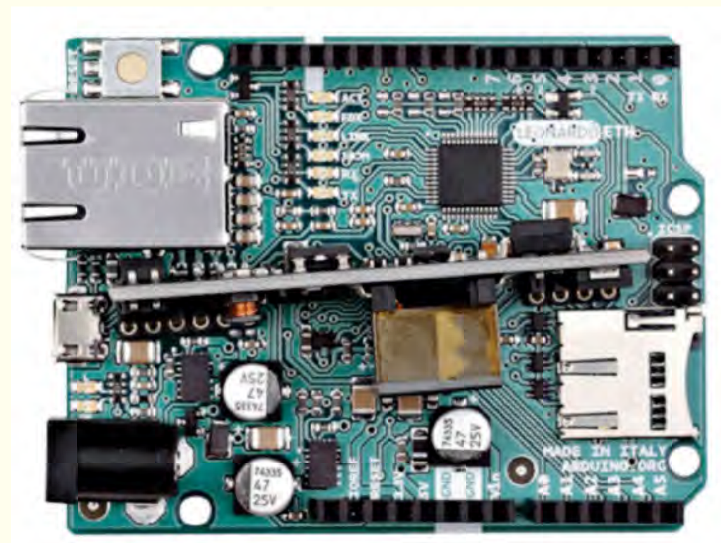


Fig. 4: Arduino Leonardo Ethernet: the micro-controller we will be using to collect and process data coming from the HVAC systems.

BOSE
Better sound through research®

Personal Radar

bose.com

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PROJECT MOTIVATION:

With an increase in technology, people have become more and more distracted by phones and other mobile devices. This can be dangerous when walking on the road due to cars, curbs and telephone poles. Recent advances in radar and its widespread use for automotive driver assistance have resulted in smaller, lower power, and cheaper systems. This project will investigate whether the technology has developed to the point where a personal, wearable radar is feasible. Using a compact radar board from Infineon Technologies, a personal collision detection system will be created which reads incoming radar signals, analyzes them using object detection algorithms and identifies potential dangers around the user. The personal radar system will be battery powered, self-contained, and able to warns users of potential dangers with a variety of methods. This device can be used by pedestrians who are constantly looking at their cellphone, or who are distracted by music. It could also be useful for people with visual impairment.

ANTICIPATED BEST OUTCOME:

The goal of the project is to have a wearable, battery powered, fully portable radar system with a functioning object recognition algorithm. Using Doppler and FMCW radar in conjunction with automotive radar equations, the wearable device should be able to detect and characterize objects in its range of vision. It should then track the object's location, speed, and acceleration and identify impending collisions. The device should alert the user, either through lights, noises, or vibrations. By the end of the project there should also be a quantifiable set of situations where the device works, and where it needs improvement.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

This is a relatively unexplored field for Bose, and when the project is complete, Bose will have a better understanding how radar systems could be used in future projects. Possible products include a radar system for the blind, or headphones that have an integrated radar system that allow the user to continuously stay aware of their situations using auditory feedback. In the future, radar will be one of many types of wearable sensors that will help the user extend their awareness of the world, and in turn will improve the quality of life for everyone.

ACCOMPLISHMENTS TO DATE:

- **Safety Testing:** Researched the possible health effects of 24GHz radar on the human body and found that due to the high frequency, the radar provides less deep tissue risk than RF radiation at the cell phone range of transmission, but due to the device being wearable, shielding the back of the board will be important.
- **Radar Testing:** Physically tested the radar board in various environmental situations to verify operating parameters of radar array and evaluate future viability of project. After initial experimentation, deficiencies in testing procedures and methods were identified, and improvements were suggested with the goal of quickly and accurately collecting large amounts of radar data in many situations.
- **Object Detection:** Existing automotive object detection and avoidance algorithms were investigated and assessed such as advanced FMCW chirp design and implementation, along with general automotive radar philosophy. Automotive radar is a well-researched and growing field which closely resembles the algorithms necessary for wearable radar.
- **Serial Communication:** Serial communication was established with the radar board using both USB and proprietary Infineon handshaking and protocols. The serial communication and data collection was implemented in Matlab to facilitate further analysis, then the serial communication API was documented for future use.
- **Data Visualization:** The radar kit includes a GUI application but is not modifiable to meet the needs of the project. To be able to easily apply algorithms and object detection, the serial communication was combined with Matlab scripts to create a personalized radar GUI. The Matlab scripts were created to visualize radar using frequency data and I/Q channel data plots. The data is also loaded in a Matlab script that will be used to extract information such as target distance, velocity, and the number of targets.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Object Detection Algorithm:** The most important and most challenging task of the project is creating the object detection algorithm. Its creation will progress incrementally. Firstly, the algorithm will be written to identify a single object in an otherwise empty environment. Then the radar system must track the object, and using the distance and velocity of the object, predict imminent collisions with the user. Once the single object case algorithm is created and tested, the complexity can be scaled up until the radar system is tracking multiple object's distance and velocity, and appropriately warning users of potential collisions. Processing will initially be done via Matlab on a laptop, but will need to be ported onto the radar board and a microprocessor to be self-contained and portable.
- **Radar Simulation:** To simplify the testing of the object detection algorithm, a Matlab/Simulink simulation will be implemented. This will enable the validation of real world radar scenarios without physically creating the setup in the lab and testing using the radar board, saving time. The simulation will need to be sufficiently complex to capture most environmental variables to best verify actual radar performance.
- **Wearable Radar:** As a wearable device, the radar board will need to be mounted to the user unobtrusively but securely. In keeping with the safety research conducted at the beginning of the semester, efforts will be made to have some shielding or space between the radar board and the user's skin. Another consideration is the size of the board. Currently a Microsoft Surface is used for data processing but this will need to be ported to the radar board or a microcontroller. Finally, the radar system must be able to warn the user of an upcoming collision using methods like a smartphone notification, a vibration, or an auditory alert.

Fig. 1. Using a corner reflector as a target in a wide-open field, we were able to achieve the most clear and understandable data, which was later used to better understand the serial output of the board.

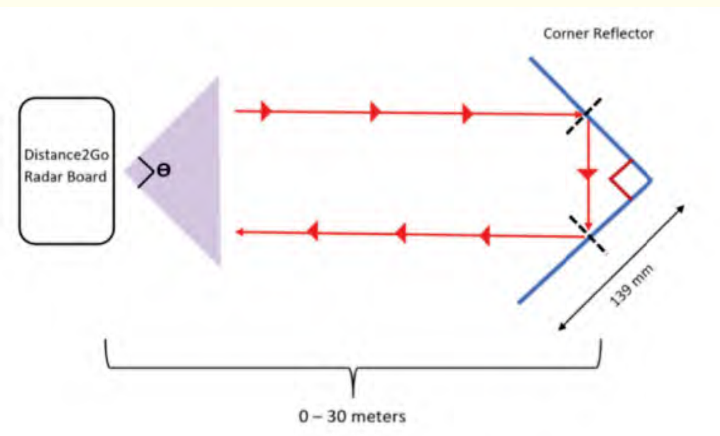

Fig. 2. With a corner reflector, the transmitted radio wave will always reflect back toward the source. We used this setup to measure max radar distance, and radar field of view.

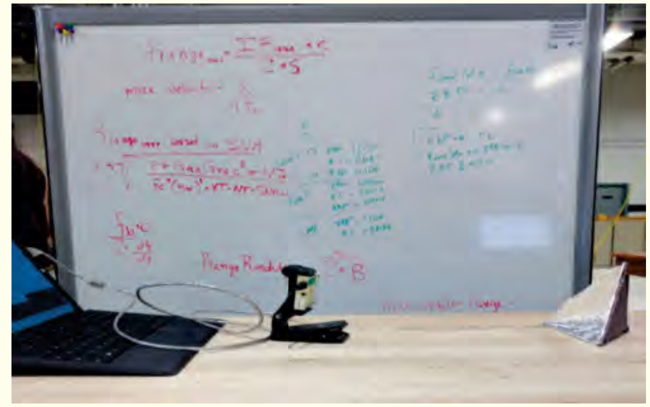

Fig 3. The radar board pointed at a corner reflector, with the radar range equations in the background.

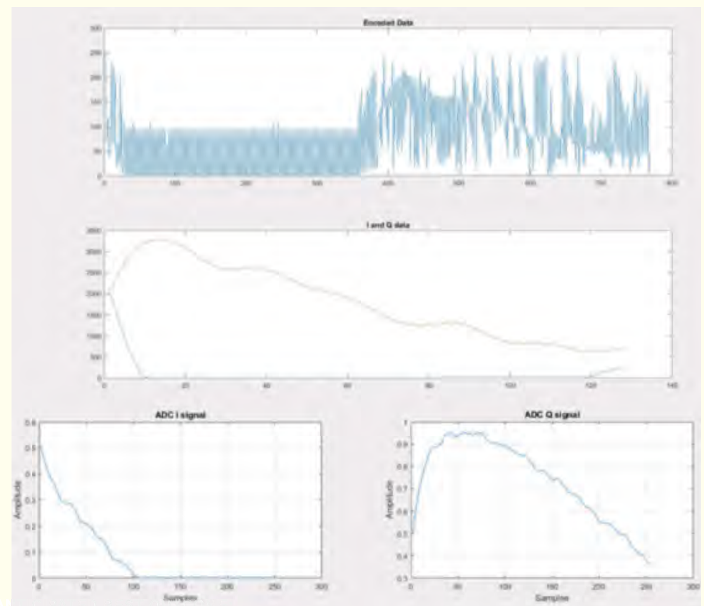

Fig. 4. Top: Raw serial data taken from Distance2Go board. Middle: IQ samples extracted from raw data. Bottom: Distance2Go GUI output from experimentation plotted in Matlab.

Wireless Pool-Side Multi-Sensor System

hayward-pool.com

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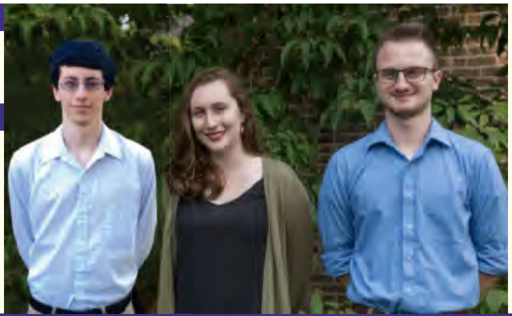

PROJECT MOTIVATION:

In many facets of life, consumers are expecting more and more tasks to be automated. Thermostats, indoor and outdoor lights, and even garage doors are now easily and instantly automated through the use of mobile applications and timed schedules. Current pool automation technologies also offer remote control and schedules but require either wired sensing of remote parameters or require the pool filtration system to be turned on. They also sense only a subset of what is needed to automate lighting and water levels. Existing aftermarket solutions are insufficiently featured or are too costly to install, resulting in an unmet market need for a comprehensive solution.

A new wireless sensing system would provide a low cost upgrade to existing automation systems. This system would upgrade existing systems and provide an extended range of highly desirable features such as precise air and water temperature measurement, water level detection, automated landscape lighting control, and pool cover detection.

ANTICIPATED BEST OUTCOME:

An alpha level prototype of a two-unit system consisting of a poolside sensor hub unit and receiver unit which communicate via radio. The sensor unit should be battery operated and collect environmental data including air temperature, water temperature, pool cover position, water level, and ambient light level. This environmental data should be communicated to the receiver unit where it will be processed and sent to the existing automation units, which will control various pool features.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

This new system will bring pool automation closer to current technology and fill a currently existing gap in the pool automation market for a comprehensive system. The poolside sensor system will give consumers the control expected of many home automation products today in a low cost package which will interface with existing Hayward pool automation products.

ACCOMPLISHMENTS TO DATE:

Product Requirements documented:

- **Initial Sensor Selection:** Possible sensors were researched. The majority of the sensors needed for the project to measure environmental factors have now been selected, ordered, and received. These include ambient light detection, air and water temperature detection, and relative humidity detection.
- **Radio and Microcontroller Selection:** An integrated radio-microcontroller package was selected after substantial research.
- **Initial Sensor Testing:** Sensor communication was achieved using an Arduino to explore I2C connection with project specific sensors. Testing was also completed using the ambient light sensor near sunset to establish a baseline level at which outdoor lighting should be turned on.
- **Radio Communication:** Initial radio communication has been achieved using two MCU development boards. A private MiWi Star network is set up between the two devices, where one is the determined transmitter (poolside sensor unit) and the other the dedicated receiver (OmniLogic Receiver), or PAN coordinator.
- **I2C Protocol Communication:** I2C Protocol was selected in order to reduce the amount of GPIO pins used by our multiple sensors, as it only requires two pins to create a data bus. Communication is accomplished via device addressing, which means that each I2C device is assigned an address that the MCU must use to communicate with it. We were able to successfully communicate with the sensors via I2C, in which we wrote the necessary configuration registers in order to read the correct measurements.
- OmniLogic interface: A confidential protocol was developed to interface with OmniLogic.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Power Budget:** A power budget must be generated and implemented so that the system can run on one pair of AA batteries for ideally a full year. Low power considerations must also be added into the system, such as sleep mode routines. The main factor that will be taken into consideration is when to transmit the sensor data, as the radio communication is the biggest power drain on the poolside sensor unit. The sensors will be taking measurements every ~1-2 seconds, but should only transmit data much less frequently than that in order to conserve power.
- **PCB Layout:** Layouts must be generated for the final printed circuit boards, which may then be printed and fitted into the selected enclosure.
- **Capacitive Sensing:** We will be designing capacitive sensing circuits to interface with the existing poolside sensor unit. Also, snap buttons may be necessary to enable user interaction at the poolside sensor unit without water interference causing false readings. The software driver for the capacitive water level circuits must be robust in handling constant changes in measurements due to disturbances in the pool, such as wind or swimmers.
- **Enclosure Selection & Waterproofing:** Research and select an enclosure for both the receiver unit and poolside sensor unit. Special considerations must be taken to ensure that the poolside sensor unit is completely waterproof but allows the sensors to read data from the pool environment.
- **Prototype Testing:** Complete testing of the final prototype in a real-life test environment, including immersion testing and communication testing.
- **Receiver Unit User Interface:** A user interface must be created at the receiver unit to enable fine tuning of desired settings such as water level, failure to fill lockout, and automated outdoor lighting. Other information such as average and total water fill time, current air / water temperatures, and current outdoor light levels will be displayed.

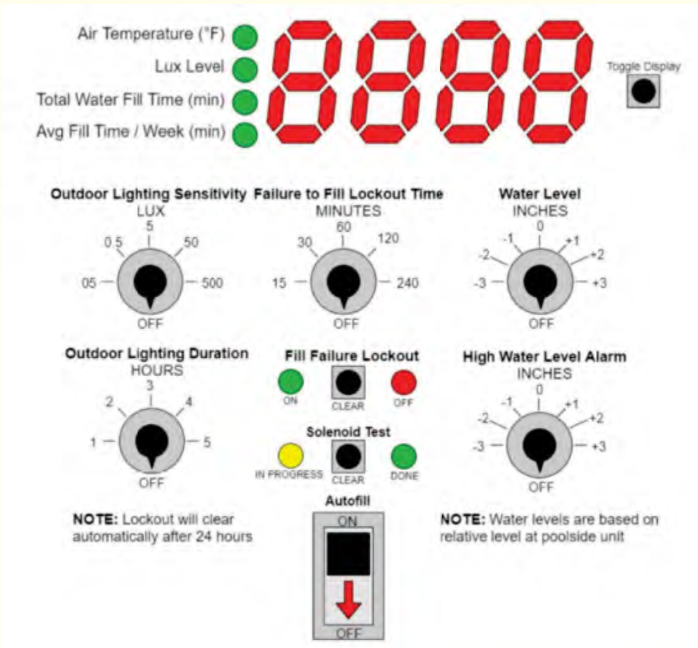

Fig. 1. Receiver Unit Interface Mock-Up

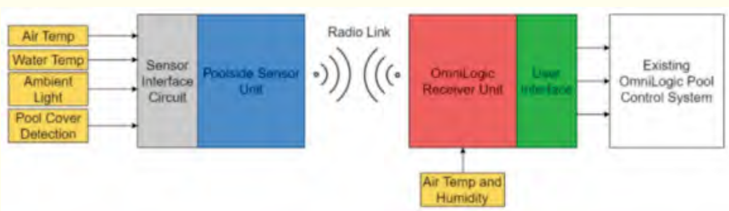

Fig. 2. System level block diagram displaying the project scope

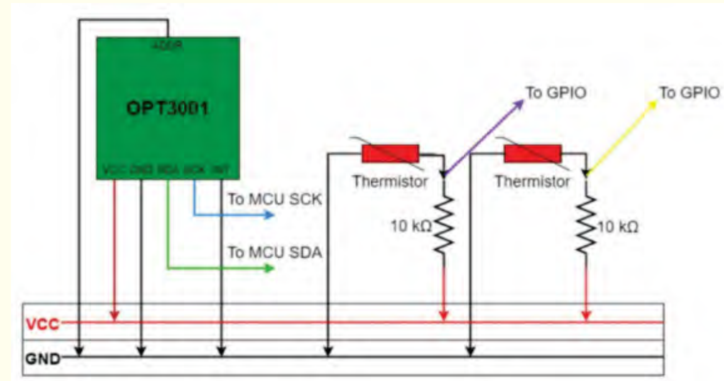

Fig. 3. Schematic of Development Setup

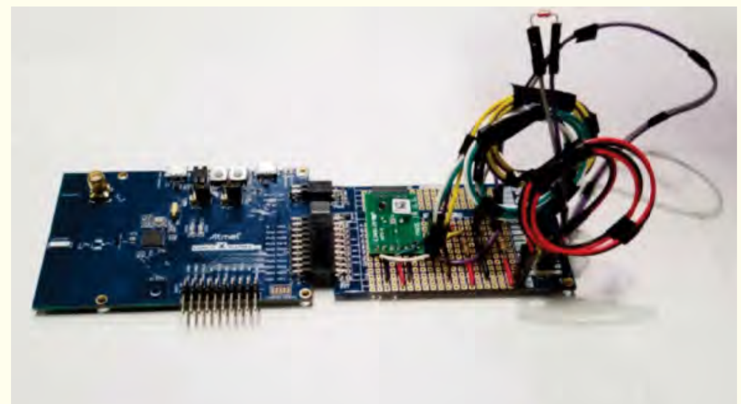

Fig. 4. SAMR30 Development board with Sensor Protoboard

Fast, Portable Chlorine Generator Cell Tester

hayward-pool.com

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PROJECT MOTIVATION:

Currently, Hayward approved servicers of the AquaRite Salt Chlorine generation system use a storefront diagnostic tool to determine if the T-Cell chlorine generator has worn out. This involves connecting the warranty T-Cell to the tester's plumbing and generating measurable chlorine, the parts-per-million of which depend on the cell's age, as well as how dirty it is. The current tool is too expensive, too bulky, too easy to misinterpret, and thus is only used by a fraction of the servicers that diagnose and make warranty claims. As such, many cells are approved for warranty claims when they are in fact fully functional, or simply dirty.

Our capstone team will use water conductivity sensing, test signal generating circuits, impedance measurement, and software to produce a new testing method that is simple for any technician to comprehend, portable and less expensive. This innovation will allow Hayward to widely deploy thousands of T-Cell testers, saving possibly 15% of total warranty claims.

ANTICIPATED BEST OUTCOME:

Ideally, by the end of the project our team will have developed a fully functional T-Cell tester. The ideal test unit should be battery operated for portability, function at a wide range of temperatures and be compatible with all Hayward T-Cell models. The tester's interface will be simple and allow the user to initialize the test and clearly see if the cell passes or fails, as well as the cell's chlorine output and other parameters. Previous test results will be stored for ease of access, and be sent to a bluetooth-enabled app for simple warranty claims. Ideally, the total cost of the tester will be $30.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

For Hayward this product will reduce illicit and costly warranty replacements of fully functional chlorine generator cells. Additionally, It could save Hayward up to $500k annually. From the end-user standpoint the new tester will assist Hayward technicians in troubleshooting faulty T-cell chlorine output, and simplify the warranty process for failed cells. By utilizing a simple yet comprehensive user interface there will be no confusion regarding whether or not a T-cell qualifies for a warranty replacement. If the cell qualifies, the warranty process will be streamlined via the tester's app. Overall, this will reduce bottom-line costs for Hayward and increase profits on T-Cell generators.

ACCOMPLISHMENTS TO DATE:

- **Designed Preliminary Testing Circuit:** The first testing circuit designed utilized a schmitt trigger oscillator to provide a 1 KHz square wave to drive each individual cell. From testing, data was collected distinguishing a functional cell from non functional cell. The data collected did not differentiate low and high salinity solutions enough though, as the output current while in an acid solution was far too low.
- **Designed Testing Circuit:** Our revised testing circuit utilized an RS485 driver to drive the T-Cell as well as a differential amplifier to sense voltage and current. This meant that the circuit will be able to properly power the T-Cell while cleaning in an acid solution.
- **Generated Square Wave:** Using the MSP430 launchpad, we were able to generate and output a 1 kilohertz square wave signal. This signal will be used by the testing circuit we designed to determine whether the T-Cell being tested is working properly or not.
- **Read Voltage from Circuit:** We were able to read the voltage from the circuit using the analog to digital converter (ADC) available on the MSP430. This voltage reading allows us to determine the effectiveness of the T-Cell.
- **Display Data on LCD:** We were able to interface the MSP430 with a LCD display. This will allow us to show results and other data to the user, as well as provide a way for the user to interact with the tester.
- **Created UI proposal:** Our User interface was designed to be simple to use and provide the user with clear results. An LED bar graph was used as a makeshift VU meter, to provide a clear indicator of the cell's output and overall health. A 2x20 LCD was utilized with softkeys to provide clear testing instructions and allow the user to make selections based on which step in the testing process was active.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **UI Circuitry:** Our user interface must be implemented utilizing soft keys underneath the LCD, to provide additional options for the user to select based off of which step in the testing process is currently active. The LED drivers must also be implemented and verified to complete the status component of the user interface. These LEDs will indicate if a testing step was completed properly, as well as any errors that may arise.
- **Capacitive Buttons:** Once the UI portion is complete with simple pushbuttons and softkeys, we will replace the pushbuttons with capacitive touch buttons to provide a sleeker appearance to the user interface. The capacitive touch buttons will require additional MCU pins and can only be implemented once our design moves off of the launchpad.
- **Bluetooth Capability:** The T-Cell Tester will eventually have Bluetooth capabilities. By using Bluetooth Low Energy (BLE), the tester will be able to communicate the test results to a companion mobile application. This will allow users to quickly and easily file a warranty claim for damaged T-Cells by automating many of the tedious and time consuming that are currently being done manually.
- **PCB:** After all components of the MCU, sensing and driver circuitry, user interface circuitry and Bluetooth are functional, a PCB of the final tester design should be created and manufactured to finalize the tester design.
- **Finalize Enclosure:** We have two possible ideas for a plastic enclosure, the first is to find a possible enclosure online that would offer CNC machining. The second option would be to 3D print a custom enclosure temporarily until a supplier can be found. Having a 3D printed enclosure temporarily would not only secure our circuit, but also give us a better idea of what our final product will look like.

Fast, Portable Chlorine Generator Cell Tester

hayward-pool.com

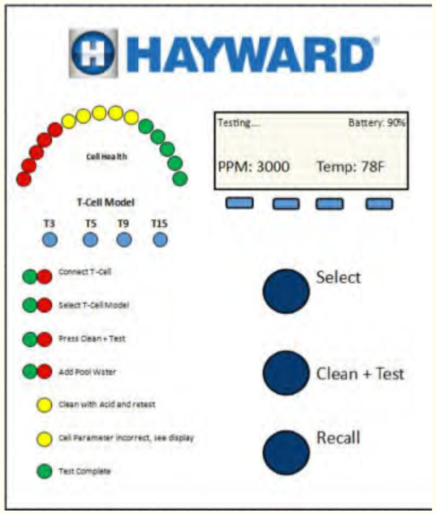

Fig.1. Design sketch of the proposed T-Cell Tester User Interface

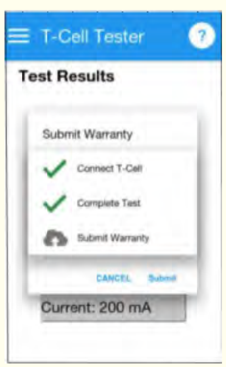

Fig. 2. Proposed Mobile App screenshot

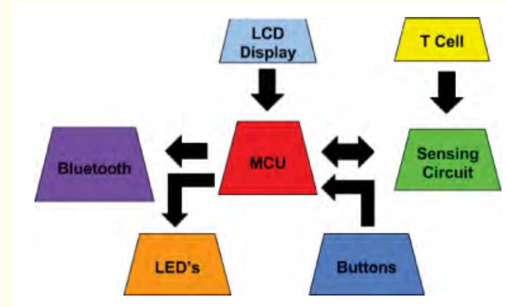

Fig. 3. Block Diagram of Tester components

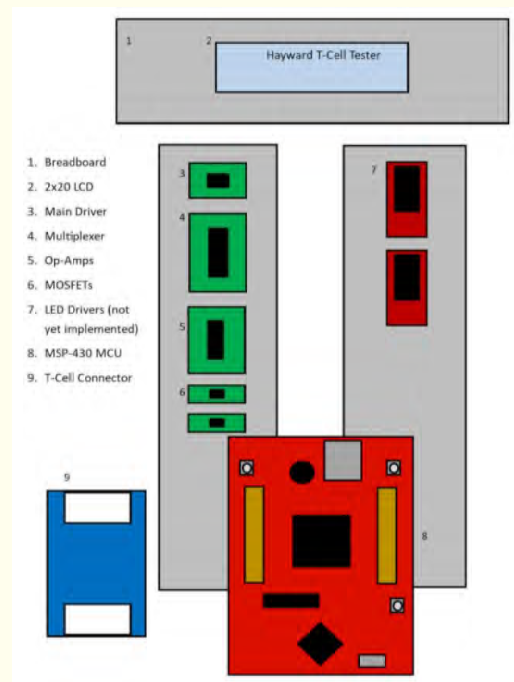

Fig. 4. Diagram of current physical prototype of the T-Cell Tester

HEXAGON METROLOGY

3D Printing Retrofit Package for a Coordinate Measuring Machine

hexagonmi.com/en-US

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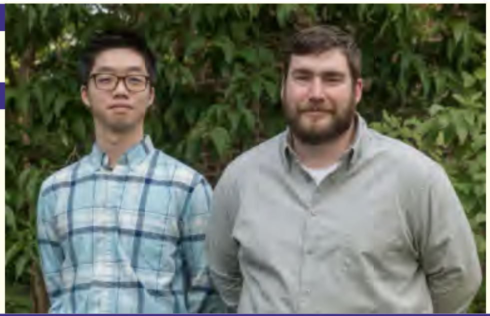
Michael Tougas (C & CS)



PROJECT MOTIVATION:

A time demanding factor of ensuring that a product is created to exact design specifications is the designing, engineering, and manufacturing of the fixtures that will hold it in place during the measurement process. The motivation of this project is to provide a retrofit package to add the capability of 3D printing to a Coordinate Measuring Machine (CMM). Adding the capability to 3D print an object on a CMM will allow users to leverage the size and precision of a CMM to design and print large format 3D prints. The intent of developing this package is to provide the means to 3D print the fixtures that will secure the product being measured by the CMM. This project will begin as exploratory research and expand into proof of concept design, testing, and demonstration.

ANTICIPATED BEST OUTCOME:

The anticipated best outcome for this project is a fully functional proof of concept 3D printing retrofit package for the CMM that provides an interface and a 3D print head assembly. The interface shall have the capability of using a 3D drawing file as a selectable input, slicing the 3D drawing into layers, translates the layers into movement commands for the print head and the CMM, and sends them to their respective devices. The 3D print head assembly shall be mountable to the existing CMM design. When installed the output shall be a usable 3D printed object.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

The implications of the BEST outcome will result in a patent and a niche market that utilizes the size and capabilities of CMMs to perform 3D printing. Additionally, by leveraging the capability to create the required fixtures for measuring a product will provide a cost saving method to owners of the system. Most CMM functions require an operator, however, 3D printing does not and as such it can be performed during the natural downtime of the system increasing productivity. On a broader spectrum, this package will help set Hexagon equipment apart from their competitors, more than it already is.

ACCOMPLISHMENTS TO DATE:

- **Research and Understanding:** Performed research into the structure and operation of 3D printing. Researched Coordinate Measuring Machines (CMM) and their design and operation. Researched G-Code, which is the programming language for 3D printers, and the slicer programs. which generate G-Code from 3D model drawings. These accomplishments provided us with the necessary understanding to make strides towards the BEST outcome goal of this project.
- **Part Selection:** Based on the research performed appropriately sized parts for the 3D print head retrofit package were selected. These parts are anticipated to be able to leverage the size of the CMM.
- **Performance Testing:** Performed performance testing on each individual component to ensure proper behavior and to confirm expected results. This was required because of the requirement for the heat bed and extruder head to operate at specific designated temperatures.
- **Printer Assembly:** Assembled the print head assembly, the heat bed assembly, as well as a stable test stand to support the printhead for individual control testing.
- **CMM Control:** Built a client program that provides a graphical user interface that can control the CMM by utilizing a TCP socket. The program and the CMM can perform two-way communication that allows the user to control the machine and receive real time updates on the completion of commands in a scrollable list built into the interface.
- **CMM Replicator:** Designed and programmed a test server that will replicate the responses of the CMM. This provides the ability to test the capabilities of the client program without needing to be connected to the CMM. The replicator also provides the ability for the programmer to witness what information and data is being passed depending on the actions of the user.
- **G-Code Interpretation:** Programmed a function that will break down a G-Code file into move commands, for the CMM, and extrusion commands, for the print head.
- **CMM Command Generation:** After parsing the G-Code, a secondary file is generated comprised of the equivalent commands written in the CMMs. This allows the program to accept a gcode file as an input and subsequently pass the generated CMM translation file to the machine.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Arduino Control:** Need to configure and test the ability to control the extrusion head temperature, heat bed temperature, and the filament feed rate with the Arduino controller.
- **Bluetooth Communication**: Need to establish an Arduino-to- Arduino Bluetooth communication link for wireless control of the extrusion head.
- **Extrusion Testing:** Testing for consistent extrusion and control of the print head assembly will need to be performed.
- **Machine Mounting:** A mounting assembly will need to be developed to fit the retrofit package to the CMM probe mount.
- **G-Code Extrusion:** A method needs to be developed to communicate the extrusion commands to the printhead assembly based on the G-Code interpreter.
- **Conversion Testing:** Testing needs to be performed to ensure the accuracy of the translated G-Code.
- **Final Product:** Final assembly and testing will need to be performed to ensure adequate performance. Changes will be made as necessary.

3D Printing Retrofit Package for a Coordinate Measuring Machine

hexagonmi.com/en-US

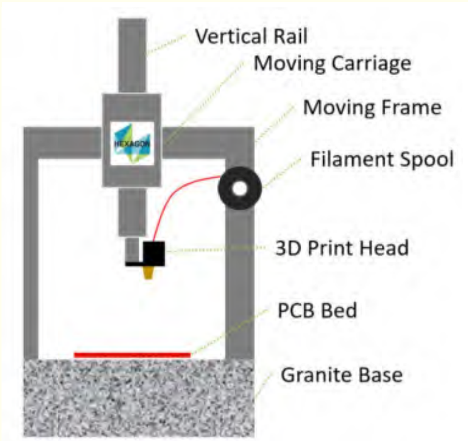


Fig. 1: The 3D printer retrofit package installed on a Coordinate Measuring Machine(CMM). The retrofit package will be able to be installed in a simple manner that will still allow full motion of the machine while operating in its 3D print mode.

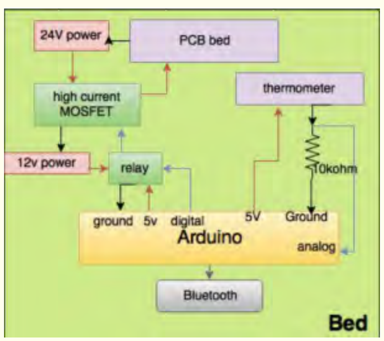


Fig. 2: Wiring diagram for the Arduino that will control the 3D print head assembly. The arduino also has a bluetooth link to another Arduino unit that controls PCB bed.

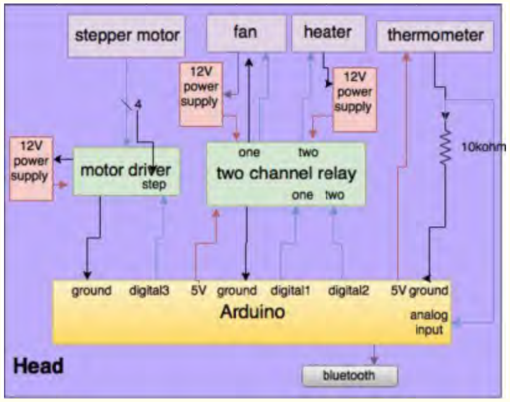


Fig. 3: Wiring diagram for the Arduino controller that will be connected to the command console and to the PCB bed. This arduino will control the PCB bed temperature as well as convey all of the print head commands to the printhead assembly Arduino via the bluetooth connection.

Fig. 4: This is a sample of the client interface in its current state during development. The interface provides the methods for the user to interact with the 3D printer retrofit.

Optical Character Recognition Reader for Manufactured Drawings

hexagonmi.com/en-US

TECHNICAL DIRECTOR:

Jonathan O'Hare

TEAM MEMBERS: (L to R)

James Luther (C & CS)
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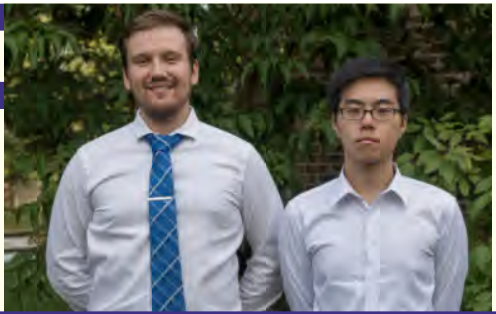

PROJECT MOTIVATION:

In the manufacturing industry, companies will often use computer aided design (CAD) software to help with the creation, modification, analysis, and optimization of a design. The utilization of CAD programs has greatly increased the efficiency and productivity of the designer as well as improved the quality of the design. Product manufacturing information (PMI) is usually included as metadata in more comprehensive CAD models, with information in the form of geometric dimensioning and tolerancing (GD&T) symbols and glyphs. Currently, most companies have not incorporated PMI in their CAD models and resort to conveying the necessary GD&T information through 2D layout drawings, which requires human interpretation. All of the information from manufacturing drawings is extracted manually and logged into other programs. This process is time-consuming and is prone to errors, which could result in massive losses for companies. Hexagon hopes that with this project, we will be able to create an application that can recognize and extract all of the relevant information from manufacturing drawings using optical character recognition (OCR) and enter the information into other programs automatically with minimal human interaction. This will reduce error rates and greatly improve efficiency.

ANTICIPATED BEST OUTCOME:

The best outcome for this project is to first train an OCR engine to recognize and extract all of the relevant GD&T symbols in the product manufacturing information with greater than 90% accuracy. The extracted information should be put into a logical format so that other programs can use it to directly create measurement routines for an automated measuring system. We would also need to integrate the OCR engine that we have trained into a standalone application as well as a mobile application, with the code being portable so that it can be used on any platform and distributed for use across multiple devices.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

A working mobile application for GD&T character recognition would be extremely useful to a wide range of customers and could be sold as an inexpensive add-on to extended capability with Hexagon's existing software products. The other benefit of having the OCR engine in the form of a mobile application is so that it could be used as a direct link between Hexagon and their individual users and could also be used as a tool to maintain customer relations with their customers.

ACCOMPLISHMENTS TO DATE:

- **Testing of different OCR engines:** Tested 7 different OCR engines and applications, Tesseract, JavaOCR, ImageGear for Java, ImageGear for C/C++, FineReader, LeadTools Winforms OCR Modules and Winform OCR Advantage to determine which engine to use for the foundation of our OCR engine.
- **Evaluation of OCR engines:** Evaluated each of the OCR engines by comparing and contrasting the supported languages, the requirements for training new language, its accuracy, as well as the licensing options for the respective engines. Determined that Tesseract is a good engine to use for this project.
- **Preparing training files:** Manually generated the training text and image file for Tesseract training, which includes GD&T symbols of different font size mixed with each other. Used Tesseract OCR Chopper to generate box file coordinates for all of the GD&T symbols. Ran commands to generate the unicharset file using the TIFF and box file pair.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Finish training Tesseract:** Finish the training process of tesseract by making a starter traineddata from the unicharset. Then run Tesseract to process the image and box file to make the data set for training. Lastly run training on the data set for Tesseract. The Tesseract engine needs to be able to recognize and extract all of the relevant GD&T symbols in the test drawings with greater than 90% accuracy.
- **Create standalone application:** Need to integrate the trained Tesseract language library and package into a standalone web application. The application should include command line and batch executable for further testing, having the output of GD&T data in XML format.
- **Create mobile application:** Finally implement OCR capabilities in a mobile application. The app should be able to take high resolution TIFF images and extract all of the relevant GD&T information in the image, with tools for GD&T validation and editing. Could also have some sort of mechanism to crop out only the relevant sections of the drawing to minimize computation. Lastly, have the option for the output to be sent over networks to other softwares or as emails.

HEXAGON METROLOGY

Optical Character Recognition Reader for Manufactured Drawings

hexagonmi.com/en-US

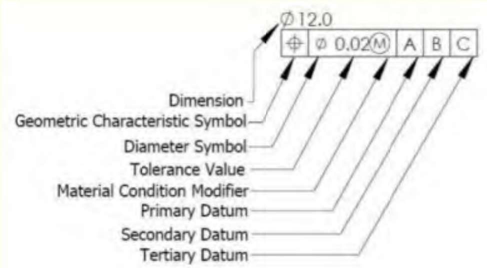

Fig. 1. Example of a feature control frame used in CAD (Computer-aided Design) blueprints to describe the conditions and tolerances of a geometric control.

TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL
FORM	STRAIGHTNESS	⏤
	FLATNESS	⏥
	CIRCULARITY	○
	CYLINDRICITY	⌭
PROFILE	PROFILE OF A LINE	⌒
	PROFILE OF A SURFACE	⌓
ORIENTATION	ANGULARITY	∠
	PERPENDICULARITY	⊥
	PARALLELISM	//
LOCATION	POSITION	⌖
	CONCENTRICITY	◎
	SYMMETRY	⌯
RUNOUT	CIRCULAR RUNOUT	↗
	TOTAL RUNOUT	⌰

Fig. 2. Some of the common GD&T (Geometric Dimensioning and Tolerancing) symbols seen in feature control frames.

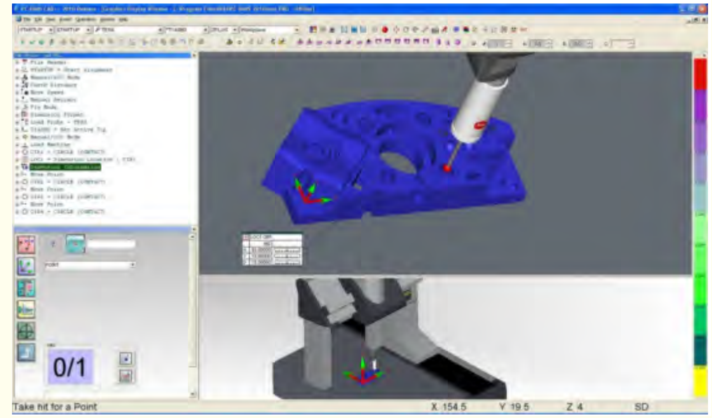

Fig. 3. Screenshot of the PC-DMIS software developed by Hexagon, used for the inspection, measurement, and analysis of parts and models.

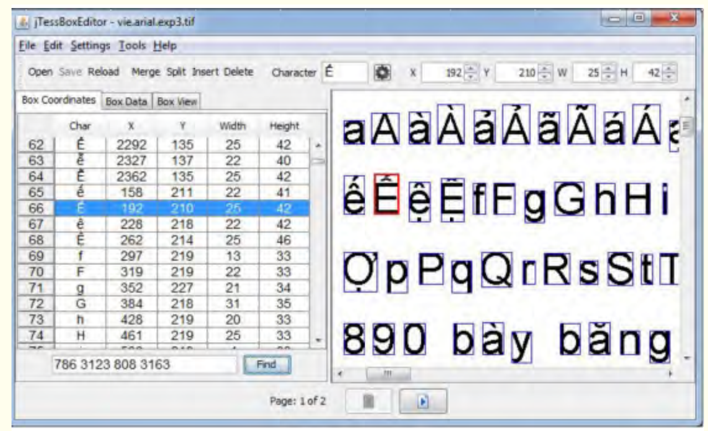

Fig. 4. Example of a box editor needed for the training process. It reads common image formats such as PNG or TIFF create boxes around the characters that Tesseract needs to recognize. Data includes the box coordinates, the font, as well as the font size of the character.

Image Processing from a Camera Type Device

igt.com

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PROJECT MOTIVATION:

The motivation for this project is to improve upon the current lottery terminal playslip reading technology. The current readers have done tasks at the same level of quality and efficiency for several years. IGT's camera readers can have trouble when sunlight is overexposing a portion of the playslip or when playslips are crinkled and bent. IGT would like a camera reader that can scan playslips in more varied lighting, using High Dynamic Range technology. IGT would also like to upgrade the scanner's ability to process uneven and obstructed images, possibly by stitching together several partial images. Image processing software using the Java programming language will be implemented to demonstrate the effectiveness of developed algorithms. Data will be received from the camera through raw image files, allowing for more control over the raw sensor data being collected by the camera. These raw image files will be processed and the image's pixel data will be extracted through the application.

ANTICIPATED BEST OUTCOME:

The best outcome of this capstone Design Project is to produce an image of significant to support the reading of numbers and text from IGT lottery slips. The playslip scanned can be of varied quality, whether wrinkled, shadowed, or angled. The code designed will use the High Dynamic Range (HDR) technique, taking multiple photos of a playslip and combining the images for the highest quality processed result. In addition to this, the process of Illumination Normalization will be used to help clearly define and remove any unintentional lighting, shadows, and blurs.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

Currently, camera-based playslip reading technology is greatly hindered by factors such as topography asymmetries and lighting aberrations. If we are successful at developing an HDR algorithm, the algorithm can be integrated into a new image processing library currently under development at IGT to combat the aforementioned obstacles. This breakthrough will grant new image processing capabilities to IGT and revolutionizes the way images are processed in the lottery industry. The data and experience gained from the project will get IGT closer to using improved image taking in unstable lighting, and processing data from combining multiple partial images.

ACCOMPLISHMENTS TO DATE:

Our team has taken large strides towards our technical goals. Our process began with a study of the project's relevant topics, including Camera Sensors, Bayer Patterns, and High Dynamic Range Imaging. Afterwards we began development of a Java application where we implemented our image processing algorithms.

- **Initial Software Prototype:** An initial prototype of our software was developed that read JPEG images and displayed them on separate windows. This design was improved to display all the images in one window, each under their own tab.
- **Raw Data Extraction:** IGT provided us with sample raw image files. Our software was modified to extract the raw image data from these raw files, outputting the camera's raw sensor data in the form of a grayscale image.
- **Bayer Filter:** Through the application of Bayer Patterns, the raw sensor data was expanded to 3 color channels, allowing for the program to display the raw image's bayer filter output.
- **Interpolation:** Afterwards, each pixel holds information on either the red, blue, or green color channels. We implemented basic interpolation techniques to determine each pixel's missing color channels by finding the average color values from surrounding pixels.
- **High Dynamic Range (HDR) Imaging:** We implemented basic solutions for the task of developing HDR images. Given both an underexposed and an overexposed raw image of the same subject, an image must be developed that combines aspects of both images. The intent is for all shadows and light glares to be removed from the result.
- **User Interface:** The prototype contains a graphical user interface where one can select a raw image file to be processed by our algorithms. The user can then save the processed images.
- **Hardware Setup:** The hardware is composed of an inverted tripod, two 12-Watt LED strips, and a Canon Powershot S110 digital camera.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

The remaining technical challenges that our team still face are:

- **Processing images of wrinkled/uneven play slips:** Due to play slips sometimes being wrinkled or folded at time of image capturing, one of the team's primary technical challenges remaining is to develop an algorithm that eliminates or reduces all topography aberrations of lottery play slips on the image.
- **Produce readable images in any range of lighting:** Lighting inconsistencies such as overexposure or underexposure of images could result in vital information from the play slips being illegible/unreadable. A more robust and efficient high dynamic range algorithm need to be implemented in order to process overexposed and underexposed images and ultimately produce an image that captures greater details from light and dark areas.
- **Develop algorithms to stitches portions of an image together:** Currently, the camera terminals used by IGT can only take pictures of a certain size, what this imply is that if a larger picture was to be captured, the program would have to take multiple pictures. IGT would like to develop a program that could take three images of the same size and stitch them together to create one larger readable image. Once the stitching process is completed, the data from the larger image would then have to be processed and read by the code used on smaller images.

Fig. 1. Inverted Camera Tripod Display

Fig. 2. Camera Output passed through our software: Raw sensor data (top) passed through a bayer filter (middle) with missing color values interpolated (bottom)

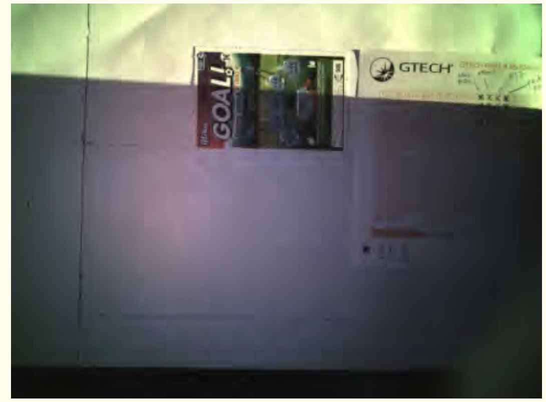

Fig. 3. The output of a raw image file, passed through our software

Fig. 4. Overexposed image (top left) and underexposed image (top right) combined to generate HDR image (bottom)

Gen-2 SPEC Tester
(System Power Extended Cycling)

infineon.com

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TEAM MEMBERS: (L to R)

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Cooper Hobbs (C)
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PROJECT MOTIVATION:

DC-DC converters must provide steady power to large processing units and as power demands are increasing, competition to make the most effective and efficient devices pushes innovation forward. Once many of the logistics of a design have been determined, minor modifications can be made in order to further optimize the performance of the design. These could be changes in the layout of MOSFETs on the chip, supporting hardware, or changes in semiconductor structure or doping levels. Testing racks are used to test sets of these chips, each divided into groups. These IC's are placed under heavy demands and held under identical conditions in order to maintain a controlled testing environment. The results of these tests can further the development of these chips. This project is motivated by the need for an efficient, compact, testing rack that can both control the conditions between chips and accurately report data. This will allow Infineon engineers to properly interpret the results and to work towards the best outcome for their DC-DC converters.

ANTICIPATED BEST OUTCOME:

By April 13th, 2018 we anticipate to have implemented a complete system capable of monitoring and managing the entire SPEC (System Power Extended Cycling) testing platform. The features/functions of this system will include the following: Telemetry data consolidation and management for 60+ I2C devices, thermal management and monitoring of local cooling fans, load control, support for different cycling modes for input power and channel enabling/disabling, and fault management through use of text/email alerts along with channel isolation and E-Fuse control. All of these features/functions will be controlled using a graphical user interface specifically designed and programmed for this system.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

The successful completion of this project has the potential to give Infineon a significant advantage in the switch-mode power electronics industry. Using the SPEC testing platform, Infineon engineers will be able to precisely test multiple design configurations of their DC-DC converters both quickly and effectively. By monitoring the individual performance of each device, the team at Infineon will be able to determine the optimal characteristics for their devices performance and efficiency. With this system, Infineon will be able to actively stay ahead of their competition in the power electronics industry.

ACCOMPLISHMENTS TO DATE:

- **Extended Test System Main Board:** Our team assisted Infineon engineers to create the basis for an extended test system. A ten chip main board has been created, representing a single neighborhood in the final six neighborhood testing rack. The board is constructed with components specific to each chip - consisting of the phase controller, custom load, and power phase - and implemented on cards, which are plugged into the main board. This modularity in the design allows Infineon engineers to easily update main components individually, replace broken components, or switch the device under test. Once final design requirements are met, this main board can be replicated to construct the rest of the testing rack.
- **Transient Generating Load Board:** The load board is used to generate current transients in order to stress the devices and to test performance. This has been accomplished using power MOSFETs driven by a control voltage detected across extremely low impedance sense resistors. Current transients can be generated with a waveform by quickly ramping the control voltage causing the load to suddenly draw a large amount of current, which could potentially reach over 100 amperes. The phase controllers must accurately control the output of the power phases to supply sufficient current to the loads. Phase controller performance is determined by the ability to maintain a steady output voltage over the course of these tests.
- **DAC Control:** The load board control voltage can be generated via an onboard potentiometer, external waveform generator, or onboard digital-to-analog converter (DAC). URI Capstone Designers worked with an Arduino microcontroller to control the output of the load board DAC. This can be used to locally control the current setpoint or even generate custom transient waveforms. Characteristics of the waveform such as rise time, fall time, duty cycle, and maximum value can be modified for varying test schemes.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

In order to achieve the best outcome, Capstone designers must work with Infineon engineers to overcome two major challenges:

- **I2C Limitations and Load Board Stress-Testing:** Currently, the load board DAC cannot generate transients at a high enough rate to sufficiently stress the regulators. These limitations are a result of the I2C protocol, which throttles the rate at which the control voltage can be stepped. This is because the waveforms to be output are stored offboard on the microcontroller. This waveform must be communicated using I2C to the DAC in real time to modify the current. The best outcome design would include a DAC with the ability to locally store a waveform directly on the load board. This would allow extremely fast output of voltage samples, removing transient rate limitations. A microcontroller would load a waveform into memory before testing, which would later be used for quick, repeated testing.
- **Phase Protection, Telemetry Data Consolidation and Management:** Not present in this design is a phase protection controller, which has the ability to protect against dangers such as over-voltage and excessive forward/reverse current. In addition to protecting the power phases, these chips also allow real-time collection of important performance data that would improve the analysis of these tests. This monitoring and protection chip allows accurate, high resolution collection of data which can be easily collected from the device's read-only registers via the I2C bus. This data will be collected using a field-programmable gate array (FPGA) to transmit streams of parallel data from all chips to a user interface. Each chip must be serialized individually and paired with its performance data in order to facilitate analysis. The user interface would allow for easier data interpretation and for custom test configurations. Implementation of these features will improve data collection and testing, allowing Infineon engineers to better improve the performance of their regulators and to remain competitive in the industry.

Gen-2 SPEC Tester
(System Power Extended Cycling)

infineon.com

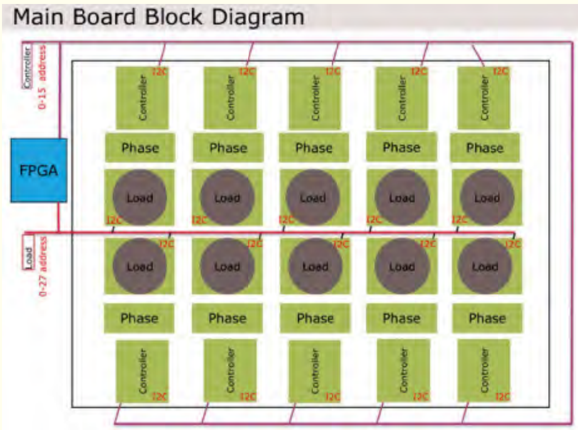

Fig 1. A diagram of one of the main boards. The final test rack will house 6 of these configurations.

Fig. 2 This is the main test rack that will hold the system that will test 60 individual voltage converters.

Fig. 3 The load board (top), single phase board (bottom right), and phase controller (bottom left).

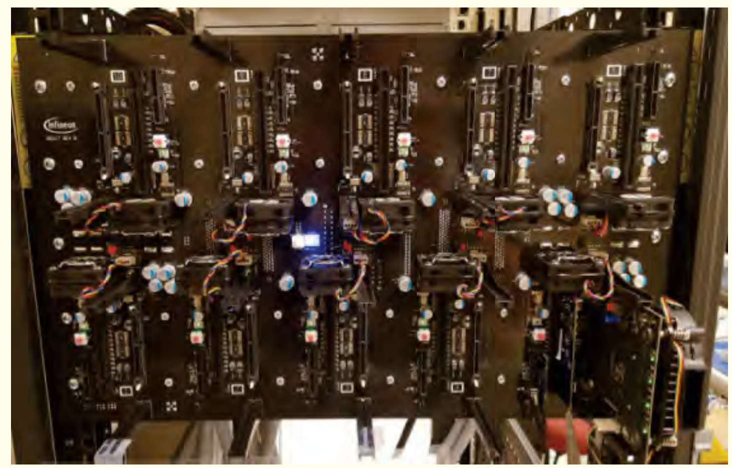

Fig. 4 One of 6 test neighborhoods that holds up to 10 devices

IRADiON Ceramic Core CO_2 Lasers

Automatic Laser Optimization

iradionlaser.com/en

TECHNICAL DIRECTOR:

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TEAM MEMBERS: (L to R)

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Domenic Ferri (C & E)

PROJECT MOTIVATION:

As Iradion further grows its product line and customer base, the ability to deliver the highest quality lasers in the allocated time becomes more and more challenging with traditional laser tuning methods. These methods consist of entering the laser with long screw drivers, making inaccurate manual adjustments, and using the laser beam to calculate complicated attributes. This process is very inconsistent, time-consuming, and dangerous.

The purpose of the AutoLase project is to offer a faster, safer, and hands-off approach to laser tuning and alignment. The adjustment process will fully computer automated by using customized actuators driven by customized hardware and software algorithms capable of reading specific laser attributes and making the necessary adjustments. Adjustments will now be far more accurate thus increasing the overall consistency of products being sold. No longer will production workers spend a large sum of their valuable time with the current trial and error process, or be required to enter the laser and place their hands next to powerful laser beams.

ANTICIPATED BEST OUTCOME:

The best outcome for this project would be to create the hardware and software required to completely automate and optimize the laser tuning and alignment process. The system will make adjustments to the laser in order to achieve the desired laser attributes. This will be achieved with a feedback loop that will take in measurements of the current attributes, and simultaneously adjust the laser in order to produce the desired output. A user friendly GUI will be used to interact with the system. The system will be portable, hands-off, meet accuracy and safety standards, and fit the required dimensions.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

Computer controlled automation of the laser adjustment process will significantly speed up production and increase worker efficiency. With the rapid optimization of desired laser attributes, Iradion will significantly increase throughput thus greatly increasing profitability of the company. The system can be applied to build a variety of laser products with greater consistency and better performance, thus keeping customers happy. The introduction of automation in the laser adjustment procedure will create an opening for increased specialization of workers within the industry. Such specialization will drive innovation and produce higher quality products at a significantly lower cost.

ACCOMPLISHMENTS TO DATE:

- **Mathematical:** We have discovered and tested the relationship between the position of the mirror adjustment screws and the position of the reflected beam. Using this relationship, we were able to create algorithms that allow us to move the reflection to any point within the mechanical bounds of the mirror structure. We are also able to accurately move the beam along the horizontal and vertical axis relative to a light detector.
- **Mechanical:** We have designed in Solidworks and realized using 3D printing technology a functional actuator that couples onto the adjustment screws and uses stepper motors to turn them. The system and motors are offset from the laser so they do not interface with the output laser beam. Therefore, we use MXL timing belts and pulleys to transfer rotary power from the motors to the couplers. The system is fully adjustable with the ability to use different size motors, smaller or larger belts, and adjustable for mirrors and lasers of different dimensions.
- **Hardware:** An FPGA is used to send the required signals to a series of stepper motor drivers in order to control the speed, direction, and amount of steps a stepper motor turns. Using the FPGA, we are also able to input and read analog voltage values from the light detector to a high accuracy. A large portion of the adjustment and movement algorithms are implemented and processed on the FPGA, and it also acts as an interface between the front end GUI software and the mechanical actuator.
- **Software:** The user can interact with the system through a simple and friendly Windows Forms application written in C#. The user is able to view the current location of the reflection and input the wanted positional adjustments. It then uses a custom serial port protocol to send these values and other information to the FPGA for processing.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Mathematical:** Our next step is to discover the relationship between the position of the mirror adjustment screws and different laser attributes such as the power output of the beam and its mode profile. The goal is to use these relationships to automatically adjust the screws to achieve the laser's datasheet requirements. When potential relationships are found, we must verify them for consistency across different mirrors, as well as discover ways to handle special cases. External sources of error may also prove problematic and we must find ways to discover and combat them.
- **Mechanical:** We want the make the actuator system automatically engage onto the screws and be as hands off as possible. This will take some extra hardware and some Solidworks additions. Some adjustments may need to be done to the couplers to be sure that the system reliably finds the screws. Eventually, we will reconstruct the system in aluminum instead of 3D printer filament for further robustness. We also must create a mounting system that allows us to mount the actuators to the production benches.
- **Hardware:** Currently, the motor drivers, ADCs, FPGA, and power inputs are all discrete parts placed on a breadboard. We want to combine all these to a single customized PCB board that is reliable and reproducible. This will make the design simpler, smaller, and open up advanced usage of the FPGA. We also must find out ways of interfacing with power meters and mode profiler to gather information as we make screw adjustments. The adjustment algorithms must continue to be improved in order to increase efficiency, speed, and accuracy.
- **Software:** The front end GUI and accompanying FPGA components need to be expanded upon to include added functionality.

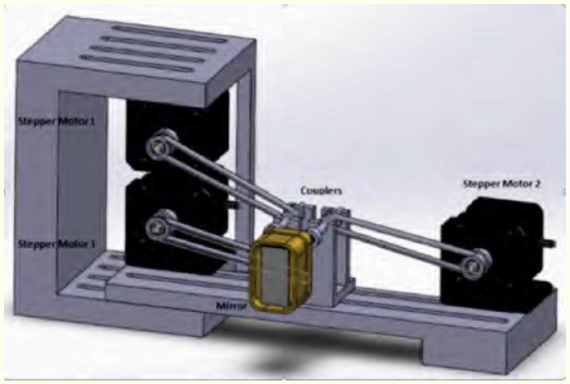

Fig. 1. Concept actuator designed in Solidworks.

Fig. 2. Current iteration of prototype actuator. Stepper motors are connected to the base with pulleys in order to turn mirror screws without obstructing laser output.

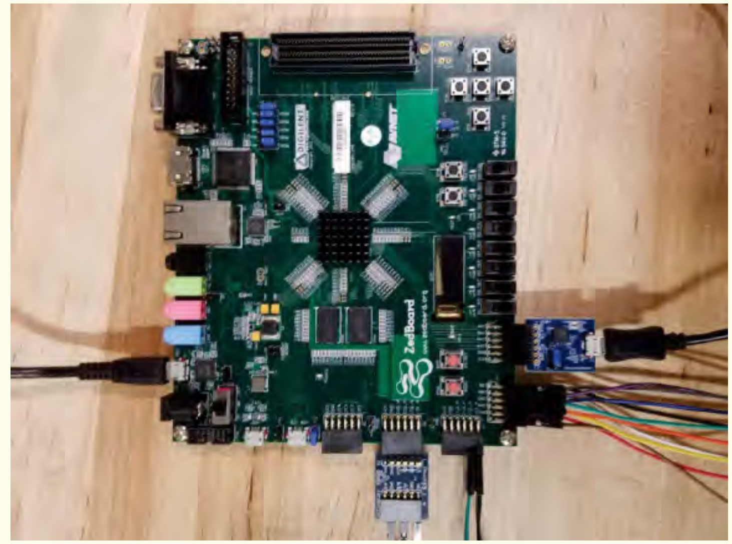

Fig. 3. FPGA development board used to drive motors. Communication through UART and ADC are connected as PMOD devices.

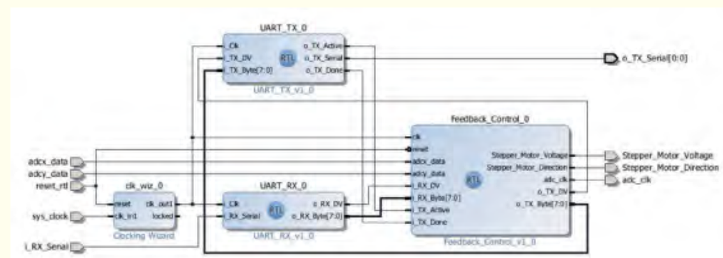

Fig. 4. Block Diagram of the feedback control loop implemented on the FPGA. Data is transferred with a front end GUI through UART serial protocol and with the position monitor through an analog to digital converter.

Web Based ON Semiconductor Integrated Circuit Simulation Development

onsemi.com

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Alejandro Hoyos (E)

PROJECT MOTIVATION:

In the field of integrated semiconductors, a plethora of SPICE simulators exist to design and troubleshoot products before production. Unfortunately, due to the limitation of some of these simulators, issues with convergence and unacceptable simulation times often occur. Therefore, people waste a significant amount of time in the development phase downloading various simulators, designing on those simulators, and then coordinating between the buyer and the manufacturer. Any questions that arise throughout this procedure also prolong the overall development process as customers clarify their intent. At the moment, no integrated circuit manufacturer has fully implemented an online simulator to reduce the time needed for ordering semiconductor products. SystemVision, a product of Mentor Graphics, provides a cloud-based platform that can solve the aforementioned interfacing problems by providing an online schematic simulator platform capable of accurately reproducing and simulating integrated circuits. With its VHDL-AMS modeling language and its graphical user interface, the design process becomes broadly accessible to customers, designers, and manufacturers.

ANTICIPATED BEST OUTCOME:

For this capstone project, each capstone member will provide extensive support by creating fully working schematic design simulations on SystemVision. At ON Semiconductor, the baseline of the products includes: switching regulators, drivers, SMART drivers, LED drivers, and low dropout linear voltage regulators. Phase one of this project focuses on developing the simulation of a buck converter product family within the SystemVision website. In phase two, the capstone team will provide demo boards of these products with their respective manuals for use in recruiting and promotional events.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

With SystemVision's powerful simulator, ON Semiconductor could gain a significant advantage by enhancing the product design-in experience. In fact, ON Semiconductor stands to transform the way people shop for integrated circuits by streamlining the design process, saving a significant amount of time in the purchasing phase. Using cloud-based simulations, a customer will be able to remotely design products and interact with ON Semiconductor representatives instead of running simulation in two different locations. Specifically, this company will have a set of web-based buck converter models and simulation benches as a part of their pilot program with the help of this capstone team.

ACCOMPLISHMENTS TO DATE:

- **Component Implementation:** Mentor Graphics SystemVision provides an online platform for circuit simulation that addresses the needs of professionals and students. As a website that continues to grow and promote shared designs, our capstone team designed a mixture of digital and analog components to serve as foundational components of the final integrated circuit. Our capstone team sequentially implemented sub-circuits of the buck converter to ensure that each of them worked as expected. On a weekly basis, our team created components for a soft-start ramp, an oscillator, an error amplifier, first for a voltage mode regulator followed by a current-mode regulator.
- **Buck Converter Simulation:** Upon combining each of the sub-circuits, the team tweaked the schematic connections and electrical component characteristics of the devices until they worked together producing the expected outcome. Finalizing that exercise, a simple buck converter was simulated in SystemVision to better understand its behavior and functionality within the VHDL-ams environment.
- **Design Within Specification:** After completing the sub-circuit and the simple buck converter designs, our capstone team designed the first buck converter within the specifications listed on the NCV890100 data sheet. Additional circuits such as a bootstrap, a saw tooth oscillator, and a gate driver were added to the previous buck converter model to reflect outputs much closer to the actual NCV890100 component.
- **Circuit Protection Components:** Additional part features outside of the main regulation functionality were also investigated and implemented in the System Vision environment. These include safety circuit part protection features overvoltage, and undervoltage.
- **Begin Simulation of More Buck Converters:** Once the first buck converter was implemented with all of its component parts on the SystemVision website, the team began simulating other buck converters in the NCV8901xx family. This task entailed adding programmable pins and modifying parameters in the original model.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Thus far, we have rigorously evaluated and revised the existing buck converter simulations to reflect the outputs of the existing NCV8901xx product family. Phase two poses more technical challenges as we translate the software simulations into physical demo boards. As we create a physical version of the simulated devices, we face issues that fall into the categories: design and craftsmanship.

Designing the Board: The NCV8901xx line of products will use the printed circuit board (PCB) method to produce physical models of the buck converter. Primarily, this capstone group faces the technical challenge of designing the PCB. Using a program (PADS) to create layers of the PCB board, the designers will have to be conscious of layouts which can be easily reproduced. Once the boards are printed, they must be perform according to the designers' expectations.

Craftsmanship for Promotional Communications: While assembling the boards, we have to ensure that each node is soldered properly to its corresponding components. If the solder is not accurately deposited with respect to solder mask expansion margins, then our circuit will not perform according to the specifications. Of course, we have to ensure that each PCB works within the tolerance specifications of the buck converter. Each board we create must be crafted so that it can endure travel and display in many different promotional events. In addition to resilience of the PCB's, we have to ensure that they all work properly over time because, as an item seen by prospective customers, each of these devices represent the quality provided by ON Semiconductor.

Web Based ON Semiconductor Integrated Circuit Simulation Development

onsemi.com

Fig. 1. Visual elements of current content of product support; Spice models, Demo boards, reference designs, reference layouts, & data sheets; and future proposed plan, to increase product accessibility via web based content.

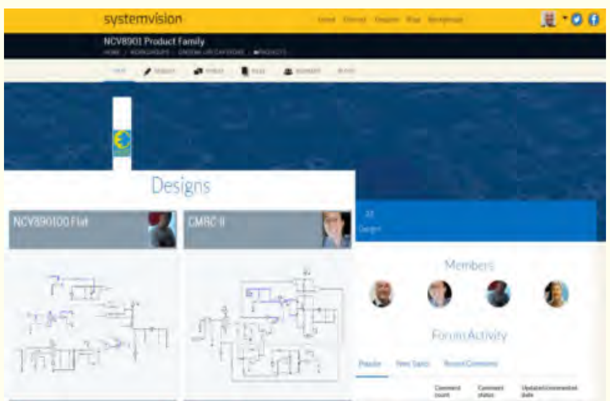


Fig. 2. Screenshot of the SystemVision Development Tool; provides user with a schematic simulation environment for customers to see accurate simulations.

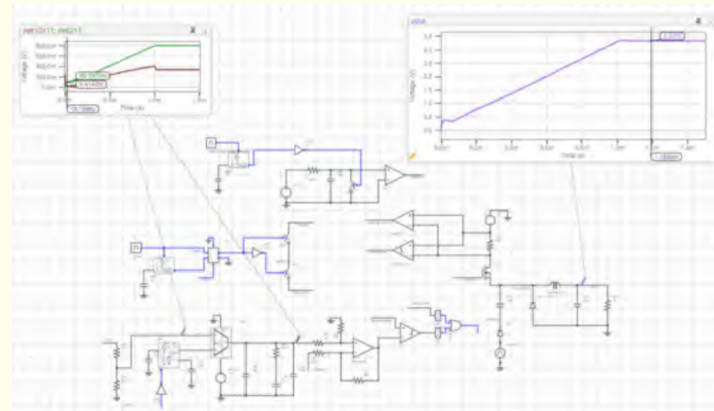


Fig. 3. Development stage of one of ON SEMI's products. Simulation replicates behavioral output of a switching regulator. These types of products will be developed.

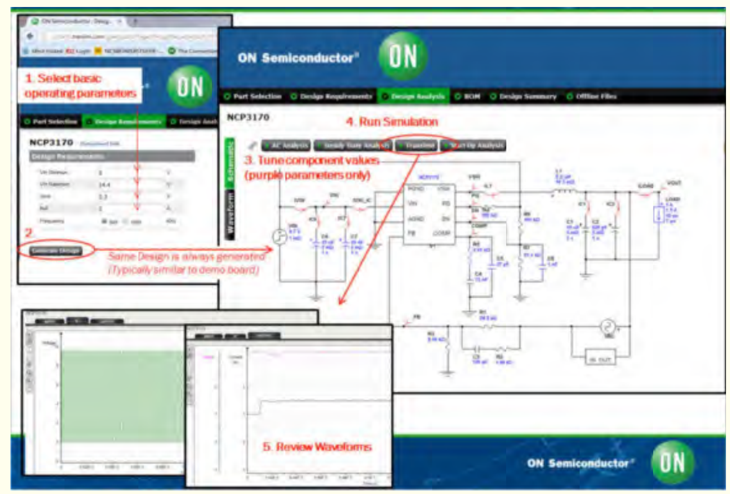


Fig 4. Implementation of SystemVision environment within ON SEMI's webpage, with useful tools: transient simulation, modification of output and input loads based on design requirements etc.

Fiber Optics Design High Voltage Equipment Control System Interface

pec-usa.biz

TECHNICAL DIRECTORS:

Sandro Silva
Mike Guerra
Mike Smith

TEAM MEMBERS: (L to R)

Chris Francis (E)
Zackery Duclos (E)

PROJECT MOTIVATION:

Electromagnetic interference threatens signal transmission and reception in copper wires. The current power grid is rarely shielded from electromagnetic interference (EMI), which makes it particularly vulnerable to terrorist attacks and other serious equipment failures that could leave entire cities or counties without power for weeks. In modern times, people are extremely dependent on electricity; no power for a week could prove fatal. Fiber optic cables are immune to EMI and provide a reliable and effective solution. Fiber provides pronounced signal quality while also not conducting electricity. Fiber is also resistant to fluctuations in temperature and can be directly placed in water without affecting the signal that it's carrying. The glass core makes tampering with fiber optic cables impossible therefore offering a higher level of security. Fiber optics are a safer, more rugged alternative to copper cabling especially in electrical facilities. Utilizing fiber optics is the next step to revolutionizing and modernizing the power transmission and distribution industry.

ANTICIPATED BEST OUTCOME:

The best outcome of this project by the end of the spring semester will be to have a functional prototype interface control system. The control system will operate with two distinct control cards. First, the master control card will interface with the previous control power hub to drive indications and relay state changes to its counterpart. The other distinct card will detect changes in connectivity, adjust relays states, and report back to the master card via the fiber. This design will have additional connections for future signals and enough extra memory for any future programming.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

The prototype will begin the push for American power companies to add additional security measures to protect power transmission and distribution facilities from EMI and terrorist threats. Phoenix Electric Corporation (PEC) will add to their marketability by adding this unique product not offered in most American markets. The product may also encourage PEC suppliers to make products to assist PEC in this new market once the control system is deployed. The Fiber Optic interface system will give PEC an exclusive edge against their competitors while providing heightened security and safer installation at a reasonable cost.

ACCOMPLISHMENTS TO DATE:

- **Buck Converter & Linear Voltage Regulator:** Investigated buck converter design to take 125 VDC and drop it to an appropriate intermediate voltage. The buck converter produces a signal that fluctuates and is unstable. The linear voltage regulator will fine tune the intermediate voltage into multiple smaller voltages that will be used throughout the circuit. This is incorporated into our design, but will not be able to be finalized until the final average power consumption is known.
- **Local Control Cabinet Interface:** Used solid state devices to interface the existing Local Control Cabinet network of indications and relays and thus essentially creating a virtual wire to the high voltage equipment replicating and mirroring connections. The interface will drive certain functions as well as indication lights.
- **Relay Switching:** Investigated switching devices. Then using MOSFETs, design subcircuits that are able to switch high current and voltage connections using a low gate voltage.
- **Fiber Optic Transceiver:** Investigated communication filters and designed a Positive Emitter Coupled Logic (PECL) filter circuit for transmitting and receiving.
- **High Voltage Equipment Interface:** Several regulatory checks will have to be performed in order to be sure signal will be able to flow. This is essential in maintaining reliability within our system. We will be using solid state devices to conduct these checks and be sure there are no interruptions.
- **Materials List:** Created materials list for future PCB design. Verified each selected component met minimum specification currents, voltages, and temperatures.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

PCB Design:

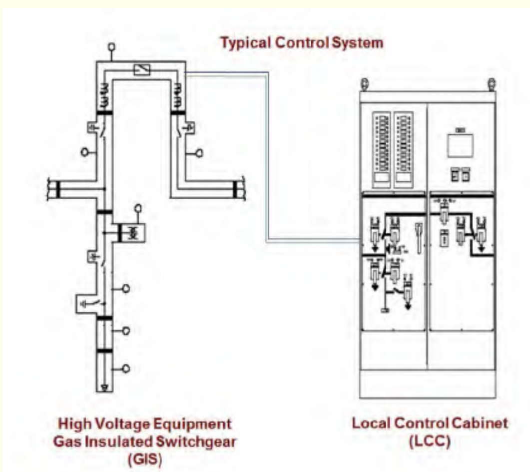
The first thing we must do is review our schematic once it is complete. This will ensure that all designed circuits make sense and that every component is terminated properly. After this is complete, the PCB design process will begin.

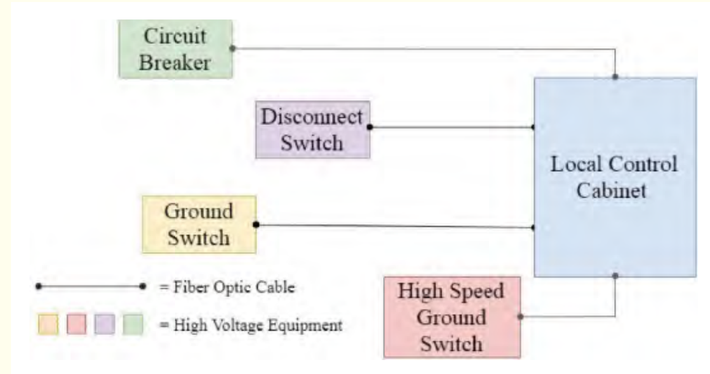
- After evaluating the circuit, an electric rule check must be performed so the schematic can be converted to a PCB layout file
- The physical size of our circuit board will be small, but the wire to board connection will prove to be difficult
- We must be able to manage the sizing constraints of the board with the 10-14 gauge wire that we will be connecting to
- After the schematic design is complete, the VHDL coding that will be implemented into our FPGA will begin
- Once the circuit boards are made, we must load the VHDL code to them and begin testing and troubleshooting our product

Fiber Optics Design High Voltage Equipment Control System Interface

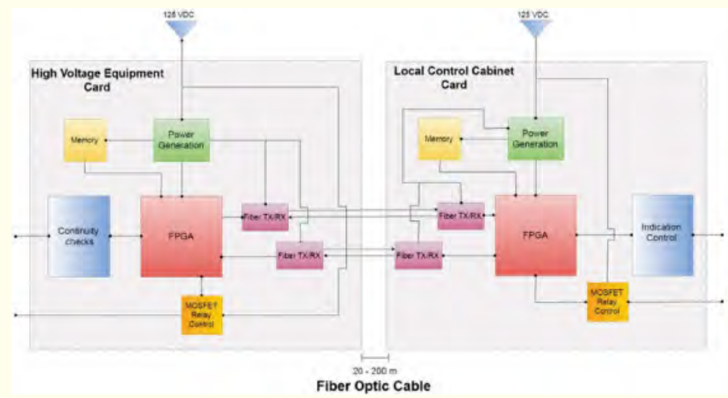
pec-usa.biz

Local Control Cabinet and High Voltage Equipment





Prototype Fiber Optic PCB's Configuration



Prototype Diagram

UPS Compliant with Department of Energy Efficiency Requirements

schneider-electric.us

TECHNICAL DIRECTORS:

Jeff August
Luka Petrovic
Mike Smith

TEAM MEMBERS: (L to R)

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Mike Smith

PROJECT MOTIVATION:

APC by Schneider Electric Uninterruptible Power Supplies (UPS) are known for their efficiency in power conditioning, and providing power backup in case of a grid power outage. The Energy Star® program for UPS products provides information so consumers can easily select more efficient models to save energy and operating costs. The Department of Energy (DoE) plans to release new efficiency regulations for these types of products. The efficiency requirements the DoE intends to release are more stringent than the current Energy Star® program. If the regulation is approved, products that are sold in the United States must comply or be removed from the market. With new Department of Energy efficiency regulations being placed into effect, Schneider Electric must revise and improve their already efficient UPS systems. To achieve this new level of efficiency, it means the redesign of several different sub-systems within the UPS.

ANTICIPATED BEST OUTCOME:

The team will have to identify several sub-circuits can be redesigned to lower power consumption. Once identified, the team will analyze the circuits and improve them without affecting the interaction with the overall system. The goal is to reduce power consumption of the UPS by several watts. In addition, the team will work on software that provides analytical data on the UPS operation. This includes analysis of cloud data as well as analysis of data from direct communication with the UPS. The analysis of the UPS data will result in dashboards to show statistics on loading, self-test results, and customer configurations.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

If the team is successful in this project, Schneider Electric could apply the changes to improve the efficiency of the UPS product. The changes could be applied to several different models. This will help Schneider Electric meet the new DoE requirements when they come into effect. The combination of the data analysis and improved efficiency could put Schneider Electric at a competitive advantage, potentially gaining market-share from key competitors in a multibillion-dollar market.

ACCOMPLISHMENTS TO DATE:

Relay Drive Comparator: A simulation of a simplified model of the relay drive comparator array was done in Multisim.

IC 412 Error Amplifier: A simplified schematic was created using NL Multisim. The thevenin voltage source and resistors were calculated, yielding a derived transfer function of the circuit. This was also used to calculate DC gain values. A spice netlist was created for the circuit, using a general op-amp, in order to obtain a frequency response for comparison to the derived equation. A Matlab script was created to view the theoretical transfer function, and adjust the values for low power consumption.

Software: Review: C programming specifics pertaining to the required methods needed to implement changes on the Uninterruptible Power Supply (UPS) firmware. Low Energy Bluetooth research, operation and implementation in current markets. Could Data Analysis, Rest API

Updating firmware: Used Eclipse to update firmware files in collaboration with firmware engineer. Used programs such as BitBucker and SourceTree to share files in collaboration with firmware engineers

Vout_Error_Amp (VEA): A SPICE netlist was made for the simplified VEA circuit model. With this, a frequency sweep was performed in order to obtain the systems transfer function (TF). A mathematical model was derived and implemented with Matlab. Using Matlab, the circuits transfer function was plotted and compared with the simulated SPICE TF. The mathematical model was used to adjust the capacitor and resistor values to reduce power consumption. The new TF was plotted against the old one to ensure that the frequency response was the same.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

IC 412: For the IC 412 circuit, the team has to finalize the new component values for lower power consumption. Once this has been done the team will then perform DC gain analysis amount other tests to ensure that the circuit behaves as intended.

VEA: For the VEA circuit, the team still has to finalize the new component values for lower power consumption. Once this has been done, the team will then perform Transfer Function testing under several different conditions to ensure that it works as intended. The team will also perform DC gain analysis along with Transfer Function testing to ensure the systems robustness.

Miscellaneous: There is still a significant amount of work to be done on the circuits that are currently being analyzed. Once the team can complete those circuits then we can move onto evaluating other parts of the UPS and attempt to determine other inefficient systems. The team will try to look for systems where a significant amount of power consumption can be reduced. After we have identified such circuits, we will most likely develop and simulate a simplified model of the circuit in order to better understand it's operations. Once we are comfortable with our understanding, then we can develop a method of analysis for this system, and see what we must do in order to reduce the circuits power consumption. Once we have developed this method, we will then implement it. If the circuit is similar to the two that are currently being analyzed, then the team will develop a corresponding mathematical model, adjust component values, and perform tests. Once the analysis and redesign portions have been completed, the team will perform tests to ensure that the circuit behaves as intended in collaboration with the rest of the system, and that the amount of power that was reduced it significant.

Schneider Electric

UPS Compliant with Department of Energy Efficiency Requirements

schneider-electric.us

Fig. 1: Uninterruptible Power Supply that Will be analyzed and Changed for Lower Power Consumption. This is a Line-Interactive UPS

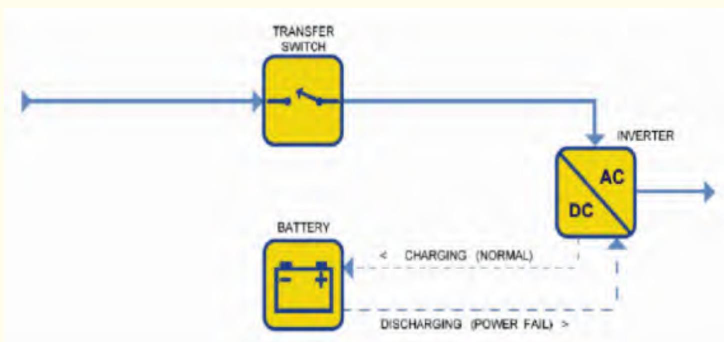

Fig. 2: This Shows the basic operation of the UPS. During Normal on-line operation, the Transfer Switch is Close. The AC Power is Passed to the Output and the Inverter is Run in Reverse to Charge the Battery. When the Input Power Fails, the Transfer Relay Opens. The Inverter Draws Power from the Battery and Provides it to the Output as an AC Voltage.

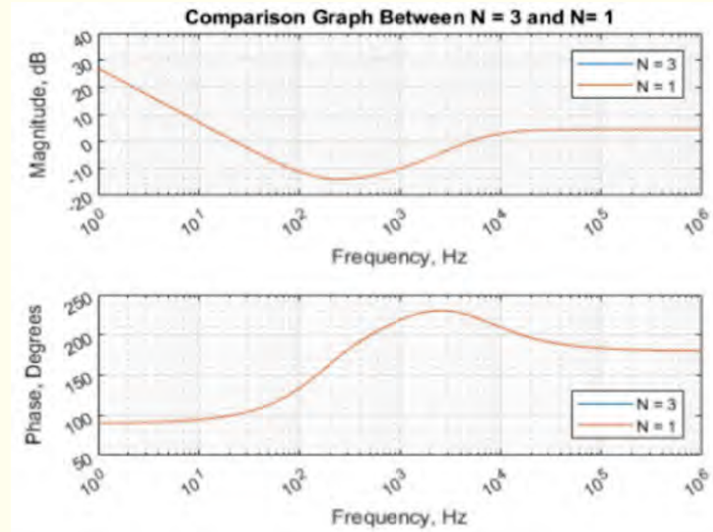

Fig. 3: MATLAB Graph Comparing the Original Transfer Function of the Vout_Error_Amp Circuit with The Newly Modified Transfer Function. From this Graph One Can Clearly See That the Two Transfer Functions Match Perfectly

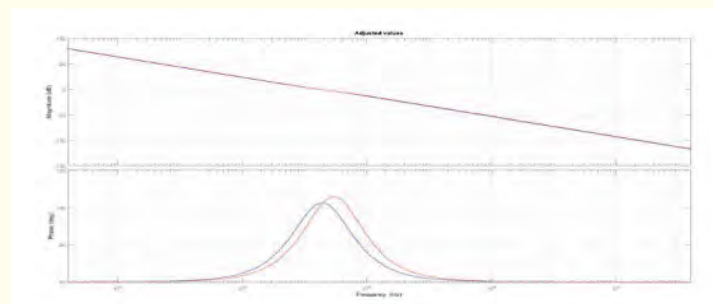

Fig. 4: MATLAB Graph Comparing the Original Transfer Function of the IC 412 Circuit With The Newly Modified Transfer Function. These is a Slight Phase Shift in the New Transfer Function Due to the Restrictions on a Resistor that Can Only be Modified a Small Amount

SESA

Blank Out Sign Connectivity Over Cellular Network

sesamerica.com

TECHNICAL DIRECTOR:

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TEAM MEMBERS: (L to R)

Justin McGrath (C)
Alexander Kenney (E)

PROJECT MOTIVATION:

This project is all centered around Blank-Out Signs, which are signs that are used on the roads that offer different messages to motorists. This works by lighting up LEDs that are implemented in the signs in different sections such that they display a message. An example of this would be the LED signs show in toll booths that represent which lanes are open or closed. These messages are predefined so a sophisticated control apparatus is not necessary in order to change the message shown. SESA designed the BOS to operate with a simple dry-contact closure driven by a low-cost microcontroller. This alternative to full-featured DMS makes BOS lack the means for communication. This means that the only way to change the message on the sign or to check for an error. The expensive installation of hardwired communications infrastructure necessary to control and monitor signs negates the cost advantages of of the BS products and renders remote use economically untenable.

ANTICIPATED BEST OUTCOME:

The anticipated best outcome for the projects is a production-ready, modularized cellular communication system interface able with the current BOS architecture. The module will allow asynchronous transmission of both the sign's status to a remote server as well as control operations from a web application. The web application will be secure and mobile friendly as well as be able to support multiple users with multiple signs. The end user will be able to manage their BOS, relay commands to other signs and allow the user to be able to check the status of their signs. When a fault is detected, the web application will send email alerts to the users.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

This product will change the way that SES America's clients interface with their signs. Currently, if the client wants to see which message their sign is displaying or even simply making sure their sign is functioning properly. This will be cost effective and time saving, which will save company cost if they have to send someone out to the sign to verify. It could potentially save full work days if the sign is far enough away. In the future a response-based BOS sign interfaced with speed or traffic sensors can alert motorists of danger so this project has road safety implications.

ACCOMPLISHMENTS TO DATE:

- **ATmega2560 Development:** The ATmega2560 is a small microcontroller that allows the user to send and store information. It has an available 8192 addresses of internal static random access memory (SRAM) ad 56832 addresses of external SRAM. We had to find a way to power this processor and use its pins to relay information between the website and the signs.
- **Daily Logs:** We created a logger.php with multiple functions to be able to create daily logs and echo back the logs created. We then updated the server files to be able to use logger.php to log processes in addition to creating a javascript logger in home.php to log client-side events, thus ensuring all events (both client-side and server-side) are captured in one daily log text file.
- **Refining the Login Process:** We edited the logout.php, login.php, home.php, and session.php to ensure that they successfully work together to log a user in (given that they know their credentials) and then keep them logged in as they redirect to different pages.
- **Allowing Uploads and Downloads:** Since the file manager on GoDaddy.com logs the user out after only a couple minutes we needed an easier way to upload/download files to and from the web server. Thus, we used an FTP and while SES America already had an FTP account, unfortunately it was using the wrong directory so we had to create our own with the correct directory. This allows us to edit files using Dreamweaver and FTP to update the files whenever needed.
- **Module Connection:** None of this project works if we can't connect the module to the TCP socket and send queries to the database. Our group successfully tested the socket connection between the apache based server and the module. The logs showed that queries were being sent to the database, but they listed the wrong sign id. We still have to test this on the AWS account.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

Module and Database Connection: While we found out that the module and the database can connect, we have to make sure that the module and the database are functioning in synch. For this I mean that when the user selects for the sign to display a "No Left Turn" message that the correct data is being sent for that message to be displayed. Then, we need to assess whether or not the microcontroller processes the information correctly and relays this information to display the appropriate message.

Change the Website: We will enhance the website, because right now, the website is very bland and not efficient. We will fix this by making the website more user friendly and appealing to the user's individual needs. This will be done by adding representative images of the signs the user can display, then allowing them to click on a message and their sign displaying that message.

Relay Correction: The way that these Blank Out Signs work and change their messages is by powering different relays. One relay will power specific points of the circuit, which will turn on certain LEDs, thus displaying one message. If the user then selects a different message on the website, our group must make sure that the relay actually switches to display the new message. What we don't want is for the website to change and then the information in the database to change, but the sign to not change its display. If that were to happen then the user would have to manually check the sign, which defeats the whole purpose of this project. This will have to be the last thing we check, because we will have to have almost the entirety of the project completed in order to test this correctly.

Fig, 1. Blank Out- Signs that are to be retrofitted with the cellular module to allow connection to the internet for change of message.

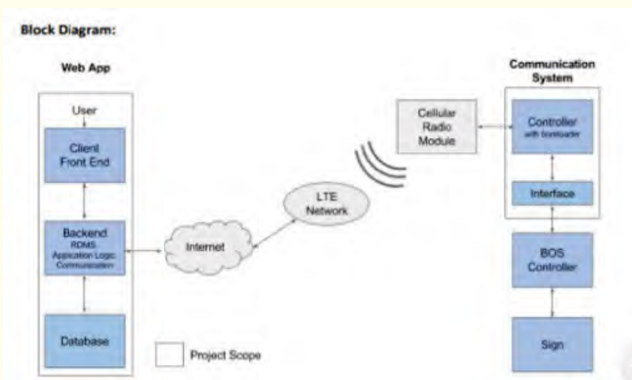

Fig. 2. Block Diagram of the system. This shows the step by step process of how the signs will interact with the users, allowing them control over the messages that the sign displays.

Fig. 3. Photo representing the user's ability to connect with a sign on their mobile device. Allowing them to manipulate their sign on the go through the use of Google Maps.

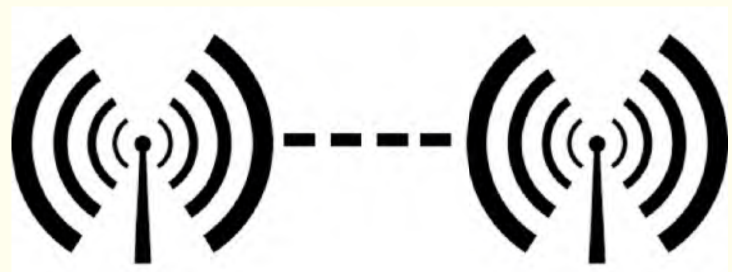

Fig. 4. Image showing the individual signs ability to connect with other signs instead of the internet for relaying information as not all signs will be outfitted with the cellular module.

Cellular Pump Control

tacocomfort.com

TECHNICAL DIRECTORS:

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Phillip Manning

TEAM MEMBERS: (L to R)

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Steven Marques (E)
Alex Ali (C)
Gregory Soito (E)

PROJECT MOTIVATION:

The mining and agricultural industries use pumps for irrigation and water removal respectively. Easy access is not always possible since the pumps are often located far from the base of operations. The operators have to either drive out into a field or travel deep into a mine to switch the pumps on and off and sometimes just to check if the pump is operating properly. If a pump was to malfunction then fields could flood destroying a farmer's crops. In the case of mining it is very important that water levels are monitored and controlled since flooded mines can result in loss of life. To better ensure the safety of their employees and to protect their operations, customers want a solution that will allow them to control and monitor their pumps remotely. There is currently no solution on the market that allows wireless long-range communication to an industrial grade water pump. Taco Comfort Solutions, Inc. hopes to be the first to put a product on the market that will satisfy their customer's requests and hopefully their competitor's customers as well.

ANTICIPATED BEST OUTCOME:

We are expecting to have a working prototype of our design soon. Minimally, we hope to have a functional proof of concept for Taco to develop and to produce. Our goal is to exceed our minimal goal. We are aiming to lay the foundation for a marketable product that the company can continue developing and begin selling by summer 2018. A large portion of this project involves the building of infrastructure which lies outside of the scope of this project. We plan to have a final design for this infrastructure. These are the best possible outcomes. Our team has the skills and passion required to complete this daunting task.

IMPLICATIONS FOR COMPANY AND INDUSTRY:

Upon the successful completion of this project, Taco will be the first company to provide an industrial grade internet of things device that is capable of controlling pumps used for agriculture and mining. Taco aims to provide a platform that will provide their clients with detailed information about their pumps. With this system, customers will be notified of any potential problems with their pump. Detecting potential issues and preemptively shipping replacement parts to the owner to eliminate costly down time. This will push the mining industry forward and save time for farmers that would be wasted managing their pumps manually.

ACCOMPLISHMENTS TO DATE:

- **Block Diagrams:** 2 created: interactions between modules and a macro view of hardware connections.
- **Requirements** created for hardware and software. Defined specific functions to be performed; each component specification and implementation of these functions.
- **User Stories:** With requirements, developed user stories for all user interactions expected. Covers the user experience with the mobile application.
- **Researched** sensors including pressure, flow and water level. Also, possible microcontroller systems utilizing Beaglebone, cellular modems; AT commands, MCT10 software for programing the motor drive and 3-phase power systems.
- **Components selected to** match requirements and performed the functions needed.
- **Bill of Materials created:** pricing, vendor part numbers and specification sheets, etc.
- **Assembly:** Began to test and assemble the components for a working prototype.
- **Motor Drive:** operational, configuration and communication with our device.
- **Web App:** Established a platform for app development through Cordova and React; Git and Bitbucket; created a template for user stories.

REMAINING TECHNICAL CHALLENGES FOR BEST ANTICIPATED OUTCOME:

- **Prototype Assembly:** To verify the sensing measurements to be made.
- **Communication:** Establish communication between the different components: sensors, controller, mobile app, motor drive and web server. Most important: cellular communication between our controller device and Amazon's Internet of Things platform.
- **Sensing:** Ensure accurate readings from all sensors: temperature, flow, level, pressure and pump speed readings.
- **Testing:** Test design functions, measure data, can communicate (i) data via cellular communication, (ii) with motor driver and can receive data via cellular communication.
- **Mobile App:** Finalize the mobile application that monitors different operating conditions of pump; to view these parameters with potential warnings; allows control of pump from the app.
- **Manufacturing Procedures:** Define exact specifications and documentation. Develop a simple process for imaging and instantiating a device so that all devices manufactured will be identical but with a unique identifier.
- **Installation Guide** to install our device correctly. A user guide will be integrated into the mobile application and a walkthrough tutorial.
- **Demonstration Display**: At Summit in May, our display will demonstrate all features, consisting of a tank of water and a pump. The pump will be controlled from our mobile application and will utilized the entire AWS backend.

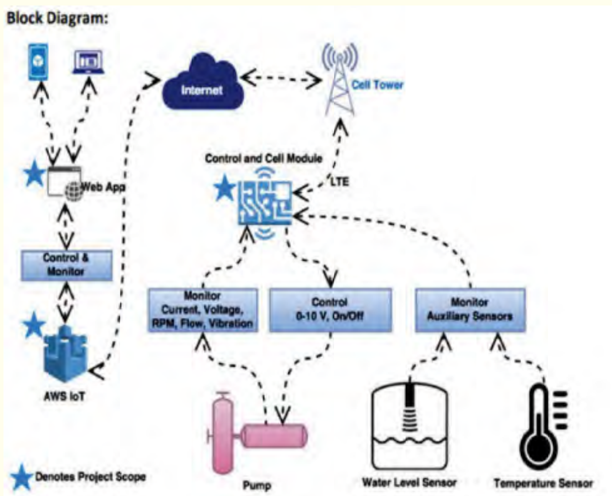


Fig. 1- A more macro view of the design that gives a broader overview of the functions of the device.

Fig. 2- A typical installation site where the device will be used and a typical pump that the device will be monitoring.

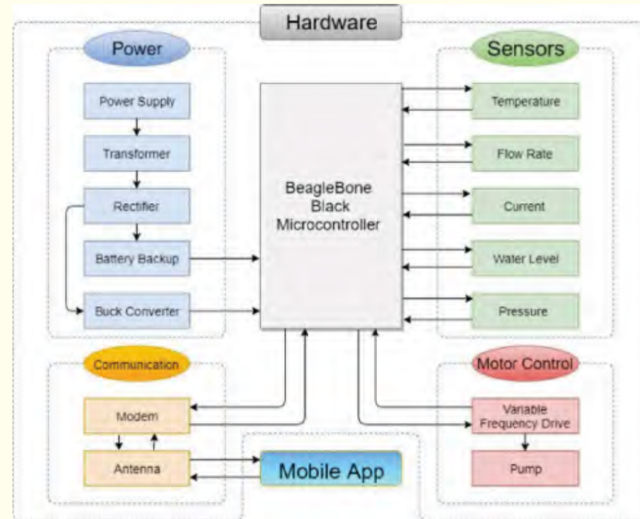


Fig. 3- This figure shows a block diagram detailing the connections between the different modules.

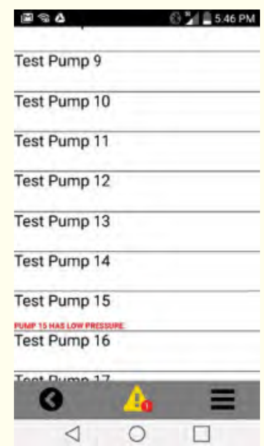
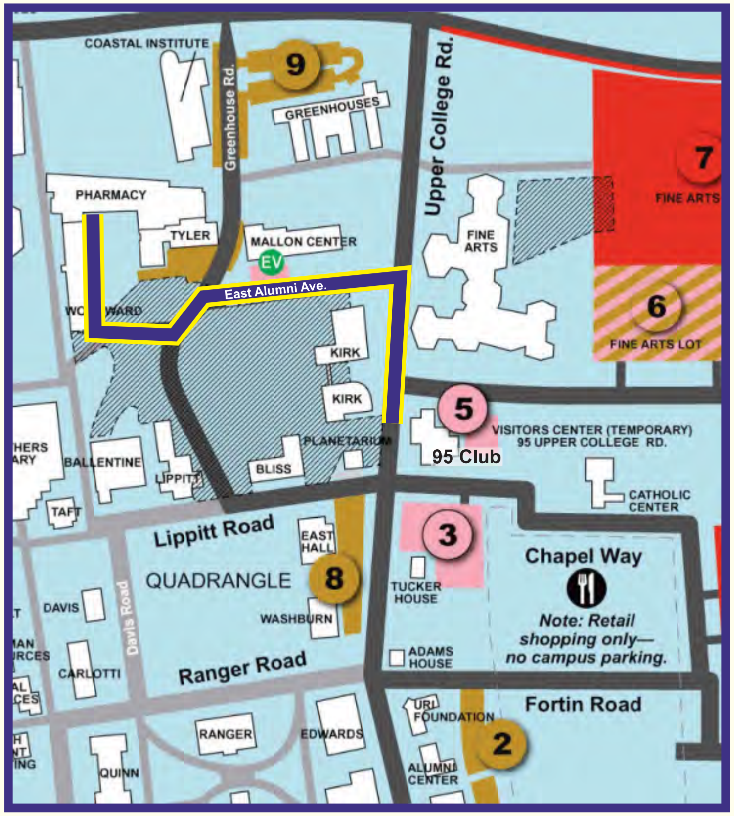


Fig. 4- A screenshot of the GUI in the app and shows how the user will be able to interact with the device.

WALKING MAP

Walking directions from the 95 Club to
Ernest Mario Auditorium, Avedisian Hall



Follow the highlighted route to walk from the 95 Club to Ernest Mario Auditorium in Avedesian Hall

NEW COE BUILDING
ELECOMP CAPSTONE WEBSITE

New College of Engineering Building

ELECOMP Capstone Design Program Website

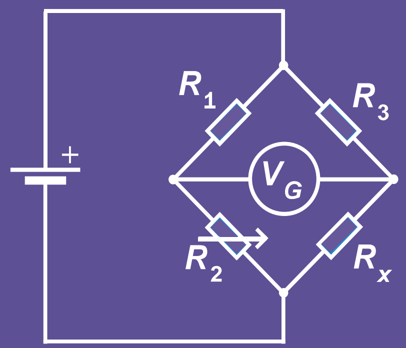
web.uri.edu/elecomp-capstone

- Capstone Program Director
- Current Projects 2017-2018
- Current Sponsors 2017-2018
- Current Technical Directors 2017-2018
- Fall 2017 Symposium
- Testimonials - Sponsoring Companies
- Testimonials - Students
- Technical Director Responsibilities
- Future Sponsors
- Frequently Asked Questions
- IP and NDA
- 2017 Capstone Summit
- Past Projects 2016-2017
- Past Technical Directors 2016-2017
- Fall 2016 Symposium
- ELECOMP Lab at Schneider Electric
- New Engineering Building
- Opening & Ribbon Cutting Ceremony Pictures

ELECOMP

CAPSTONE BRIDGE

The Capstone Bridge mirrors the well known Wheatstone Bridge, shown in the diagram below.



The unknown resistance Rx is to be measured; resistances R1, R2 and R3 are known and R2 is adjustable. Only when the bridge is adjusted to be in PERFECT BALANCE, the measured voltage VG is zero, and the unknown Rx is determined.

Now we can see the parallel with the 3 important aspects of the Capstone Bridge:

R1: ELECOMP Capstone Design Program

R2: ELE & COMP Seniors with diverse talents

R3: Sponsor’s Technical Director & Problem to be solved

When these aspects are in perfect balance and collaborate in excellent harmony, SUCCESS is achieved in the UNKNOWN (Rx): The Best Outcome of the Sponsor’s Problem

THINK BIG WE DO℠

web.uri.edu/elecomp-capstone